POTENTIAL OF ESTABLISHED PASTURES IN THE WINTER RAINFALL REGION

[by]
JOHANN MYBURGH VAN HEERDEN

June 1986

Submitted in partial fulfilment of the requirements for the Doctor of Philosophy degree in the Department of Grassland Science, Faculty of Agriculture, University of Natal, Pietermaritzburg.

LIST OF CONTENTS

SUMMARY

The seasonal production of 11 pastures was evaluated in dryland and irrigated trials at eight sites in the Winter Rainfall Region. These data were related to climatic conditions using the Growth Index concept to produce a model for pasture growth.

Under dryland at Tygerhoek, the animal production potential of lucerne and medic was compared in grazing trials. Lucerne was found to be the higher producing of the two. At this site also, the influence of chemical control of volunteer grasses in dryland pastures on animal production potential was tested. Weed control had a positive influence on animal production at low, but not at high stocking rates.

Under irrigation at Tygerhoek, the grazing capacity of a complex grass/legume mixture was established under continuous and rotational grazing. While rotationally grazed pastures produced the highest yields, the clover component of these pastures proved to be most productive under continuous grazing. As a result, rotationally grazed pastures, could carry more animals, but animal production was generally highest under continuous grazing.

Under irrigation at Outeniqua, seven grass and grass/legume mixtures were compared in grazing trials. Pastures based on

fescue generally had the highest grazing capacity, but those based on white clover the highest animal production potential.

These data were used to produce a climate:pasture:animal production model, which was validated using independent grazing trial data. This model was used to predict animal performance of two-species mixtures at a number of sites. These results suggested that while grass pastures allowed more animals to be carried than did mixtures, both animal performance and gross returns were highest in grass/legume mixtures.

DECLARATION

I hereby declare that this thesis and the associated research is my own original work, except for assistance which is acknowledged, or where due reference is made in the text.

J M VAN HEERDEN

ACKNOWLEDGEMENTS

I gratefully acknowledge the extremely valuable support and guidance of my supervisor, Professor N M Tainton of the Department of Grassland Science of the University of Natal, during the compilation of this thesis. His enthusiasm and, above all, his insight into the various aspects reported on, was invaluable to the successfull interpretation of the results.

Research comprising a large number of aspects, covering trials distributed over large distances and involving grazing animals, require the support of a large number of personnel. I am, therefore, extremely grateful for the enthusiastic support of Mr P R Botha, Senior Technician at Outeniqua Experiment Station (George), and Mrs M Botha, Technical Assistant at the same site, Mr W R Langenhoven and Mr L Metcalf, Senior Technicians at Tygerhoek Experiment Station (Riviersonderend), Mr J H van Wyk, Senior Tecnician at Elsenburg, and Mr A P Koen, former Responsible Officer of Oudtshoorn Experiment Station. All these persons lend the all important technical support in the execution of the trials at each of the abovementioned sites during various stages, as well as support in administering financial aspects.

I also thank Mrs G C Kroese for her extremely valuable and conscientious support with the coding, processing and graphing of the data and Mrs G C Diener for the lettering of all the figures. A very important contribution was also made by Mr A van Rooyen, Data Metrician at Elsenburg, who compiled the programs for the processing of the plot and grazing trial data. He also played a major role during the coding of the climate:pasture:animal production model into Fortran and developing it into a workable interactive model.

I also acknowledge the support of Mr J Blomerus, Responsible Officer at Outeniqua and Assistant Director (Extension) of the South Coast sub-region and Mr J E Wicht, Assistant Director (Pastures), at crucial stages. I thank Mr D Labuschagne, former Special Degree Control Farm Manager of the Winter Rainfall Region, for his assistance in organising the financing and installation of the necessary irrigation equipment at Outeniqua and Tygerhoek. The support of the animal and soil science sections with the analysis of soil and plant samples are also acknowledged.

A special note of thanks to my wife, Anna, and my children, Gerhard, Jana and Careen, for their patience and moral support during the many years needed to complete this study, especially if one considers all the time I had spent working on this thesis, time which should actually have been spent with them. My wife was also responsible for the word processing of this manuscript.

I finally acknowledge the fact that this thesis is the product of six registered facets of the Department of Agriculture and Water Supply (Winter Rainfall Region), which therefore financed the research and in the employ of which I was not only responsible for the initiation and execution of these facets, but also for the interpretation of the results and subsequent compilation of the manuscript.

1 INTRODUCTION

1.1 Regional organisation

As indicated by it's name, the Winter Rainfall Region (WRR) receives the most effective part of it's annual rainfall during winter, i.e. the period April/May to October/ November. The farming area of South Africa included within this region forms two narrow and almost rectangular corridors along the South-western and Western seaboard. North and eastwards the winter rainfall component declines as an increasing proportion of the total rainfall falls in the summer months (see figure 1.1), i.e. South West Africa/Namibia, and the Karoo and Eastern Cape Regions.

The WRR is agriculturally divided into five sub-regions differing widely in annual and seasonal precipitation, as influenced by topography. The regional boundaries of these five sub-regions are indicated in figure 1.1

In figures 1.2 to 1.6 more detailed maps of each of the sub-regions, depicted in figure 1.1, indicate the different areas within each sub-region where established pastures are an important part of the farming system (Streeks-ontwikkelingsprogram, 1981).

The areas indicated in figures 1.2 to 1.6 are as follows:

1 natural veld only;

2 localised areas of irrigated pasture interspersed in natural veld, or wheat, vine and fruit producing areas, where the occurrence of established pastures are dependent on the availability of adequate amounts of irrigation water;

Figure 1.1 Regional and sub-regional boundaries of the Winter Rainfall Region

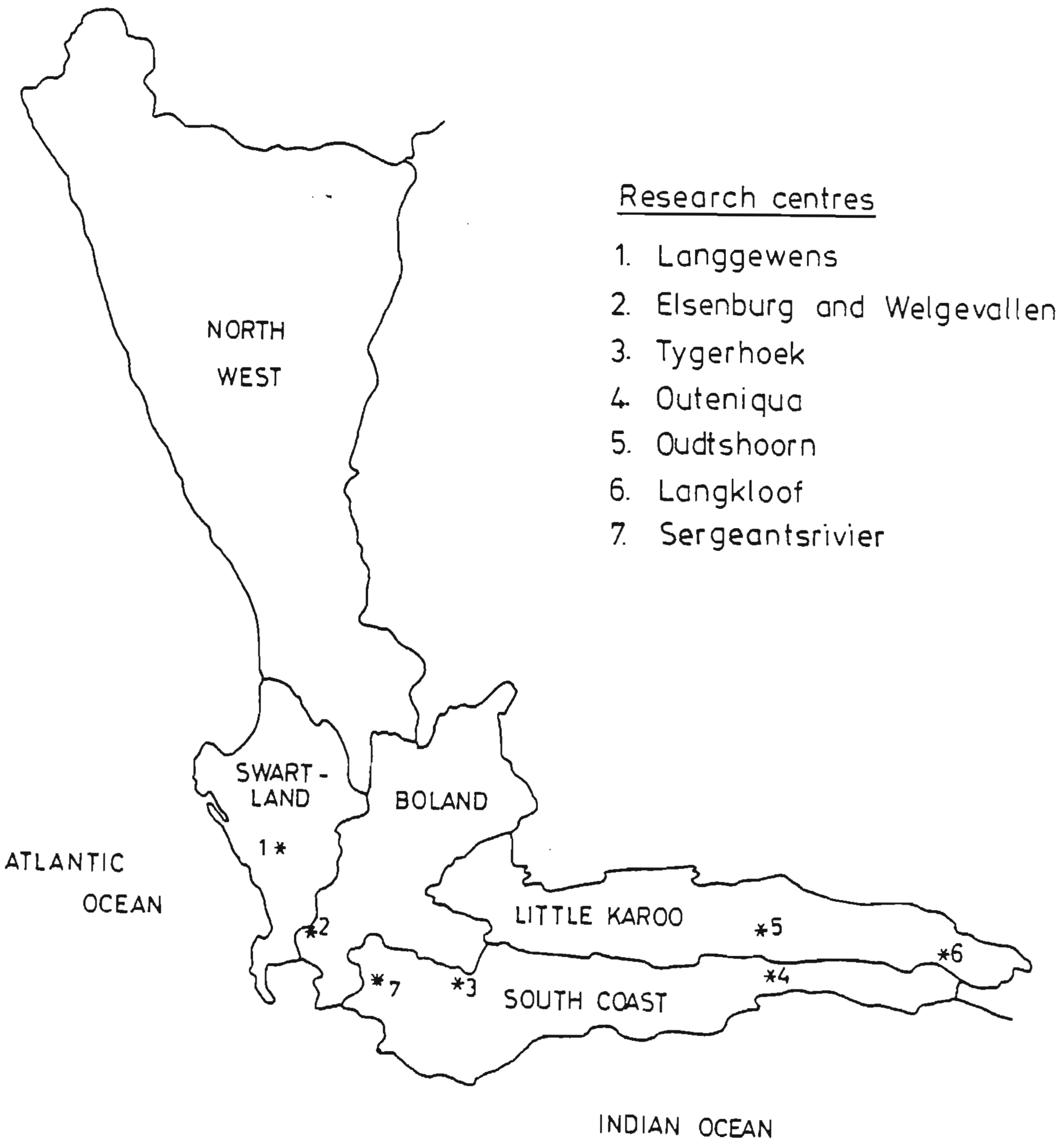


Figure 1.2 North West (for explanation of key see page 1 of text)

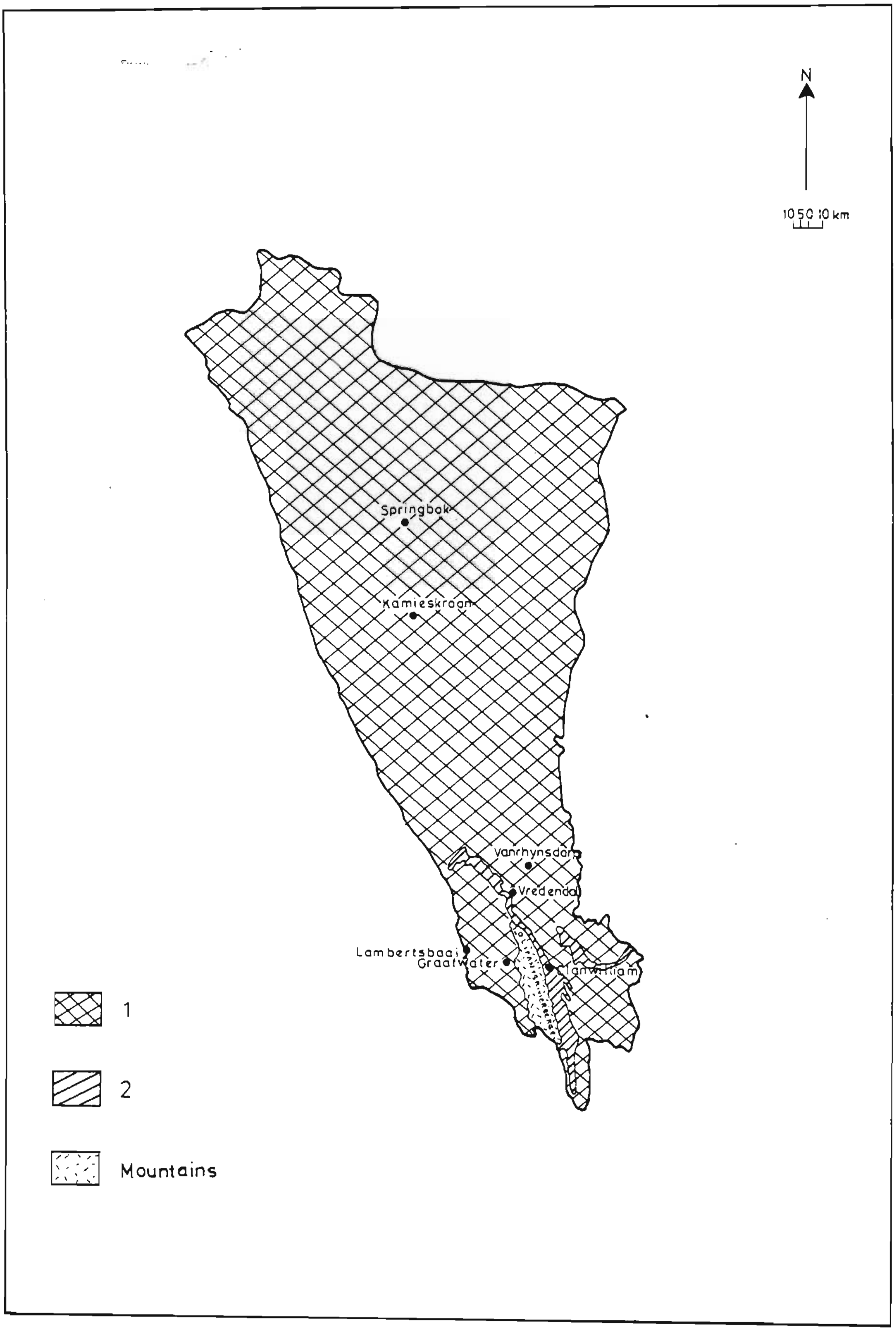


Figure 1.3 Swartland (for explanation of key see page 1
of text)

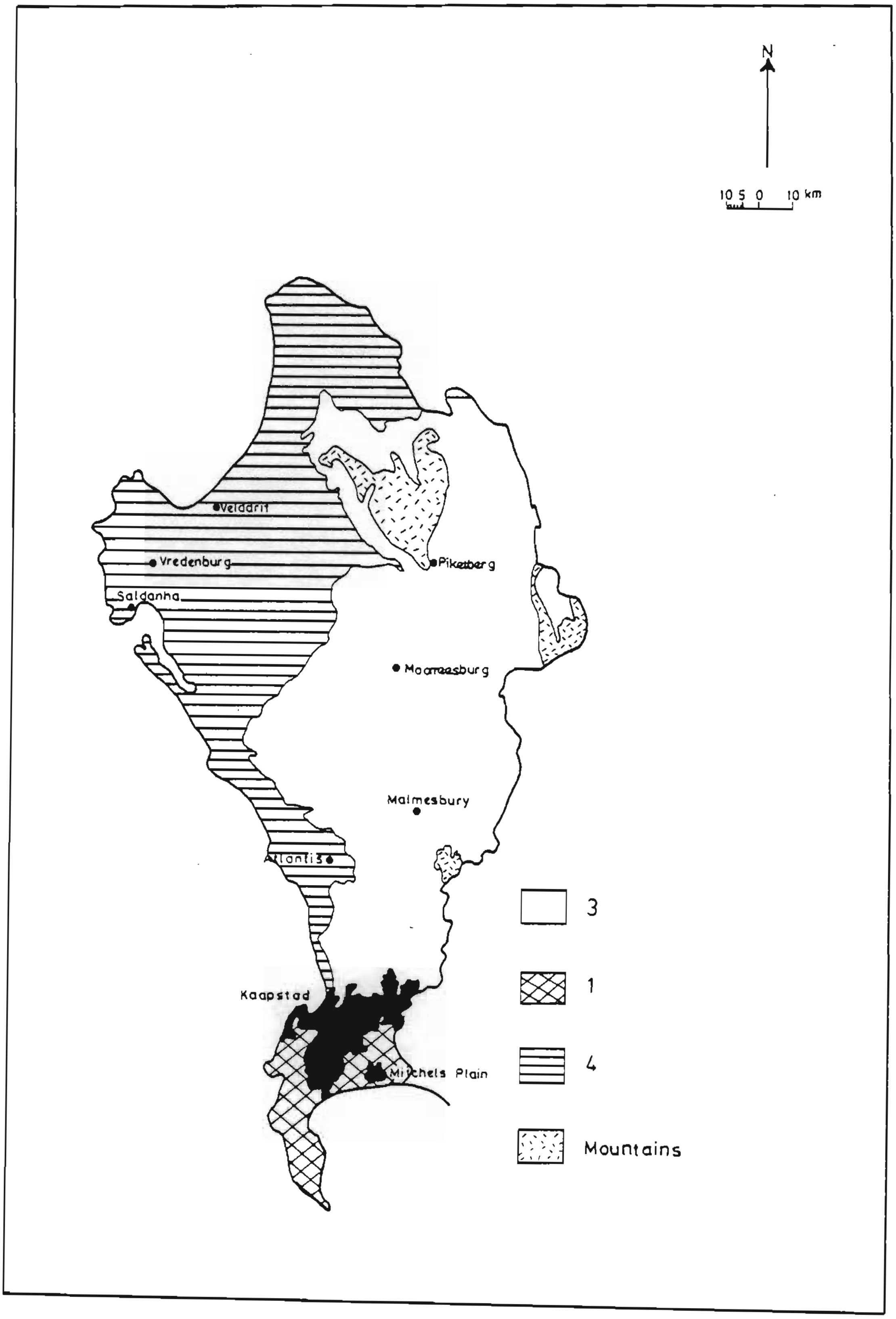


Figure 1.4 Boland (for explanation of key see page 1 of text)

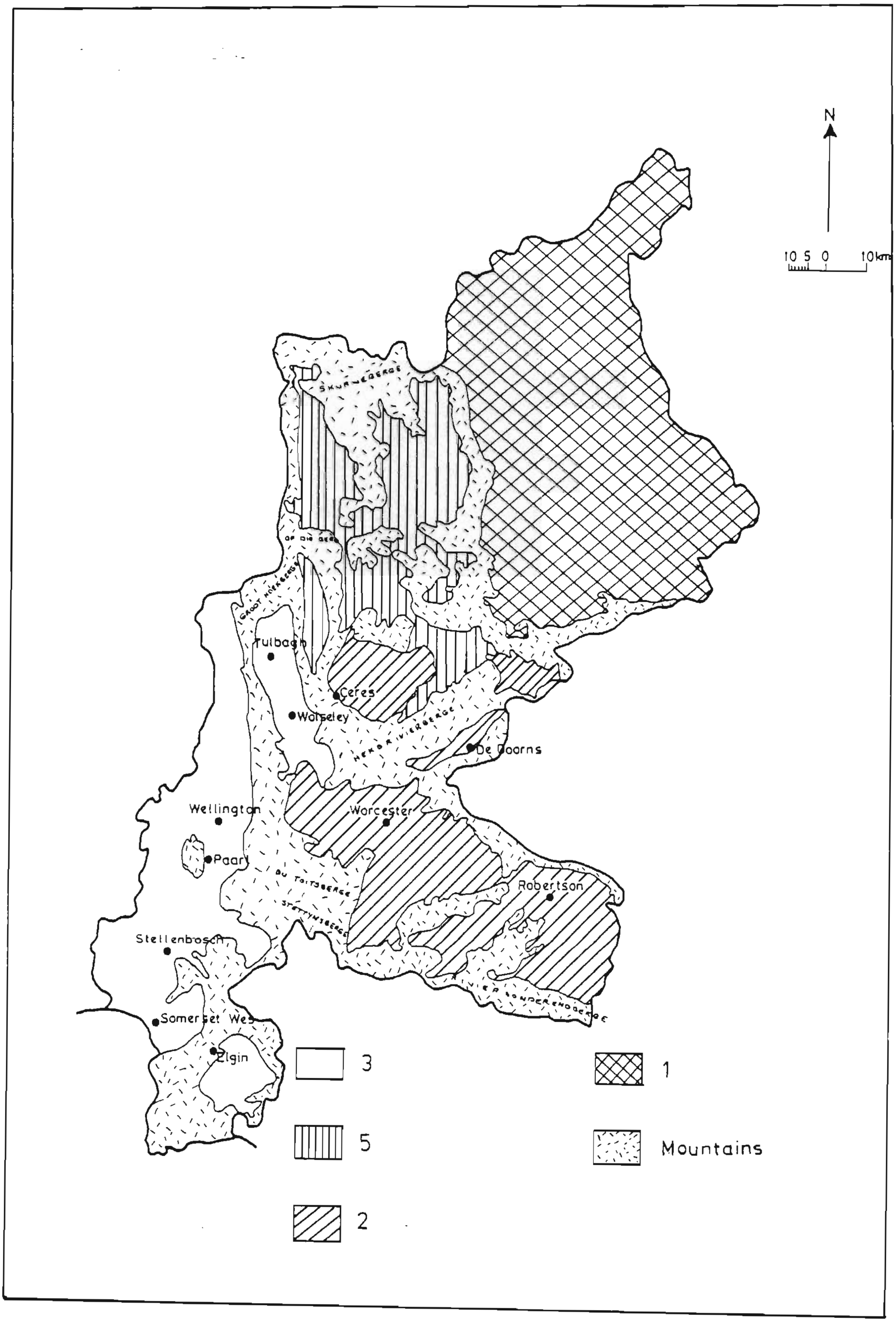


Figure 1.5 South Coast (for explanation of key see page 1 of text)

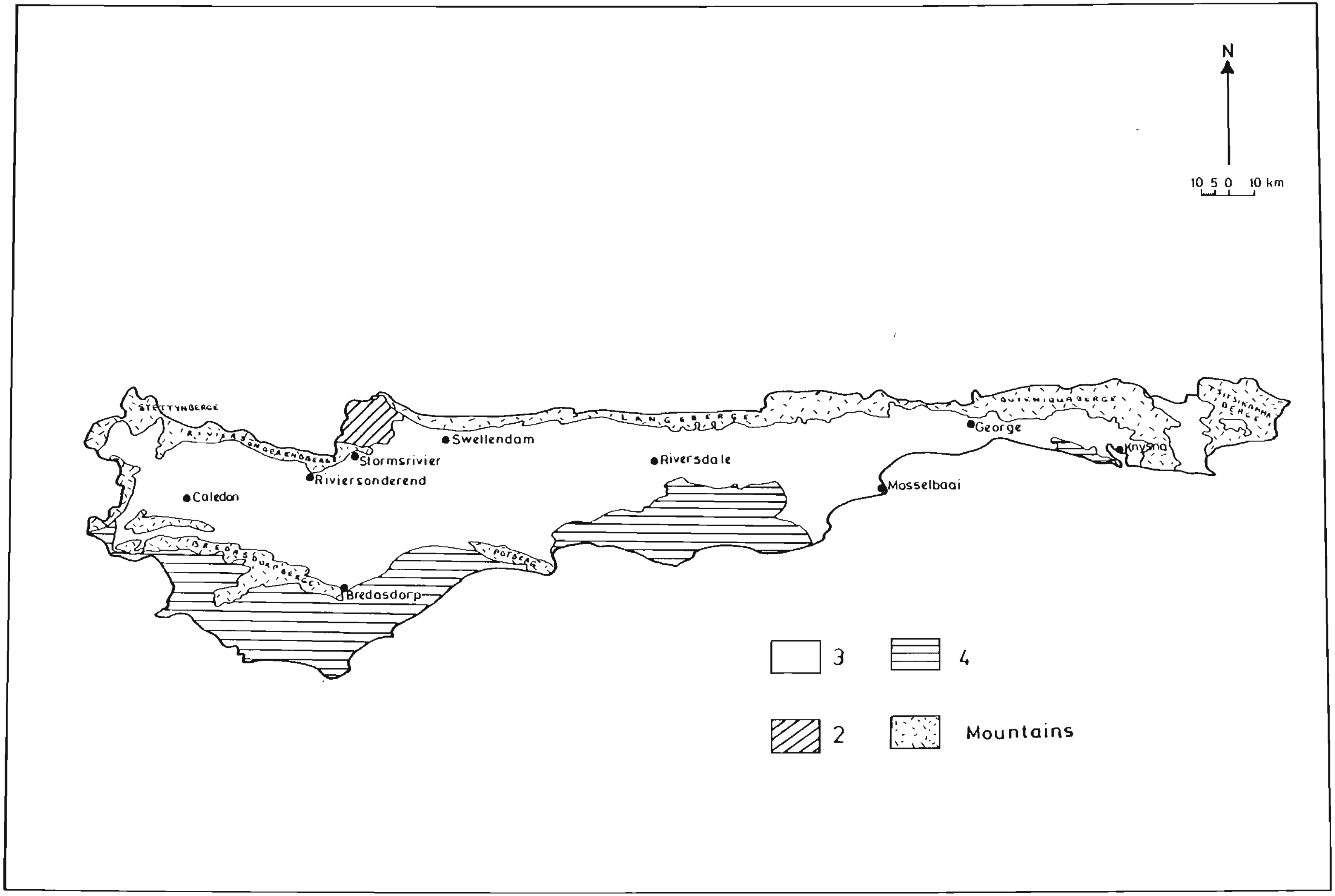
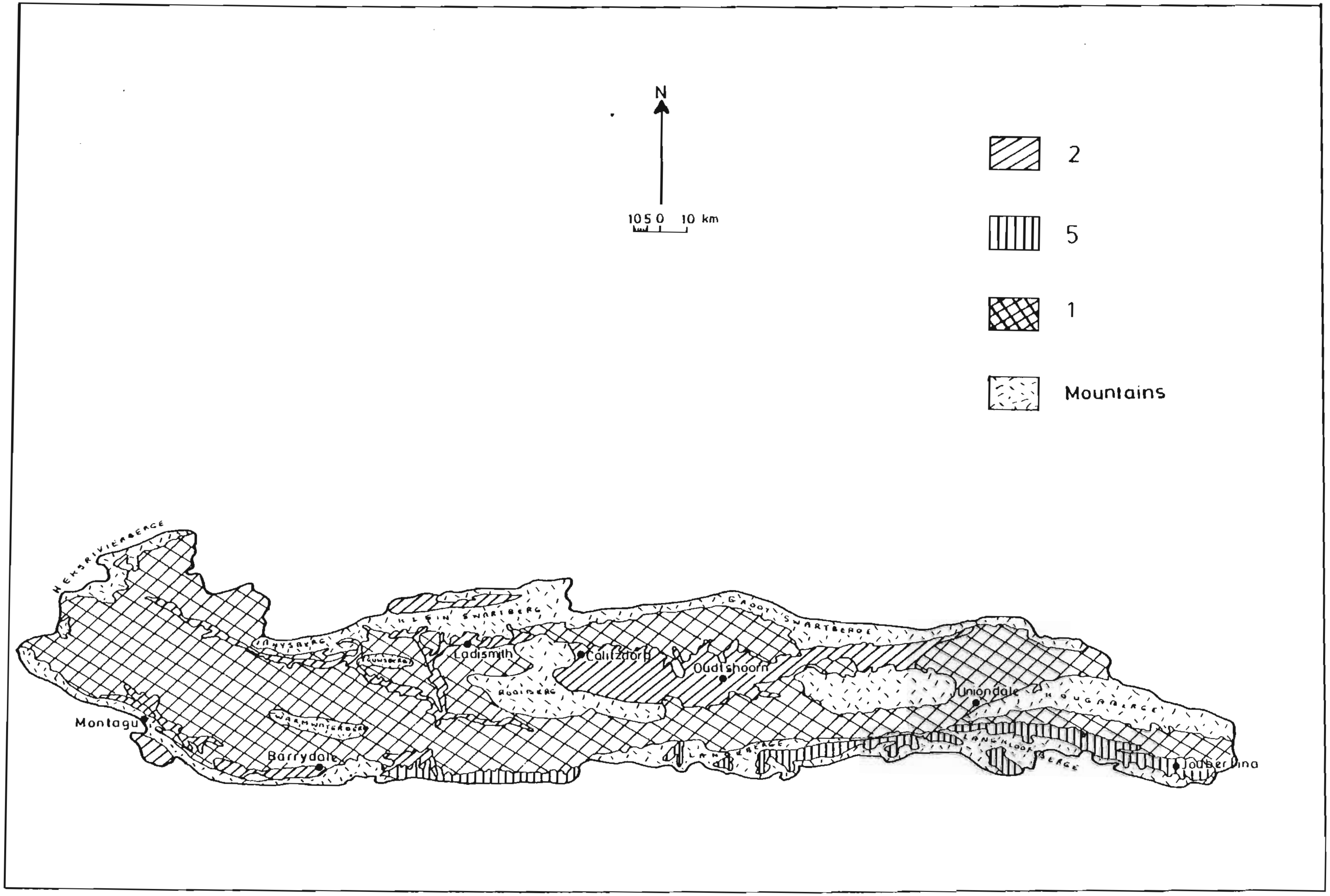


Figure 1.6 Little Karoo (for explanation of key see page 1 of text)



3 high potential for dryland, as well as irrigated pastures based on the species evaluated, where the occurrence of irrigated pastures is once again dependent on the availability of adequate amounts of irrigation water;

4 low potential for dryland pastures based on the species evaluated, due to the sandy nature of the soils, but a higher potential for irrigated pastures, if adequate amounts of irrigation water are available;

5 low potential for dryland pastures, based on the species evaluated, due to low or variable rainfall and/or low winter temperatures, while the occurrence of irrigated pastures is largely dependent on the availability of adequate amounts of irrigation water

According to the regional development program (Streeksontwikkelingsprogram, 1981) the total area of the WRR is about 12,8 million ha, of which approximately 10 million ha (78%) is natural veld and 2,8 million ha (22%) is cultivated. Of the cultivated area about 125 000 ha is irrigable. Natural veld, with the exception of the mountain catchment areas (1,8 million ha or 14%), comprise mainly the northerly and low rainfall parts of the WRR, i.e. the greater part of the Little Karoo and North West sub-regions. This area is therefore largely unsuitable for high potential established pastures. The cultivated high rainfall and irrigable farmland, however, comprises a formidable area with a high, but variable, potential for established pasture. This area is mainly (76%) situated in the Swartland, Boland and South Coast sub-regions.

1.2 Climate

The long-term climate of the five sub-regions has been well documented (S.I.R.I., 1985; Streeksontwikkelingsprogram, 1981). The North West, Boland and Swartland sub-regions receive most of their rain in winter. While the North West has a very low rainfall of approximately 50 to 200 $mm.A^{-1}$, the Boland and Swartland receive approximately 320 to 800 $mm.A^{-1}$. Within each sub-region the total annual rainfall, however, varies considerably. In the Swartland (figure 1.3) there is a decrease in total annual rainfall in a southerly and north westerly direction, while the rainfall in the Boland (figure 1.4) decreases in a northerly and north westerly direction. In the above-mentioned sub-regions a decrease in rainfall also occurs from the mountainous to the lower lying areas.

Within the South Coast (figure 1.5), the total annual rainfall not only increases, but its seasonal distribution also improves gradually in an easterly direction. However, generally speaking, the rainfall is much more evenly distributed over the summer and winter seasons within this sub-region than in the previously mentioned three sub-regions. The total annual precipitation within the sub-region varies between 400 and 1100 mm and generally increases in an easterly direction, as well as from the coast to the mountains.

The Little Karoo (figure 1.6) also receives a reasonably even distribution of annual rainfall over summer and winter which, in the greater part of the sub-region, averages about 250 $mm.A^{-1}$. The mountainous areas and the Langkloof valley do, however, have a much higher annual precipitation of 400 to 600 $mm.A^{-1}$. The Langkloof valley is therefore the only substantial area within the Little Karoo sub-region where high potential established dryland pastures would be a viable proposition.

The WRR has a reasonably moderate temperature regime, though very high maximum temperatures (±40°C) can occur in summer in most of the sub-regions. With the exception of certain high lying areas, such as the Grabouw and Villiersdorp area, the Koue Bokkeveld and the Langkloof valley, mean minimum winter temperatures are also reasonably moderate (±5°C) and frosts seldom occur.

1.3 Soils

The main feature of the soils of the WRR is their substantial variation in morphological, chemical and physical characteristics. This can be attributed to a substantial variation in geology (Coetzee & Schifano, 1970) and climate within this region. The majority of the soils are acid and very low in P. Soils derived from table mountain sandstone, however, also have a low K content. Generally, legume based pastures can, therefore, only be introduced where there has been a considerable input of fertilizer P and K and lime (Beyers, 1983).

No extensive description of the soils of the WRR has yet been published, but the regional development program (Streeksontwikkelingsprogram, 1981) provides a reasonably accurate and concise description. In the North West and the Little Karoo sub-regions established pastures are mainly limited to the irrigated areas along the Olifants river in the North West and the Groot, Gamka and Olifants rivers in the Little Karoo. The soils within these relatively small irrigable areas are complex and mainly of alluvial nature, although soils of table mountain sandstone parentage are also found. The main soil forms are equally varied and include anything from deep Hutton's, Dundee's and Oakleaf's to shallow Glenrosa's and Mispah's.

The Boland also has a very complex geology with a large variety of soils of which the Mispah, Glenrosa and Swartland forms are the most important for dryland pastures. In the Swartland the main parent rock is Malmesbury shale and the soil forms which have developed from it are mainly shallow Glenrosa's and Swartland's, but a small percentage of Shortland's and Hutton's also occur. These soils have a high potential for established dryland pasture. Nearer to the coast, however, sandy soils of medium to low potential for established pasture can be found. The two main soil forms in this area are Estcourt and Kroonstad.

The soils of the greatest part of the South Coast, i.e. the central area, have developed from Bokkeveld shale and the dominant soil forms are shallow Mispah's, Glenrosa's and Swartland's. This area has a high potential for established pasture. Eastwards soils overlaying granite, with the soil forms Estcourt, Kroonstad and Sterkspruit in the majority, can be found. These soils have a high clay content and tend to become waterlogged where rainfall is high. In the southern part of this area sandy soils with the Sterkspruit, Valsrivier and Estcourt forms dominant, can be found. These soils have a much lower potential for established pasture than those of the rest of the sub-region. The success of established pastures, however, varies and is largely dependent on the clay content of the soils.

Within the Little Karoo there is also the Langkloof valley which, as has already been indicated, is an area where dryland as well as irrigated established pastures are utilised. The valley is completely surrounded by table mountain sandstone ranges and much of the soil is derived from this material. Once again, however, the geology of the area is complex and has led to the development of a complex range of soil forms. Most of those already mentioned can be found here.

1.4 Main farming systems

As indicated in section 1.2, the rainfall of the two drier sub-regions, the North West and the Little Karoo, is very low. Within these two sub-regions high potential established pastures are, therefore, with the exception of the Langkloof valley and very small areas along the mountain ranges, only a viable proposition under irrigation. One of the major farming systems in these two regions is therefore sheep farming on natural veld. In the irrigable areas, especially in the Little Karoo, fruit, vine and vegetable farming, as well as dairying on high potential irrigated grass/legume pastures, are also very common.

The higher and better distributed rainfall in the Boland, Swartland and South Coast, however, allows the utilisation of high potential established pasture under dryland conditions. Between, but also within the two sub-regions the potential, however, varies quite substantially due to soil and climatic differences brought about by differences in temperature and total and seasonal rainfall distribution.

The Boland is perhaps the most complex of the three sub-regions, and fruit, vegetables and vines form a large part of the agricultural produce in the intensive areas. In these areas irrigated grass/legume pastures are also used on low potential soils. In the extensive areas of this sub-region small grains are the main crop, with the emphasis on wheat. Irrigated as well as dryland pastures are, however, also utilised for dairy and sheep farming. The dryland pastures are presently mainly based on medics (annual *Medicago* spp.), but nearer to the mountains in the higher rainfall areas, pastures based on lucerne (*M. sativa L.*) and subterranean clover(*Trifolium subterraneum L.*), are also used.

In the Swartland the major crop is wheat. Due to the seasonality of the annual rainfall, only the annual types of pasture, such as medics, are used. The use of this type of pasture is, however, still very limited because of the extent to which wheat production is subsidised (Wicht, *et al*, 1978).

Of the five sub-regions the South Coast has the highest potential for dryland and irrigated pastures. This sub-region already has about 250 000 ha (Wassermann, 1979) under dryland legume based pasture. Due to the more even distribution of rainfall in this sub-region, lucerne is the most important pasture legume. These pastures are generally grazed for five and in some cases ten or 15 years and then ploughed under and sown to wheat or barley for a number of successive seasons. More to the east, in the George area, the main emphasis is on vegetable farming and dairying. This latter area has a very well distributed rainfall and perennial pastures proliferate under dryland and irrigation.

The South Coast, Boland and Swartland are therefore the only sub-regions with a potential for high potential established dryland pastures. The South Coast has the greatest potential for the introduction of perennial, as well as annual species under dryland, while the Boland and Swartland are, with the exception of the high rainfall areas within each, largely suited for annual types of pasture. Irrigated pastures, however, occur within all the sub-regions and their use is limited only by the availability of irrigation water.

It is therefore obvious that the WRR has a formidable area of land with a high potential for established pasture. The region's unique rainfall distribution and relatively poor soils, however, have as a consequence also a very unique research requirement and research results derived in other regions often, therefore, have only limited application. The diversity of farming systems practised in this region and the fact that animal production systems dependent on established pastures very seldom form the main farming component on the farm, results in a very complex situation. Pastures are generally only a part of a wheat and/or fruit producing farming system and any new pasture type or pasture management system must, therefore, also be compatable with the other systems on the farm.

A further complicating factor is the fact that established pastures often, and in fact in the majority of cases, form the only source of feed for an animal production system. In dryland situations the main animal utilising these pastures is sheep and, as only very limited amounts of supplementary feed are made available during the dry summer period, the pressure, due to overgrazing, on a dryland pasture is very high. A research program endeavouring to evaluate suitable pasture species or to unravel the numerous relevant aspects of pasture management, will therefore have to be a formidable one.

2. RESEARCH OBJECTIVES

2.1 General background

Until the mid 1970's research on established pastures received only limited attention in the WRR and the main emphasis was on agronomic, viticultural, pomological and animal science research. Pasture research reported since then has also mainly been of an agronomic (Starke, 1955; Sim, 1958; Walters, 1968; Wassermann & Wicht, 1972; Van Heerden & Wassermann, 1977; Langenhoven, 1978; Lamprecht, 1983; Van Heerden & Beukes, 1984) or plant physiological (Wicht, 1970; Van Heerden & Wassermann, 1981; Van Heerden, 1984) nature. Only two research projects in which grazing animals have been included have been reported on (Terblanche, 1974; Wicht, et al, 1978). This indicates the substantial need for basic and applied pasture research, with special emphasis on pasture:animal relationships.

Because of the considerable variation in annual and seasonal rainfall within the region and the importance of irrigated pastures, a wide variety of pasture species are at present in use in the WRR. Dryland, as well as irrigated pastures, are mainly legume based. The most important legumes used under dryland conditions are lucerne (*Medicago sativa* L.), medics (annual *Medicago* spp.) and to a lesser extent subterranean clover (*Trifolium subterraneum* L.). The majority of the dryland pastures are either pure stands or mixtures of two or more of the above-mentioned legumes. Grasses such as cocksfoot (*Dactylis glomerata* L.), tall fescue (*Festuca arundinacea* Schreb.), *Phalaris aquatica* L. and annual ryegrass (*Lolium multiflorum* L. or *L. rigidum* L.) are, however, also included in mixtures with lucerne in the higher rainfall areas of the South Coast.

Under irrigation the emphasis is mainly on grass/legume mixtures, and pure stands of legumes or grasses are the exception rather than the rule. In most cases pure pastures consist either of lucerne or kikuyu (Pennisetum clandestinum Hochst ex Chiov.). Generally the pasture mixtures have lucerne and/or white clover (Trifolium repens L.), with or without red (T. pratense L.) and strawberry clover (T. fragiferum L.), as main legume components. The grass component consists mainly of the above-mentioned temperate grasses and perennial ryegrass (Lolium perenne L.).

The large number of species used in pastures, the complexity of the WRR as far as soil and climatic factors, the uniqueness of the region's rainfall distribution and the very limited amount of previous research on established pasture, necessitated the initiation of a well planned and coordinated research programme. An intensive research programme with a broad base rather than in depth research on a limited number of aspects was therefore started shortly after the formation of the present pasture research section during the early 1970's. This thesis will essentially report on the results of some of the various facets executed as steps in this research programme over the period 1976 to 1985.

The following investigations were carried out and will be reported on:

1 total annual and seasonal production of a number of pasture legumes and grasses grown in plots under dryland and irrigation;

2 the relationship between the seasonal production of legume and grass species and climatic variables and, as a further step, extrapolation using long-term climatic data under dryland and irrigation;

3 the seasonal and mean annual grazing capacity of different grass/legume, legume and grass pastures under dryland and irrigation;

4 the influence of certain management factors, such as weed control, cutting frequency and grazing management, on pasture production and composition, and their influence on animal production; and

5 the development of a preliminary climate:pasture:animal production model, using the data derived in the plot and grazing trials.

2.2 Research centres

The major part of the five phases of the above-mentioned research program was executed at experimental stations situated within four of the five sub-regions. Data acquired at two other sites, Sergeantsrivier, and the Langkloof Experimental Station were, however, used for the validation of the models developed at the other sites. The sites of research, the specific sub-region within which they are located, the type of research done at each, the pasture species involved and the basic soil form at each trial site are summarised in table 2.1.

The sites in table 2.1 are climatically and edaphically reasonably representative of the sub-regions within which they are located. As has already been stated, considerable variation in soil and seasonal and annual precipitation occurs within the sub-regions and this limits the direct extrapolation of research results within or over sub-regional boundaries. The development of a simple but effective model or models describing the relationships between weather data and seasonal pasture production at

TABLE 2.1 RESEARCH CENTRE, SUB-REGION AND TYPE OF RESEARCH

Research Centre (E = experimental, V = validation)	Sub-region	Type of Trial	Type of research	Soil form	Dryland (D) or Irrigated (I)	Species
Langgewens (E)	Swartland	Plot	Seasonal dry matter production	Glenrosa	D	Annual Medicago spp.
Elsenburg (E)	Boland	Plot	(a) Seasonal dry matter production (b) Influence of frequency of cutting	Hutton Hutton	D D	Annual Medicago spp., lucerne, tall fescue, cocksfoot, Phalaris, subterranean clover
Welgevallen (E)	Boland	Plot	(a) Seasonal dry matter production (b) Influence of frequency of cutting	Katspruit Katspruit	I I	Lucerne, tall fescue, cocksfoot, Phalaris, annual and perennial ryegrass, kikuyu, white clover, red clover
Sergeantsrivier (V)	South Coast	Plot	Seasonal dry matter production	Glenrosa	D	Annual Medicago spp, subterranean clover
Tygerhoek (E)	South Coast	Plot	(a) Seasonal dry matter production (b) Influence of frequency of cutting	Glenrosa Glenrosa	D D	Lucerne, tall fescue, cocksfoot, Phalaris, annual Medicago spp and subterranean clover
		Paddock	(a) Comparison of the grazing capacity of pastures (b) Influence of weed control practices on the mean annual grazing capacity (c) Influence of grazing management and grazing pressure on mean annual and seasonal grazing capacity	Mispah Glenrosa Glenrosa	D D I	Lucerne, annual Medicago spp. Lucerne, annual Medicago spp, and subterranean clover Lucerne, white clover, red clover, perennial ryegrass, tall fescue, cocksfoot
Outeniqua (E)	South Coast	Plot	(a) Seasonal dry matter production (b) Influence of frequency of cutting	Estcourt Estcourt	D and I D and I	Lucerne, white clover, red clover, annual and perennial ryegrass, tall fescue, cocksfoot, Phalaris, kikuyu, subterranean clover
		Paddock	Influence of mixture and length of rotation on seasonal grazing capacity	Estcourt	I	Lucerne, white clover, perennial ryegrass, cocksfoot, tall fescue
Oudtshoorn (E)	Little Karoo	Plot	(a) Seasonal dry matter production (b) Influence of frequency of cutting	Oakleaf Oakleaf	I I	Lucerne, white clover, red clover, annual and perennial ryegrass, tall fescue, cocksfoot, Phalaris, kikuyu
Langkloof Exp. Station (V)	Little Karoo	Plot	Seasonal dry matter production	Estcourt	D	Lucerne

different sites should, however, make possible the long-term extrapolation of data at a specific site to a variety of seasonal conditions as well as to sites with the same soil form or even to soil forms of similar potential at other sites.

Figures 2.1 to 2.3 depict the long-term mean monthly maximum and minimum temperature, solar radiation and rainfall at each of the research sites (S.I.R.I., 1985).

Figure 2.1 indicates that Langgewens, Elsenburg and Welgevallen have a typical Mediterranean temperature regime. This is indicated by the high summer maximum and relatively moderate winter minimum temperature regimes recorded. Tygerhoek, Outeniqua, Langkloof Experimental Station and Sergeantsrivier, have a more moderate summer temperature regime, but winter minimum temperatures are, especially at Tygerhoek, much lower. Oudtshoorn has, in contrast to the other sites, a much more extreme temperature regime characterised by low winter minima and high summer maxima.

Figure 2.2 indicates that a slightly lower solar radiation level is experienced during summer at Tygerhoek and Outeniqua than at the other sites, while radiation at Oudtshoorn is slightly higher than at the other sites. Generally, however, differences in solar radiation received at the different sites are small in comparison with the variation of the other climatic factors.

The greatest difference in climate between the different sites is found in their mean monthly rainfall. As shown in figure 2.3, the rainfall at Langgewens, Elsenburg and Welgevallen is very seasonal and strictly winter orientated. Welgevallen receives the highest annual precipitation and Langgewens the lowest of the three. The distribution at the other sites is, however, much more even through the year.

Figure 2.1 Long-term mean monthly temperature at the six experimental (E) and two validation (V) sites

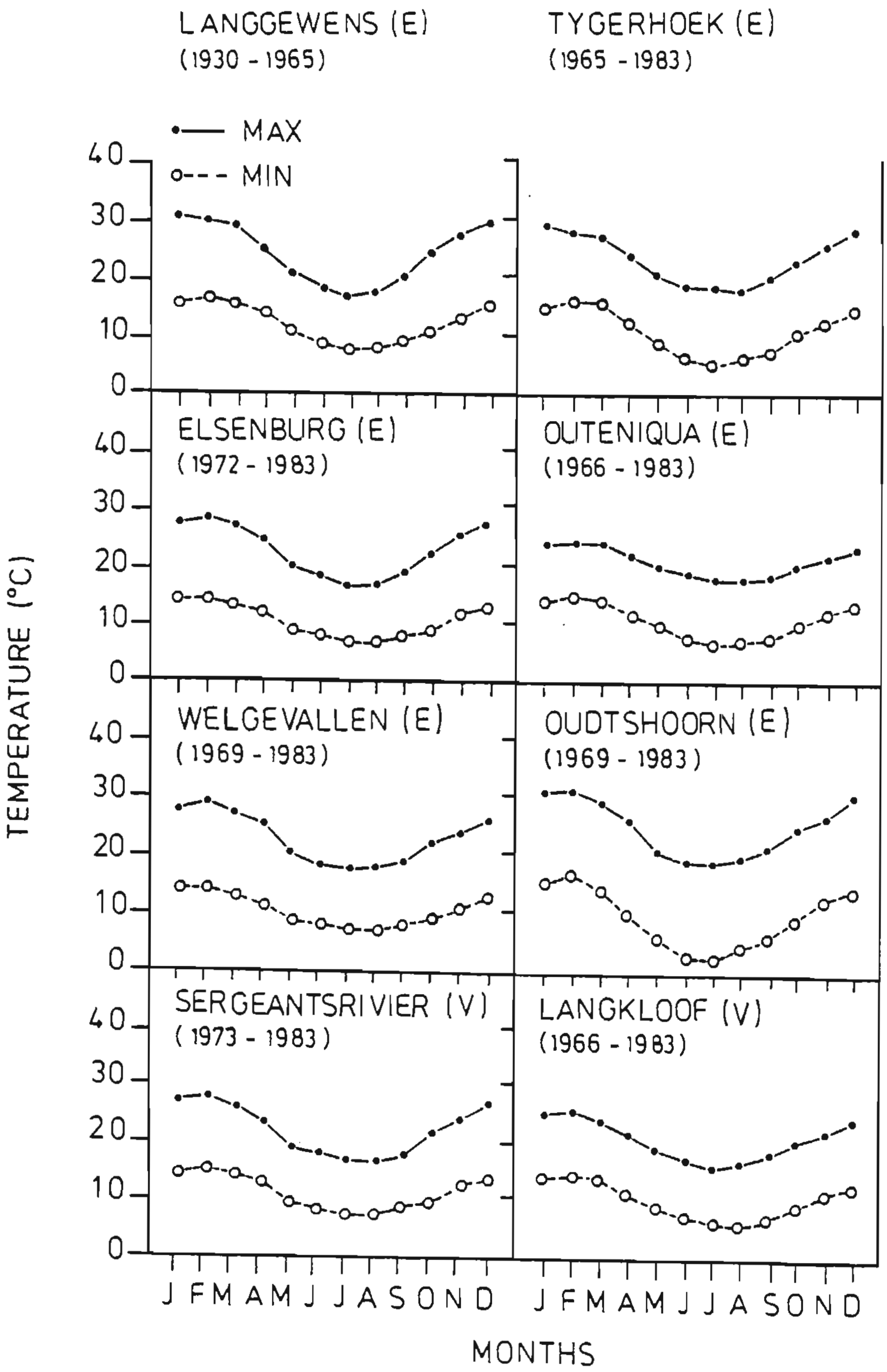


Figure 2.2 Long-term mean monthly total daily solar radiation at the six experimental (E) and two validation (V) sites

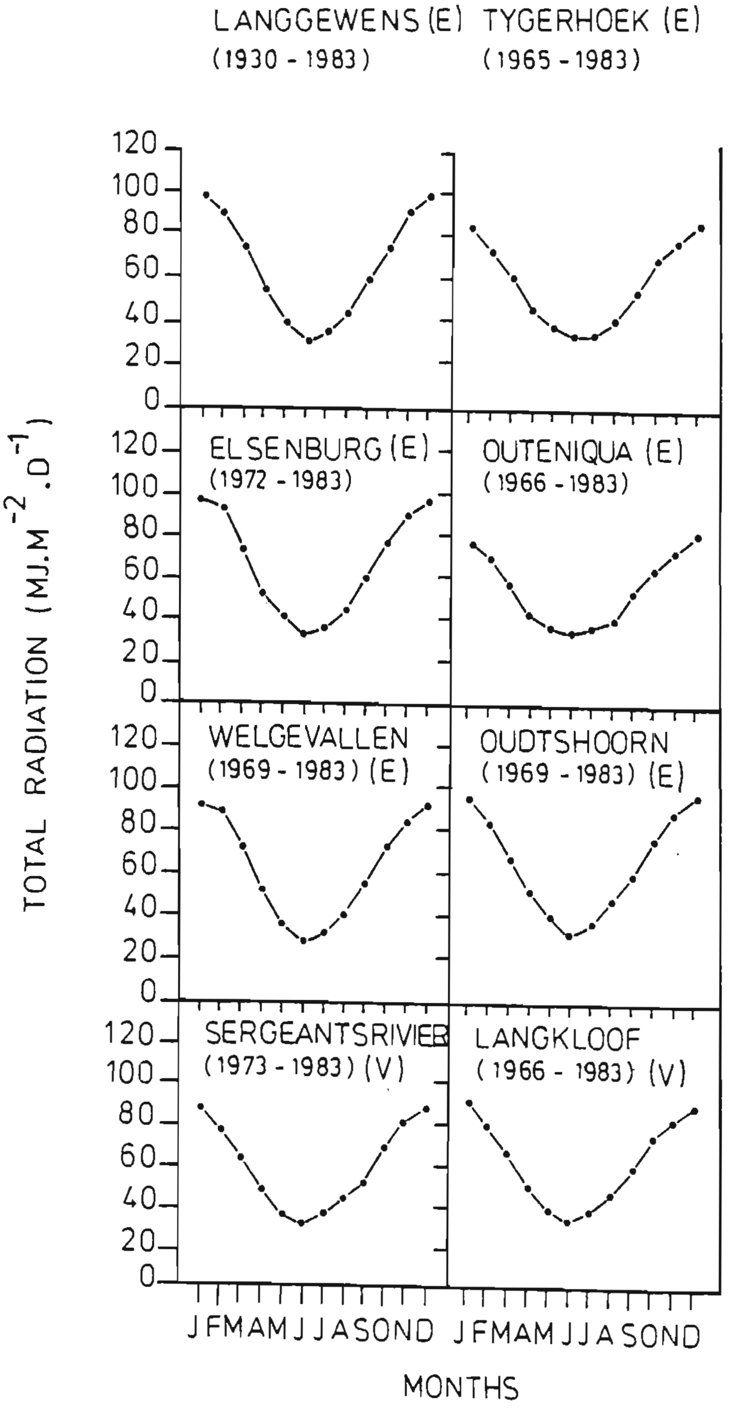
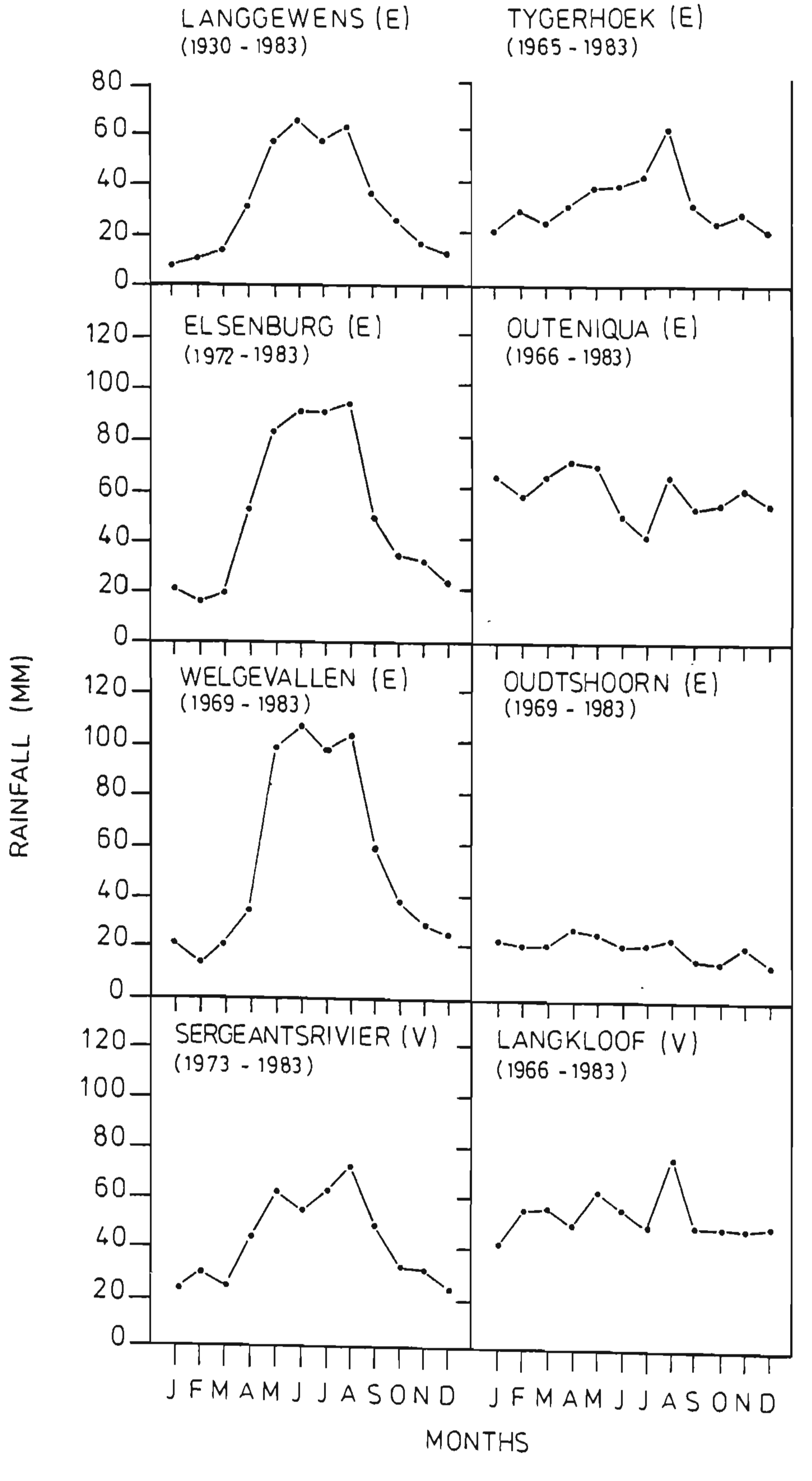


Figure 2.3 Long-term mean monthly rainfall at the six experimental (E) and two validation (V) sites



The highest rainfall occurs at Outeniqua and the lowest at Oudtshoorn.

3. SEASONAL PRODUCTION OF PASTURE LEGUMES AND GRASSES AS DETERMINED IN CUTTING TRIALS

3.1 Introduction

3.1.1 Objectives

This study had three main objectives:

(a) the evaluation of the most important pasture species at a number of localities;

(b) the characterisation of the species in terms of their seasonal production potential at each locality, and

(c) the long-term extrapolation of the data, with weather data as basis, in order to characterise each locality in terms of it's seasonal production potential.

3.1.2 Selection of trial sites

The different trial sites have been indicated in figure 1.1 and table 2.1 and the main climatic features of each was described in section 2.2. The majority of the cutting trials were situated at research stations distributed through the region, but one additional site was used for co-operative trials. The stations were Langgewens, between Moorreesburg and Malmesbury; Elsenburg and Welgevallen, at Stellenbosch; Tygerhoek, near Riviersonderend; Outeniqua, near George; Oudtshoorn, near Oudtshoorn; and the Langkloof Experimental Station, between Misgund and Joubertina. The data of one other site, Sergeantsrivier, near Caledon, were used to evaluate the yield:weather data models for medic and subterranean clover. The specific sites were used because they were near weather stations and also because sufficient labour and technical assistance was available.

The sites were, however, also climatically and edaphically reasonably representative of the different sub-regions.

3.1.3 Selection of species

The large number of species in general use in the WRR can be attributed to a number of factors. Due to the relatively low input into research on established pastures in the WRR, there has been an equally low input into the evaluation of species. Only two papers (Sim, 1958; Wassermann & Wicht, 1972) reporting on actual evaluations done in the WRR have thus far been published. The recommendations of species and cultivars have, therefore, up to this stage, largely been based on relevant overseas literature (Whyte, et al, 1953; Donahue, et al, 1956; Whyte, et al, 1959; Spedding & Diekmahns, 1971; Leigh & Noble, 1972; Langer, 1973), on intelligent guesses and on the success of complex mixtures sown on farms as demonstrations. Pasture mixtures which have been recommended have, therefore, been extremely complex (Pienaar & Volschenk, 1970; Wassermann, 1981).

The manner in which established pastures are utilised in the WRR is another possible reason for the use of a wide range of species. They are mainly utilised for all-year grazing and a specific pasture often serves as the only component of the whole fodder production system. To comply with this requirement mixtures usually contain a large number of species. Only in very limited cases are special purpose pastures established with the specific aim of providing feed to bridge a period of feed shortage.

A third and equally important reason for the diversity of pasture species used, is the large soil and climatic variation and the importance of irrigated pastures in the WRR. This broadens the spectrum of species that are successfully established and utilised.

The species selected for evaluation in cutting trials have already been listed in table 2.1. Out of the large number of species available only the most important and those on which the most breeding work is currently being undertaken, were selected for evaluation. As the main objective was the evaluation of species and not cultivars as such, only the results of the most successful cultivars, which have been evaluated at all sites, will be discussed.

The species selected were the following:

(a) Legumes

(i) Lucerne (*M. sativa*)

Lucerne is undisputably the most important pasture and fodder legume in the WRR. As will be discussed in subsequent chapters, it is the main legume component of the very successful dryland legume-based pastures in the South Coast sub-region and in the higher rainfall areas of the Boland and the Swartland. It is also very effectively utilized under irrigation on well drained soils in all parts of the WRR. In the Little Karoo, lucerne is not only an important pasture and fodder legume in irrigated pastures for dairying and sheep, but also the main pasture for the ostrich farming industry.

Lucerne is often utilized as a pure stand for grazing, but in most cases it is only one of the major components of a mixture. Under dryland conditions it is mainly planted in mixtures with subterranean clover and/or medics (Pienaar & Volschenk, 1970; Van Heerden, 1981; Wassermann 1981).

Under irrigation and under dryland in the all year rainfall area of the South Coast east of Mosselbay, lucerne is also included in mixtures with temperate grasses such as cocksfoot (D. glomerata), tall fescue (F. arundinacea), Phalaris (P. aquatica) and perennial (L. perenne) and annual (L. multiflorum and L. rigidum) ryegrass (Pienaar & Volschenk, 1970; Van Heerden, 1981; Wassermann, 1981).

Lucerne is mainly utilised for grazing in the WRR and will be evaluated as such. The only cultivar evaluated was S.A. Standard. This is to a certain extent a limitation of the work, but when this investigation commenced aphid infestation was not a serious problem. The control of aphids is still relatively cheap and this fact and also the fact that S.A. Standard has been very successful under dryland, has lead to its continued use in practice.

(ii) Medics (annual Medicago spp.)

As dryland pasture legumes in the WRR, medics are second in importance only to lucerne. Medics have a much wider adaptation than lucerne and are successfully utilized in most parts of the South Coast, and to a lesser extent also the Swartland and Boland. This is made possible by their winter growth habit and the relatively short growing season (April/May to October/November) necessary for the completion of a full growth cycle. They are, therefore, able to utilize a short winter growing period. Their hard seededness also enables their utilization as short rotation leys for wheat.

Medics are mainly established as pure stands or in mixtures with lucerne and/or subterranean clover (Pienaar & Volschenk, 1970; Van Heerden, 1981; Wassermann, 1981). Their use in mixtures with annual ryegrass (L. multiflorum and L. rigidum) has been recommended (Wassermann, 1981), but they are very seldom utilized in this way. The main reasons for this are the problems which have been experienced with annual ryegrass toxicity, the danger of ryegrass becoming a weed in the subsequent wheat crop and the strong and often detrimental competition from ryegrass in such mixtures.

The main species at present in use in pastures are M. trunculata (cv's Jemalong, Borung, Cyprus, Hannaford and Paraggio), M. littoralis (cv. Harbinger), M. tornata (cv. Tornafield) and M. rugosa (cv. Paragosa, Paraponto and Sapo). The two most successful species are M. truncatula and M. littoralis. The cultivars Jemalong, Borung and Cyprus are generally recommended for use in areas with heavy soils, and Harbinger for areas with light soils (Van Heerden, 1981).

The problem of aphid infestation has, however, complicated recommendations. Some of the above-mentioned cultivars are extremely susceptable to the pea aphid (Acyrthosiphon pisum). Thus far only one commercially available aphid resistant cultivar, Paraggio, has shown any promise, although Paraponto and Sapo are also supposed to be aphid resistant. However, the evaluation of cultivars as such was not the main objective of this study and no aphid resistant cultivars have thus far been effectively evaluated. Only those cultivars which have been effectively evaluated, namely Jemalong, Borung and Cyprus are, therefore, selected for further discussion.

(iii) Subterranean clover (T. subterraneum)

Subterranean clover is generally used in dryland pasture mixtures in the higher rainfall areas of the South Coast, Boland and Swartland (Van Heerden, 1981). This species, however, generally needs a much longer growing season. It is also not as hard seeded as the medics and therefore is more susceptible to out of season rains. These shortcomings not withstanding, a reasonable amount of success has been attained with this legume. A large number of cultivars varying in the length of their growing season have been available on the market over the last number of years. The most important of these have been Clare, Woogenellup, Mt Barker, Geraldton, Daliak, Howard, Seaton Park, Nungarin, Larissa, Northam A and Trikkala. The most successfull of these have been Clare, Woogenellup, Mt Barker and Geraldton.

Subterranean clover generally produces more dry material than the medics in the higher rainfall areas with a longer growing season, but in areas with a short growing season, the early cultivars (e.g. Geraldton) have not been able to compete with the medics.

A sudden outbreak of root diseases during the 1978/79 season, mainly caused by Fusarium spp, has reduced the number of cultivars that can be used in the WRR and presently only one cultivar, Woogenellup, is recommended. The seasonal production of this cultivar will therefore be compared with that of two equally high producing cultivars, Clare and Mt Barker.

(iv) White clover (T. repens)

This legume adapts and produces fairly well in cutting trials on dryland sites in the high rainfall areas of the South Coast, east of Mosselbay, but is not as successful under dryland grazing conditions. Under irrigation, however, it is used as the main legume component of intensively irrigated pastures (Van Heerden, 1983). As it is very shallow rooted and therefore needs very frequent irrigations (Van Heerden & Beukes, 1984), it's use is limited to poorly drained soils or intensively irrigated pastures.

At present white clover is mainly included in mixtures with temperate grasses such as tall fescue, cocksfoot and annual and perennial ryegrass. The renewed interest in irrigated pastures in the fruit and vine producing areas, has necessitated a greater input into research on this legume. The shallow root system and resistance to waterlogging of white clover allows it to be used in pastures established on soils not suitable for other permanent crops. The main cultivars presently available in the WRR are Ladino, Permanent Pasture, Huia, Haifa and Tamar. The cultivars Ladino and Permanent Pasture were evaluated at all the sites and are therefore those which will be considered in later discussions.

(v) Red clover (_T. pratense_)

This legume has generally been included in intensively irrigated grass/legume mixtures with lucerne and/or white clover (Van Heerden, 1981). There are presently only three cultivars available, Kenland, Hamua and Turoa. Kenland and Hamua were the only two cultivars evaluated at all the sites and only the results from these two cultivars will be considered.

(b) Grasses

(i) Kikuyu (_Pennisetum clandestinum_)

Kikuyu is as a rule utilized under irrigation and also mainly as a pure stand, as very few other pasture grasses and no legumes can successfully compete with it. As the combination with a legume is out of the question, pastures based on kikuyu in the WRR require a very high level of nitrogen fertilization. This makes kikuyu a relatively expensive pasture and combined with a high seasonality of production, limits its use in the WRR. Generally it is therefore used only in extreme situations where, due to severe waterlogging or salinity, no other pasture species are suitable.

At present the seed of one cultivar, Whittet, is available, but generally the non-seeding local strains are planted vegetatively. This is partly due to the fear of kikuyu becoming a weed in orchards or vineyards, as Whittet produces seed very freely. The results that will be discussed are those derived from trials with the local strains and Whittet.

(ii) Tall fescue (F. arundinacea)

Tall fescue is, as has already been indicated, one of the major components of dryland as well as irrigated grass/legume mixtures (Van Heerden, 1981; 1983). This grass produces high yields but is very unpalatable when not grazed intensively enough or when the rotation is too long. Its productive capacity, however, does make it a very important component of mixtures. At the start of the trials, there were only four cultivars, Kentucky 31, Festal, Demeter and Kenhy, commercially available in South Africa. There is not much difference in the production potential of the individual cultivars under irrigation and under dryland in the higher rainfall areas. Under dryland in the lower rainfall areas with a more seasonal precipitation, however, only Demeter survives. The seasonal production of Kentucky 31, Alta, Demeter and Kenhy will be compared in the subsequent discussions.

(iii) Cocksfoot (D. glomerata)

This grass is generally utilized under the same situations as tall fescue (Van Heerden, 1981; 1983). Though cocksfoot has a lower production potential than fescue, it is much more palatable and therefore also much more susceptible to hard grazing. The cultivars that have been in use in the WRR over the last number of years are Currie, Hera, Danish and Karkloof. As in the case of fescue there is very little difference in production between the different cultivars under irrigation and under dryland in the higher rainfall areas. Under dryland in the areas with a short growing season, however, only Currie survives. The cultivars that will be compared are Currie, Danish, Hera and Karkloof.

(iv) Phalaris (P. aquatica)

Phalaris is often included in irrigated and dryland grass/legume pastures in the WRR. Usually it is included for its winter production in mixtures with Lucerne, tall fescue and cocksfoot. Its high winter production and summer dormancy makes it an extremely successful dryland pasture grass in a larger part of the WRR than either cocksfoot or tall fescue. At present the seed of only two cultivars is available commercially, i.e. Seedmaster and Sirolan. The latter is an improved selection and is still being evaluated. The only cultivar that has been extensively evaluated at all sites is Seedmaster and results of this cultivar only will be discussed.

(v) Annual ryegrass (Italian, i.e. L. multiflorum and wimmera, i.e. L. rigidum)

Both Italian and wimmera ryegrass have an annual growth habit in the Winter Rainfall Region and are therefore utilised as such. These two types of ryegrass are usually included in dryland and irrigated mixtures (Van Heerden, 1981; Wassermann, 1981), but are also utilized as special purpose pastures during winter. For this purpose they are usually utilised as pure stands or sown in mixtures with woolly podded vetch (V. dasycarpa) or shaftal clover (T. resupinatum) under irrigation, as well as under dryland conditions. The advent of the problem of annual ryegrass toxicity in the WRR has, however, brought about a drastic decrease in the use of this type of grass. There are presently a large number of cultivars available and they change every few years. The main cultivars that have been available over the last number of years are Midmar, Wimmera, Tama, Gulf, Energa and Billion. Of these only Midmar (L multiflorum) has been evaluated at all the sites and will therefore be considered in this discussion.

(vi) Perennial (L. perenne) and hybrid (L perenne x multiflorum) ryegrass

Ryegrass with a perennial growth habit in the Winter Rainfall Region is, as has already been indicated, an important component of irrigated grass/legume pastures (Van Heerden 1981; 1983). As in the case of the annual type of ryegrass it is usually included for it's winter production as its total annual production is usually much lower than that of, for instance, tall fescue. It is, however, not very drought resistant, and although it survives and produces fairly well in dryland plot trials in the high rainfall areas of the South Coast, it does not survive under grazing conditions.

There have been a large number of cultivars available on the market the last number of years. The main cultivars have been Nui, Ruanui, Agresso, Ariki, Derby, Citadel, Tetrone, Fantoon and Bonita. Only Ruanui, Agresso and Ariki will be discussed.

3.2 Methods

3.2.1 Collection of yield data

The seasonal production patterns of the different species have been derived from plot cutting trials on pure swards. The trials were laid out as random blocks with three replicates. In the case of the medics and subterranean clover only one sampling frequency and a gross plot size of 2 m x 4 m was used. The perennial grasses and legumes were evaluated in two sets of trials. The first trials were cut at one frequency and therefore only needed a gross plot size of 2 m x 4 m, but the second group of trials was cut at three different frequencies and this necessitated a larger, 4 m x 4 m gross plot.

Within the plots the species were either sown or planted, as in the case of kikuyu, in 200 mm rows at twice the commercial seeding rates to ensure effective establishment. Before establishment the soil at each trial site was fertilized with the prescribed amounts (Beyers, 1983) of lime, P and K, based on a soil analysis. Irrigated and dryland grass plots were respectively fertilized with 1200 (100 kg $N.ha^{-1}.M^{-1}$) and 600 kg $N.ha^{-1}.A^{-1}$ (50 kg $N.ha^{-1}.M^{-1}$). Irrigated trials were irrigated at weekly to twice weekly intervals, based on tensiometer readings. Soil moisture was therefore largely eliminated as a limiting factor in these trials.

The trials were kept completely weed free by spraying, where appropriate, with grass and broad leaved weed killers. The weed killers used were propyzamide (0,74 kg $ai.ha^{-1}$), Dinoseb (0,90 kg $ai.ha^{-1}$) and 2,4-DB (1,63 kg $ai.ha^{-1}$). When necessary weeds were, however, also manually weeded from the plots. The legumes were sprayed at least once every growing season with dimethoate (60g $ai.ha^{-1}$) or methoate (32g $ai.ha^{-1}$) to control pea aphid (Acyrthosiphon pisum), blue green aphid (Acyrthosiphon kondoi), lucerne springtail (Sminthurus viridus) and red legged earth mite (Halotydeus destructor) infestation.

The medic and subterranean clover trials were sampled at four-weekly intervals during the growing season. This was done by hand clipping and consisted of cutting to ground level a 0,25 m^2 area, chosen at random within each plot. At every consecutive sampling a different area was chosen within the plot. The particular sampling procedure was employed partly because of the sensitivity of the medics to cutting at the wrong stage. At the stage when the medic and subterranean clover trials commenced there was also no suitable mechanical apparatus available for the mowing of trials scattered over such a large area and at some distance from the headquarters at Stellenbosch.

The trials for the evaluation of perennial grasses and perennial legumes were cut with a small-plot forage harvester. Sampling consisted of cutting a swath down the length of the plot. The net plot size depended on the cutting width of the different machines used at each trial site, but was generally about 1 m^2. The first set of trials was cut each time the growth attained a certain height (150 to 200 mm). The second group of trials was cut at three set frequencies i.e. four, six and eight weekly and for this purpose each 4 m x 4 m plot was divided into three equal subplots to which the cutting treatments were applied at rondom.

Cut samples were dried at 60°C for the determination of dry matter yield. The mean rate of dry matter production (kg dry matter.$ha^{-1}.d^{-1}$) was subsequently calculated between each harvest date. These data were processed annually for the calculation of mean monthly rates of production, which were in turn used for the calculation of the mean monthly production rate at each site over years. It is this latter data which will form the basis of later discussions.

Each trial was generally executed over a period of three years, after which a new trial was established. This was necessary, partly to prevent excessive weed infestation and also to ensure that age did not affect production. At each site the data for one or two consecutive trials were therefore available.

3.2.2 Collection of weather data

Each trial was established at a site near a weather station which was erected and serviced by personnel of the Soil and Irrigation Research Institute (S.I.R.I.). The basic weather data necessary for the development of the weather:pasture production models were therefore readily available. The weather data used were kept as simple as possible and limited only to the mean monthly temperature, sunshine hours, the total monthly rainfall and class A pan evaporation.

Mean monthly temperatures were derived, using the mean daily maximum and minimum temperature values and the total monthly rainfall and class A pan evaporation, by using the measured daily values. The mean daily solar radiation was calculated using the mean daily sunshine hours averaged over each month, adjusted using a modified Angstrom (1925) formula:

$$Q_{TOT} = C.Q_{EXT}\ (A+B(SUN.DAY^{-1})),$$

where Q_{TOT} = total daily radiation in $MJ.M^{-2}.d^{-1}$,

Q_{EXT} = extraterrestrial radiation in Langleys ($ly.d^{-1}$),

SUN = Sunshine (h),

DAY = daylength (h),

C = 0,041855 and is a constant used for the conversion of $ly.d^{-1}$ to $MJ.M^{-2}.d^{-1}$,

A and B are constants, the values of which depend on the degree of latitude and would therefore vary between sites. Louw (1965) found the values of A and B to equal 0,24 and 0,53 respectively. Mathee (pers com), however, calculated A and B for the WRR and found them to be about 0,23 and 0,44 respectively. Due to a relatively small variation in degree of latitude between sites, especially if variations in the pasture production data was taken into consideration, it was decided that the same constants would be used for all sites. It was decided that the values recommended by Mathee (pers com) would be used, because they had been developed in the WRR.

The values of Q_{EXT} and DAY not only varied from site to site, but also through the growing season. However, between site variation was relatively small and was therefore ignored for the same reason mentioned above. Mean monthly values of these two parameters, calculated over sites, were therefore used. These values are tabulated in table 3.1.

3.2.3 Extrapolation of yield data

For the determination of the long-term seasonal production potential of a pasture species at a particular site a basis for extrapolation had to be derived. It is generally accepted that the main factors determining pasture yield at a particular site are soil type, the availability of nutrients, soil moisture, solar radiation and the ambient temperature (Fitzpatrick & Nix, 1975). The influence of soil type is very difficult to quantify and it would therefore be extremely difficult to extrapolate to sites in which the soil form was not represented in one of the trials. As one would also expect the production potential to vary within a specific soil form, it is clearly an almost impossible task to establish enough trials to incorporate all possible combinations of soil form, aspect, depth, etc. The number of trials executed was hopelessly inadequate for

TABLE 3.1 THE MEAN MONTHLY VALUES OF EXTRATERRESTRIAL RADIATION (Q_{EXT}) AND DAYLENGTH (DAY) USED FOR THE CALCULATION OF THE MEAN DAILY RADIATION PER MONTH

Month	Q_{EXT} ($ly.d^{-1}$)	DAY(h)
J	1031	14,1
F	935	13,4
M	773	12,3
A	597	11,2
M	457	10,4
J	392	10,0
J	420	10,2
A	534	10,9
S	699	11,9
O	869	13,0
N	995	13,9
D	1051	14,3

this purpose. It was therefore decided to correlate seasonal production with climate only at each site and, whenever possible, also over sites. Where appropriate, trial sites were combined into two main groups based on soil potential, i.e. a high potential and a low potential soil group.

For each site the insufficiency of soil nutrients was removed as a limiting factor by maximal fertilization. In the dryland trials the main factors considered to limit seasonal pasture production were therefore soil moisture content, temperature and the available solar radiation. In the irrigated trials soil moisture content was also eliminated as a determinant of production by regular irrigation.

The relative importance of temperature, solar radiation and soil moisture content in determining pasture production, is likely to vary between sites, as well as seasonally and annually, at a specific site. In a mediterranean environment soil moisture content is the major limiting factor during summer (Smith & Stephens, 1976). During autumn and winter and also during summer under irrigation, however, the rate of pasture production is also limited by the available solar radiation and by temperature (Brougham, 1959).

As to the relative importance of solar radiation and temperature, there are considerable differences of opinion. Weihing (1963), Brougham & Glenday (1969) and Smith & Stephens (1976) found temperature to be the more important factor, while Stanhill (1962) and Cocks (1974) found solar radiation to be the more important. Other workers however, have shown them to be equally important (Brougham, 1959; Alberda & Sibma, 1968; Lynch, 1976; Fukai & Silsbury, 1978). This controversy can be attributed to the fact that both these parameters have an influence on growth, but do so by separate mechanisms. Temperature seems to have the greater influence on respiration, while solar radiation influences photosynthesis directly (Stanhill, 1962; Fukai & Silsbury, 1978). The influence of solar radiation and temperature on seasonal pasture production is further complicated by the fact that both have an important influence on phenological development (Cooper, 1960). This influence of solar radiation stems from its correlation with daylength. Matters are, however, further complicated by the fact that temperature is also correlated with daylength.

A relationship, therefore, had to be determined between variations in the three above-mentioned parameters (temperature, solar radiation and soil moisture), and the variation in seasonal pasture production. There are basically two alternative approaches to this problem: the first is the use of an empirical-statistical approach (Brougham & Glenday, 1969) and the second the more detailed simulation approach (Vickery & Hedges, 1972; Rose, et al, 1972; McGown, 1973; Smith & Williams, 1973). The latter approach has only recently become a viable proposition with the advent of large computers.

The empirical-statistical approach has the advantage that it is very simple and often gives good results with only limited climatic data. The main disadvantage of models developed in this manner is that they are often essentially specific to a particular historical environment and also to the technology of the particular experiment of which the data were used for the derivation of the model (Baier, 1973; Rose, 1973). Another aspect to keep in mind is that climatic parameters such as solar radiation and temperature are highly correlated. This theoretically prohibits the use of simple multiple regression procedures to separate their effects. The reason for this is the basic assumption of the regression technique that the different parameters are not correlated (Lewis-Beck, 1980).

The dynamic simulation approach has the advantage of being able to describe change and of containing hypotheses of how the system actually functions. This makes extrapolation not only possible, but also much safer (Baier, 1973; Rose, 1973). Although this approach is generally accepted as more desirable, the lack of accuracy of functions used in such models often means that they are not very effective (Rose, 1973).

Another problem is the fact that the development and validation of a complex simulation model requires a considerable input of data and time. Such an approach is therefore generally not possible when neither a large amount of data are available nor a large number of researchers of diverse disciplines are involved. Also, in this study a large variety of species were evaluated and the development of complex models for each of these species was therefore not practical. The main approach was therefore to develop climate:production models which would enable the prediction, rather than the explanation, of variations in monthly pasture production. The second prerequisite was that the models should use only simple and readily available climatic data as input and thirdly that these models should be able to predict the long term seasonal production potential at a particular site.

The following simple growth index (GI) approach, successfully utilized by Fitzpatrick & Nix (1975) and used for the quantification of the climatic factor in the Australian grasslands, was therefore adopted. The GI is defined as the dimensionless ratio of actual growth rate (AGR) to potential growth rate (PGR), i.e. $GI = AGR.PGR^{-1}$, with $0 \leq GI \leq 1$. It is calculated as a product of a soil moisture index (MI, with $0 \leq MI \leq 1$), a solar radiation index (RI, with $0 \leq RI \leq 1$) and a temperature index (TI, with $0 \leq TI \leq 1$), i.e. GI = MI X RI X TI.

Each of the climatic indices are therefore dimensionless ratios predicting GI, assuming that the other two climatic indexes are non-limiting. Variations of this same approach have been used by Lynch (1976) and Smith & Stephens (1976). In all cases mean weekly climatic indices were calculated and used to calculate weekly GI values. In the present study, however, mean monthly values were used, as these data would be more readily available for further extrapolation and would make the models more usefull.

For the derivation of the three components of GI the following logic and methods were employed.

(a) Moisture index, MI

For the calculation of MI, Fitzpatrick & Nix (1975), Lynch (1976) and Smith & Stephens (1976) applied variations of the same method of simulating the soil moisture balance. This method was largely similar to that used by a number of other workers for the simulation of soil moisture content (Baier & Robertson, 1966; McGown, 1973; Hanks, 1974; Johns & Smith, 1975; Smith & Johns, 1975). These methods simulated soil moisture content by using maximum soil moisture storage capacity, weekly rainfall as well as class A pan evaporation data as inputs. Rainfall greater than the present soil moisture storage capacity is ignored as runoff or deep percolation. Actual evapotranspiration is simulated as a function of the potential evapotranspiration and the soil moisture content.

The method of calculating the relationship between the soil moisture content and the actual evapotranspiration differed between different workers (Johns & Smith, 1975), but was generally based on the relationship between the soil moisture availability and the soil moisture content (Slatyer, 1956; Chang, 1968; Fitzpatrick & Nix, 1975). The potential evapotranspiration is, however, simply calculated as a fraction of the class A pan evaporation (Johns & Smith, 1975).

An approach employing a soil moisture balance simulation model has certain disadvantages. It for instance needs the following inputs:

(a) the rooting depth of the crop;
(b) the moisture storage capacity of the soil;
(c) the form of the relationship between the soil moisture content and the ratio of actual to potential evapotranspiration; and
(d) the ratio between the pan and the potential evapotranspiration (the so-called crop factor).

In most instances all these data are not available and certain assumptions therefore have to be made. To overcome this problem certain simplifications are often employed (Lynch, 1976). This is, however, often considered acceptable as it has in some cases been found that the simplest approach gives the best results (Johns & Smith, 1975).

As the approach in this study was to keep the methods of determining the GI as simple as possible and also due to the fact that many of the above-mentioned inputs ((a) to (d)) were not available, it was decided not to use a moisture balance simulation method. A further determining factor was that mean monthly, and not weekly, values of class A pan evaporation (E) and rainfall (R) are generally more readily available in practice. The moisture balance method requires the use of weekly values, which would generally not be available to those making use of the model, while monthly values are generally more readily available in practice. A different approach for the determination of MI, therefore, had to be devised.

The method eventually used was largely based on the approach of Trumble (1939). He predicted the length of the growing season by using the simple relationship $0,3E \leq R$. Other similar approaches such as the relationship $0,5E^{0,7} \leq R$ employed by Scott, et al (1972) and Scott & Brownlee (1976) was also considered. The above-mentioned indices simulated the length of the growing season by the calculation of the amount of rainfall (R) needed to be effective, using only E as input. Although these methods could by no means accurately simulate soil moisture content, they did indicate periods of soil moisture stress.

These methods were not, however, appropriate in this instance as the determination of MI needed the development of a method to determine a dimensionless ratio ($0 \leq MI \leq 1$). The relationship eventually used was therefore simply the ratio between R and E. For most of the pasture species the relationship $R.(0,5E)^{-1}$ was used. The factor 0,5 was based on the results of a study by Van Heerden & Beukes (1984), which indicated this to be the mean crop factor for most of the species evaluated under normal practical management conditions. For species less resistant to soil moisture stress, however, a more strenuous measure of MI, $R.E^{-1}$, was used.

To accommodate soil moisture storage the MI for a particular month was, in the case of some species, calculated as the mean value for that month and for one or two previous months. As MI was supposed to be dimensionless, with values between 0 and 1, the problem of values of $R.E^{-1}$ or

$R.(0,5E)^{-1} > 1$, during periods of high rainfall (R), was solved by accepting MI = 1 for $R.E^{-1}$ and $R.(0,5E)^{-1} > 1$.

(b) Radiation index, RI

A diminishing returns relationship between pasture production and incident solar radiation has been suggested by certain workers (de Wit, 1959; Black, 1963). At sward level the shape of this relationship is, however, greatly influenced by LAI, leaf orientation, leaf shape and chlorophyll content (Brougham, 1958; 1960; Monteith, 1966), as well as by the reproductive stage of the plant (Alberda & Sibma, 1968). In many cases, however, a simple linear relationship has been found between solar radiation and the rate of pasture production at sward level (Loomis & Williams, 1963; Holliday, 1966; McCree & Troughton, 1966; Alberda & Sibma, 1968; Cocks, 1974).

The relationship between rate of pasture production and incident solar radiation is therefore extremely variable and a general relationship for the derivation of RI would be difficult to develop. Fitzpatrick & Nix (1975), Lynch (1976) and Smith & Stephens (1976) used one relationship for all species, i.e. RI = 1,0 - exp (-3,5x) where $x = Q_{TOT}.750^{-1}$, with Q_{TOT} expressed in $ly.d^{-1}$. They assumed LAI = 5 in accordance with findings of Brougham (1958), which indicated the existence of an optimum LAI of 4,5 for grass/clover swards.

The large number of species involved in this study, the large variation in seasonal production between them as well as the above-mentioned diversity of factors which can influence the shape of the relationship between solar radiation and rate of pasture production, prompted the use of a new approach. In the first place a separate relationship was derived for each species. This was done by tabulating the mean monthly rates of pasture production and the mean monthly solar radiation (Q_{TOT}) for each trial site. The optimum level of solar radiation (Q_{OPT}) was accepted as the value of Q_{TOT} coinciding with maximum rate of pasture production. Rate of pasture production was accepted to be linearly related to solar radiation (Q_{TOT}) up to Q_{OPT}, i.e. $RI = Q_{TOT} \cdot Q_{OPT}^{-1}$, when $Q_{TOT} \leq Q_{OPT}$ with $0 \leq RI \leq 1$.

When $Q_{TOT} > Q_{OPT}$ two different approaches had to be adopted. In the case of those species for which rate of pasture production was constant beyond Q_{OPT}, RI = 1 for all $Q_{TOT} > Q_{OPT}$. There were, however, species in which the rate of production decreased beyond Q_{OPT}, even under conditions of optimum moisture supply (MI = 1). This can be attributed to the attainment of the reproductive and/or seed ripening stages, beyond which increases in Q_{TOT} was negatively correlated with the rate of pasture production. In these cases a different approach was needed i.e. $RI = Q_{TOT} \cdot Q_{OPT}^{-1}$ when $Q_{TOT} \leq Q_{OPT}$, but when $Q_{TOT} > Q_{OPT}$, $RI = Q_{OPT} \cdot Q_{TOT}^{-1}$ with $0 \leq RI \leq 1$ in all cases.

(c) Temperature index, TI

The existence of typical thermal response curves for different species with a specific optimum temperature beyond and below which growth rate is below the maximum, are generally accepted (Mitchell & Lucanes, 1962; Weihing, 1963; Chang, 1968). This general relationship was therefore accepted as the basis for the calculation of TI. To accommodate differences in response between different species, separate curves were used for different response types by Fitzpatrick & Nix (1975), Lynch (1976) and Smith & Stephens (1976). Three curves were used, one each for tropical grasses, tropical legumes and temperate species. Chang (1968), Colman, et al (1974) and Mitchell & Lucanus (1962), however, also found differences in response between different temperate species. This fact, and also the fact that such a large variety of species, with an equally large variation in seasonal production, was evaluated, necessitated the development of a separate curve for each. This prompted the use of an approach similar to that used for the determination of RI.

As a first step two separate general response curves were derived for tropical and temperate species. These curves were derived from data interpolated from curves used by Lynch (1976). One of the problems encountered was that of finding a suitable method of curve fitting. A curve proposed by Landsberg (1977) was eventually used. This curve had the following general form:

$$TI = A \exp(-(T-B)^2 . C^{-1}),$$

where A and C = constants derived when fitting the curve,

T = the temperature (°C),

B = the optimum temperature (°C), a constant for each species.

The curve derived for temperate species was:

$$TI = 1{,}051\exp(-(T-21{,}1)^2 . 86{,}015^{-1})$$

and was simplified to:

$$TI = \exp(-(T-B)^2 . 86^{-1}).$$

The curve for tropical species was:

$$TI = 1{,}015\exp(-(T-32{,}5)^2 . 233{,}459^{-1})$$

and was also simplified to:

$$TI = \exp(-(T-B)^2.233^{-1}).$$

Thermal response curves for the calculation of TI for the different species could now be derived by inserting different values for B, i.e. the temperature (°C) coinciding with the maximum rate of production. In only one case, annual ryegrass, was a different value for the constant C = 66 used. In all other cases a good relationship between GI and seasonal pasture production was possible by accepting C = 86 for temperate species and C = 233 for tropical species.

It was now possible to manipulate values of GI until a good fit was obtained. This was done by simply changing the methods for the calculation of either MI (i.e. $MI = R.E^{-1}$ or $R.(0,5E)^{-1}$), RI (i.e. RI = 1 for Q_{OPT}/Q_{TOT} beyond Q_{OPT}) or TI (i.e. changing B and in extreme cases C).

In most cases the above-mentioned three climatic indices sufficed and GI was generally highly correlated with seasonal production. In the case of perennial ryegrass, however, no influence of RI could be found and this index was replaced by a new index (RTI), incorporating both solar radiation and temperature. The relationship was based on the finding that the GI, derived in the conventional fashion, deviated from the seasonal production in a manner similar to the known relationship between temperature and solar radiation. The new index (RTI) was therefore derived, using the following procedure:

$RT = Q_{TOT}.T^{-1}$,
where T = the mean temperature (°C)
and $RTI = RT.RT_{MAX}^{-1}$,
where RT_{MAX} = the maximum calculated RT.

Using RTI, the GI for perennial ryegrass was then calculated as:

GI = RTI X MI X TI.

This index (RTI) was also added to the other three indices when GI was calculated for cocksfoot and annual ryegrass and improved the results. In the case of these two species, GI was therefore calculated as follows: GI = RI X MI X TI X RTI. This resulted in a good fit, but the interpretation of the relationship was very difficult. It can, however, perhaps be interpreted as the result of a substantial influence of daylength on the growth pattern of these two grasses, which could only be incorporated into GI in this manner.

Determination of the predicted potential production rate

Production rate data, derived from the cutting trials undertaken at the different sites (APR), were subjected, together with the climatic data for each site, to regression analysis to providė the appropriate constants for the functions used for the derivation of RI, MI, TI and RTI, such that

$$APR\ (Kg\ DM.ha^{-1}.d^{-1}) = a + b.GI$$

However, as this last mentioned function is only an approximation of the relationship between APR and GI, its output was designated as the predicted potential production rate (PPR), i.e.

$$PPR\ (Kg\ DM.ha^{-1}.d^{-1}) = a + b.GI$$

This procedure was repeated separately for each species tested, for dryland and irrigated sites and, where appropriate, for high and low potential soils. Under dryland conditions, no effect of soil potential was evident, but under irrigation a separate relationship between GI and APR had to be derived for the lower potential soils at Welgevallen and Outeniqua, and another for the higher potential soil at Oudtshoorn.

Having derived the appropriate GI functions for each species from the experimental data, the functions were validated by testing against yields recorded at designated validation sites or against yields from experimental sites which had been specifically reserved for such a testing. If found satisfactory, the functions were applied to the long-term cimatic data for each site to derive the long-term predicted potential production rates (PPR) for that site.

3.3 Results

3.3.1 Lucerne

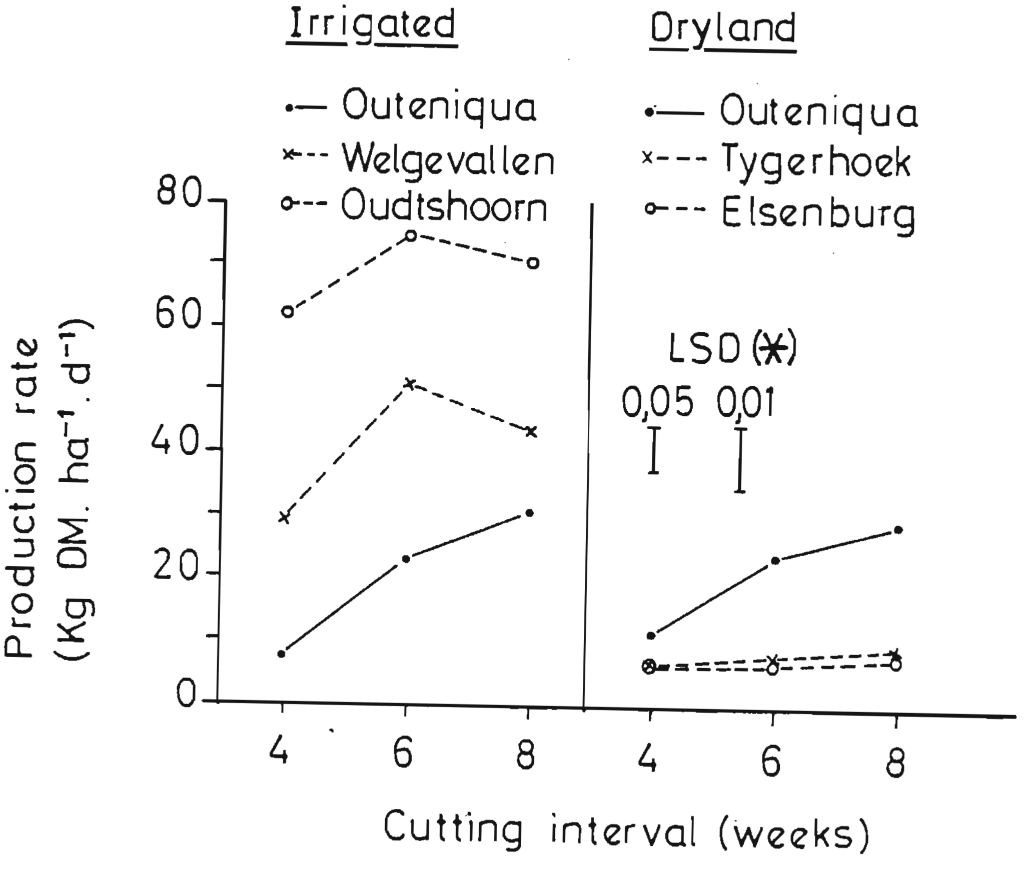
3.3.1.1 Influence of cutting frequency

The mean production rate (kg $DM.ha^{-1}.d^{-1}$) of lucerne (cv. S A Standard) in three dryland (Elsenburg, Tygerhoek and Outeniqua) and three irrigated (Welgevallen, Outeniqua and Oudtshoorn) trials, cut at three frequencies (four-, six- and eight-weekly), are depicted in figure 3.1.

Site, and therefore soil and climatic differences, tended to have a greater influence on the mean production rate than cutting frequency. The degree and form of response to cutting frequency, however, differed at the different sites. The only significant responses were found at the three irrigated sites and one dryland site, Outeniqua, and only between the four- and six-weekly cutting frequencies.

Under irrigation at Oudtshoorn and Welgevallen, the production rate was highest at the six-weekly cutting frequency, while irrigated, as well as dryland production rates at

Figure 3.1 Influence of cutting frequency on the mean production rate of lucerne under irrigation and dryland at Elsenburg (1981-84), Tygerhoek (1981-84), Outeniqua (1981-83), Welgevallen (1979-81) and Oudtshoorn (1981-84) (* LSD's for dryland and irrigated trials)



Outeniqua were highest at the eight-weekly cutting frequency. At two dryland sites, Elsenburg and Tygerhoek, no significant response to cutting frequency was found, though the production rates tended to increase with a decrease in cutting frequency from four- to eight-weekly.

3.3.1.2 Seasonal production

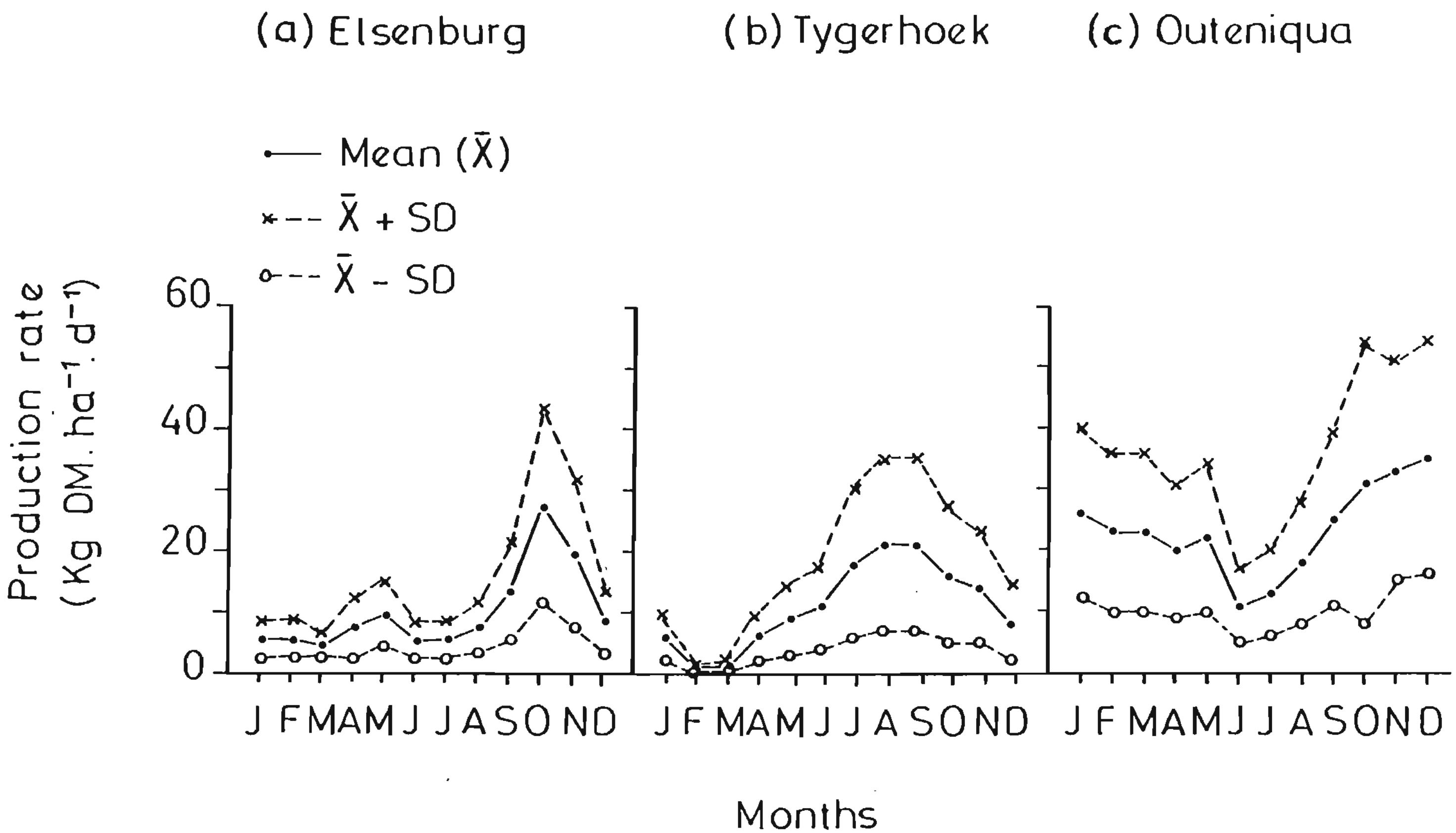
In the cutting frequency trials it was found that site had a much greater influence than cutting frequency on the mean production rate of lucerne. This, therefore, indicated that data derived in two or more consecutive trials at the different sites, cut at frequencies which were not too different, could be pooled for the calculation of the production rates at each site. The production rates (kg $DM.ha^{-1}.d^{-1}$) thus derived at the dryland sites, are depicted in figure 3.2.

Also indicated in figure 3.2, is the standard deviation of the data at each site, indicating the seasonal variation in production rate. A substantial variation is evident and this may limit the accuracy of extrapolation. The data, however, do indicate the differences in seasonal production at the different sites.

The seasonal production pattern of lucerne differed greatly at the three sites. At Elsenburg the production peaked very sharply during October. During the period December to August, production rates at this site were generally very low and did not fluctuate much.

At Tygerhoek the production rates were low during the period January to March, but increased gradually thereafter to peak during August and September, and dropped off again from October through to December. The production rates at Outeniqua fell from January to June, and then rose steadily

Figure 3.2 The production rate of lucerne under dryland conditions at Elsenburg (1981-84), Tygerhoek (1981-84) and Outeniqua (1978-83)



from June through to December. The highest production rates were attained at this site during spring, summer and autumn, with the peak occurring during the period October to December and the lowest rates during winter (June and July).

The production rates and standard deviations for the three irrigated sites are depicted in figure 3.3. The standard deviations were much smaller than those of the dryland data and allow for more accurate extrapolation. The most striking feature of the data is the exceptionally high production rates that were recorded at Oudtshoorn. As will be seen later, this can mainly be attributed to the high soil potential (Oakleaf) at this trial site. Production rates also tended to be slightly lower at Outeniqua than at Welgevallen. The production pattern did, however, not differ much between different sites. The peak production at all sites generally occurred during summer (November to February) and was much higher than during winter (May/June to July/August).

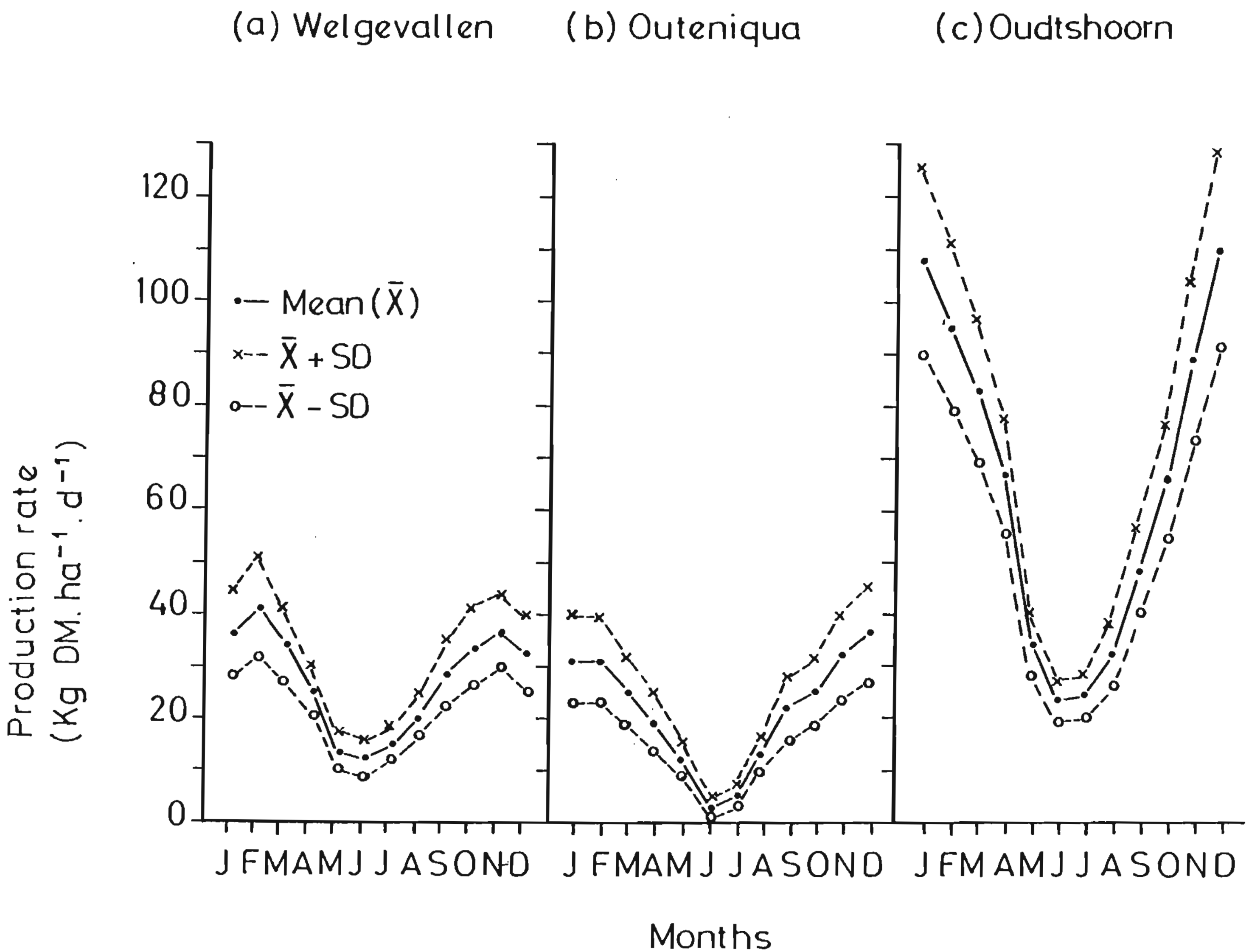
3.3.1.3 Extrapolation of production rate data

Seasonal production data, derived at the three irrigated (Welgevallen, Outeniqua and Oudtshoorn) and three dryland (Elsenburg, Outeniqua and Tygerhoek) sites, were used for the development of functions for the extrapolation of the seasonal production rates to different seasons. The following functions were derived:

$MI = R.(0,5E)^{-1}$ (three-monthly means),
with R = total monthly rainfall (mm) and
E = total monthly class A pan evaporation (mm);

TI = $\exp(-(T-2$[illegible]$)^{2}.86^{-1})$,
with T = mean monthly air temperature (°C);

Figure 3.3 The production rate of lucerne under irrigation at Welgevallen (1979-81), Outeniqua (1978-83) and Oudtshoorn (1981-84)



$RI = Q_{TOT}.24^{-1}$,
when $Q_{TOT} \leq 24$ and

$RI = 1$,
when $Q_{TOT} > 24$ and with Q_{TOT} = total daily solar radiation ($MJ.M^{-2}.d^{-1}$);

$GI = MI \times RI \times TI$.

Three separate relationships between GI and the actual production rate (APR) were developed for the calculation of the potential production rate (PPR). The three relationships are depicted graphically in figure 3.4. Under dryland conditions a single relationship sufficed, as soil did not have much influence on the production rates at the different sites. GI was, therefore, the main determinant of seasonal pasture production rate. The following function was derived for use under dryland conditions:

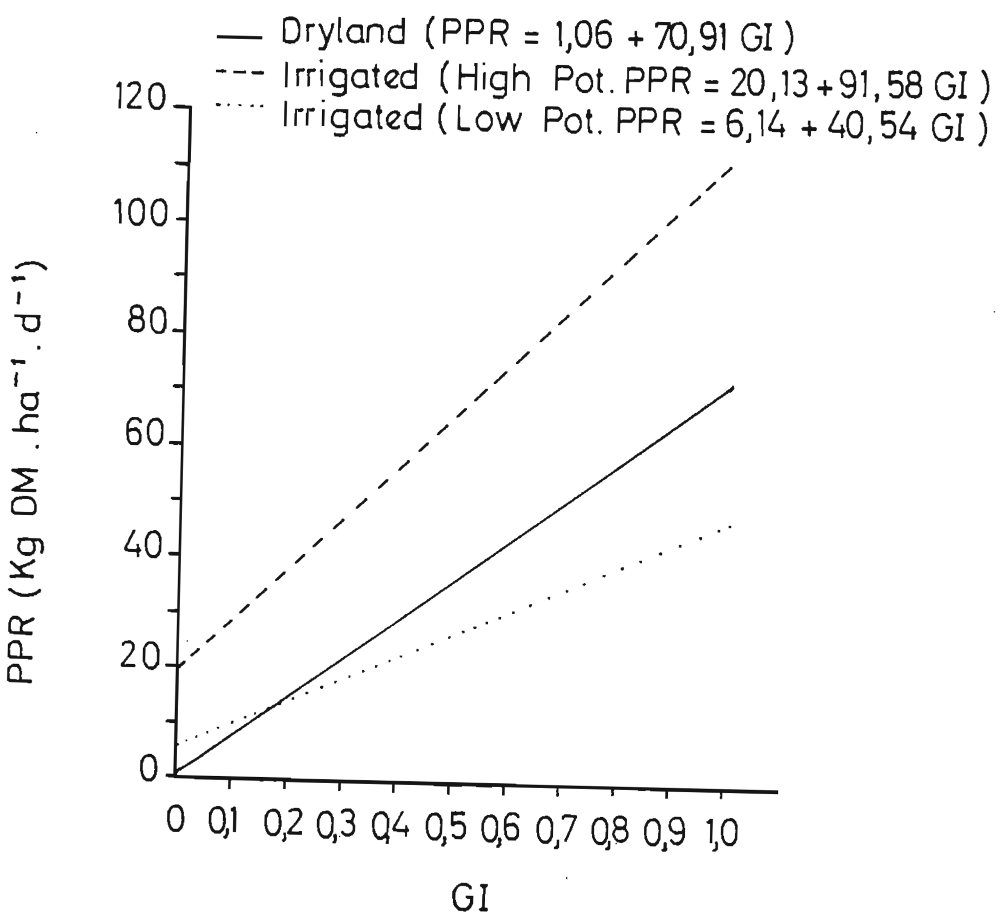
$$PPR = 1,06 + 70,91GI.$$

Under irrigation two functions had to be developed, due to the large influence of soil potential on seasonal production. A function was, therefore, developed for a high potential soil, represented by the Oakleaf soil form of the Oudtshoorn trial site, as well as one for a low potential soil, represented by the Estcourt and Katspruit soil forms respectively, of the Outeniqua and Welgevallen trial sites. The functions were as follows:

$$PPR\ (\text{high potential soil}) = 20,13 + 91,58GI$$
$$PPR\ (\text{low potential soil}) = 6,14 + 40,54GI.$$

For the derivation of the three above-mentioned functions, data acquired during the last season at most sites were

Figure 3.4 Relationships between the growth index (GI) and the potential production rate (PRR) for lucerne under dryland and irrigated conditions



excluded, so that it could be used to validate the model. The only site at which more data were excluded, was Tygerhoek, where data for two seasons were used for validation.

As a first step, the mean monthly PPR and APR were compared over the whole trial period at each site. These results are presented graphically in figures 3.5 (dryland) and 3.6 (irrigated). The PPR curves follow the APR curves very well under dryland, as well as under irrigation, and R^2 was significant at all the sites.

The fact that R^2 was so high under irrigation suggests that RI and TI serve as useful indices of the effect of radiation and temperature on production. The lower R^2 associated with the dryland trials would seem, therefore, to result from the fact that MI is a relatively inefficient indicator of the effect of soil moisture. This could perhaps be attributed to the fact that lucerne is very deep rooted. Soil moisture storage within the effective rooting depth was, therefore, substantial and had an important influence on the production rate.

In spite of the above-mentioned difficulties under dryland conditions, the results are very promising, especially if the limited amount of data that were available at some of the sites is considered. Further validation of the models was, however, necessary, using the data not used for the development of the models. These results are depicted in figures 3.7 (dryland) and 3.8 (irrigated).

The results found at the dryland sites (figure 3.7) were satisfactory, although the correlation was not significant in the case of Tygerhoek. The largest deviations between PPR and APR occurred at Tygerhoek and Langkloof, but at different seasons at the two sites. The deviation could, therefore, not be related to soil differences and ruled out

Figure 3.5 Comparison of the actual (APR) and the predicted potential (PPR) production rate at three dryland sites, over the whole trial period

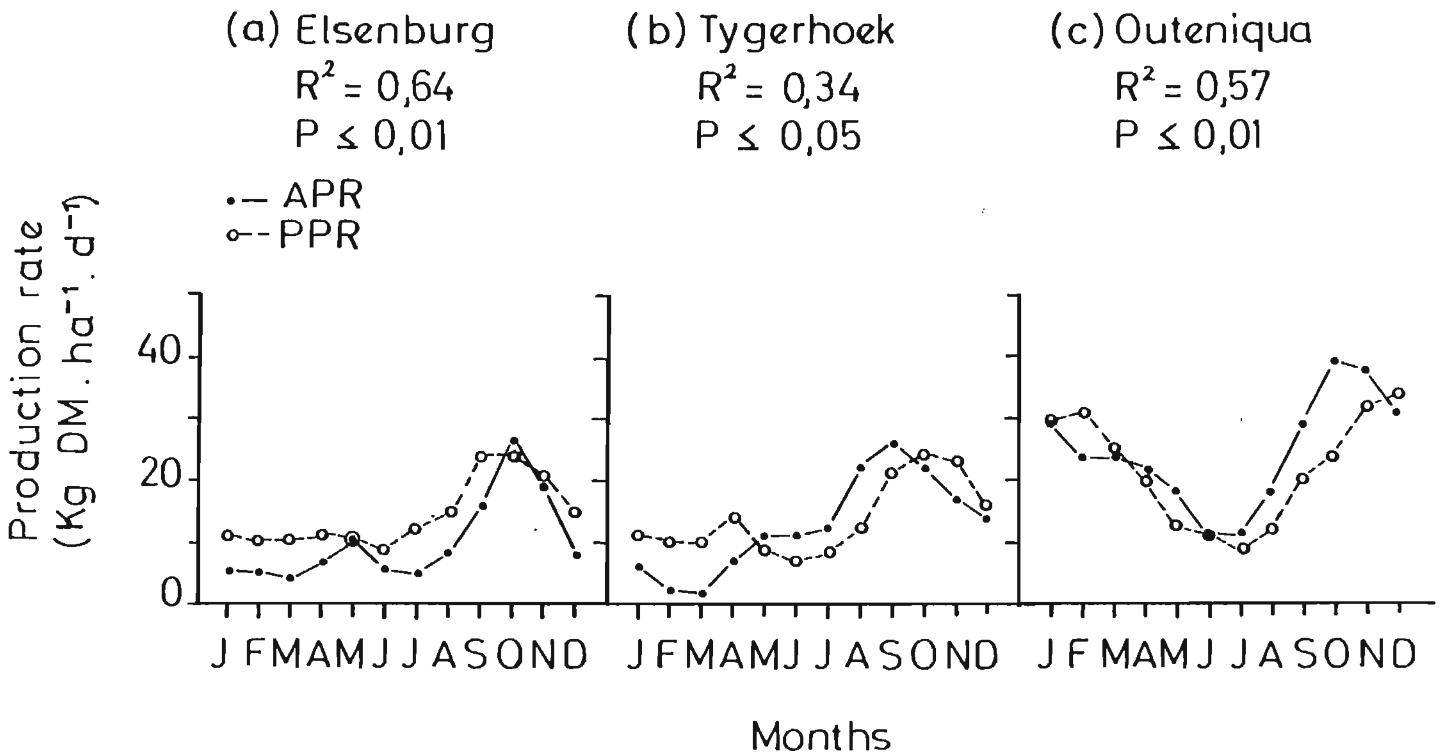


Figure 3.6 Comparison of the actual (APR) and predicted potential production rate (PPR) at three irrigated sites, over the whole trial period

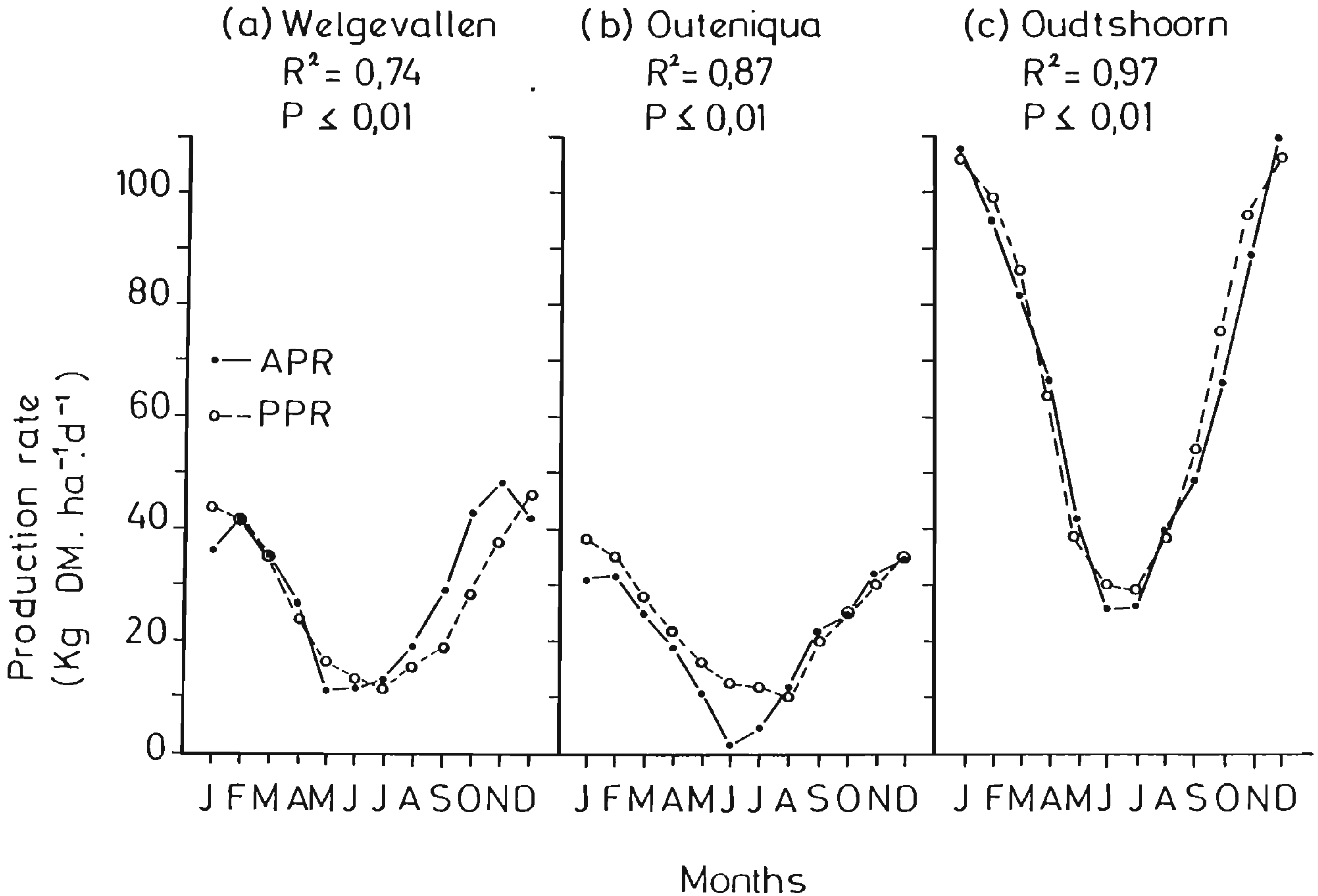
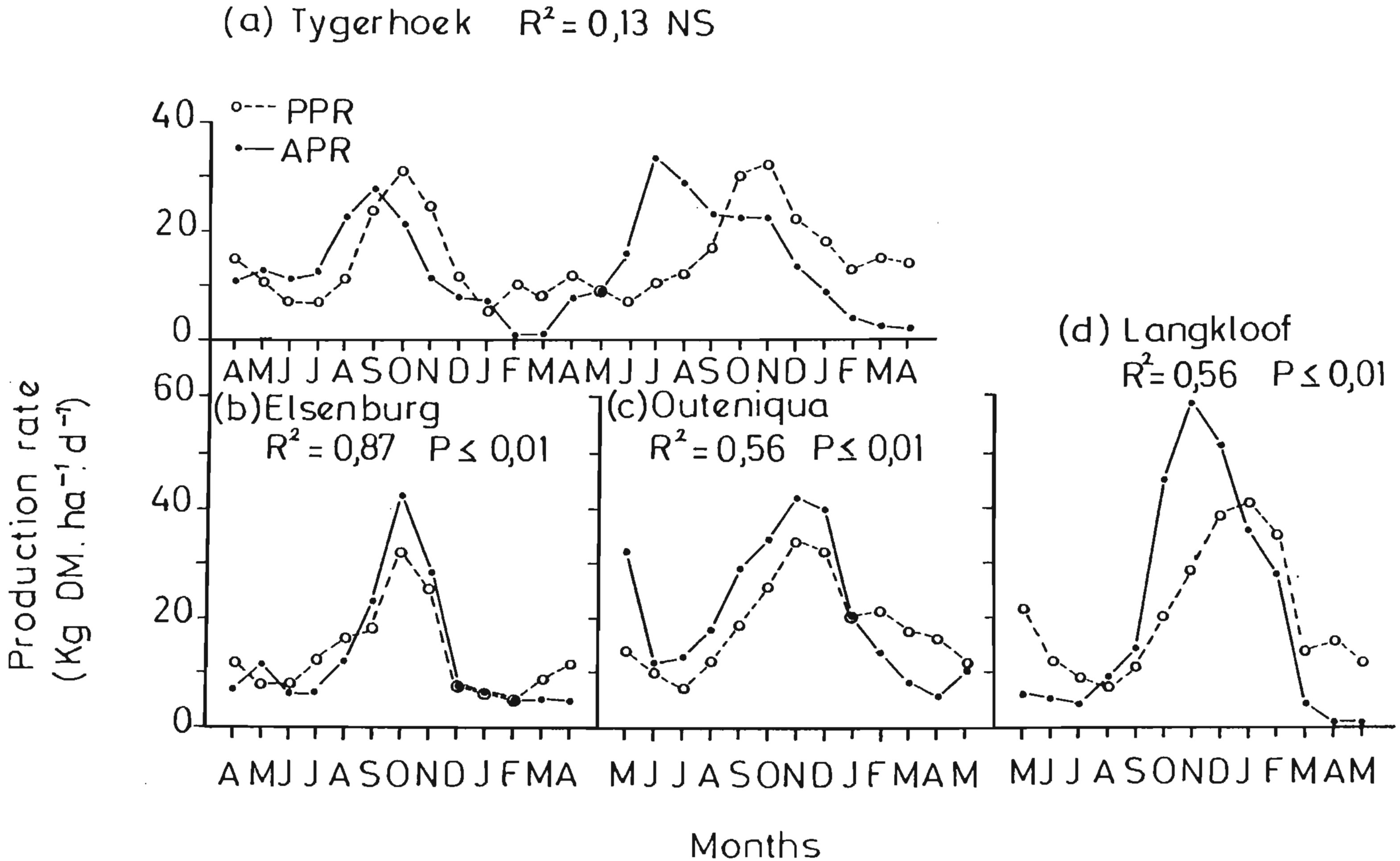


Figure 3.7 Comparison of the actual (APR) and predicted potential production rate (PPR) under dryland at Tygerhoek (1982-84), Elsenburg (1983-84), Outeniqua (1982-83) and Langkloof (1983-84), using data which had not been utilised during the development phase



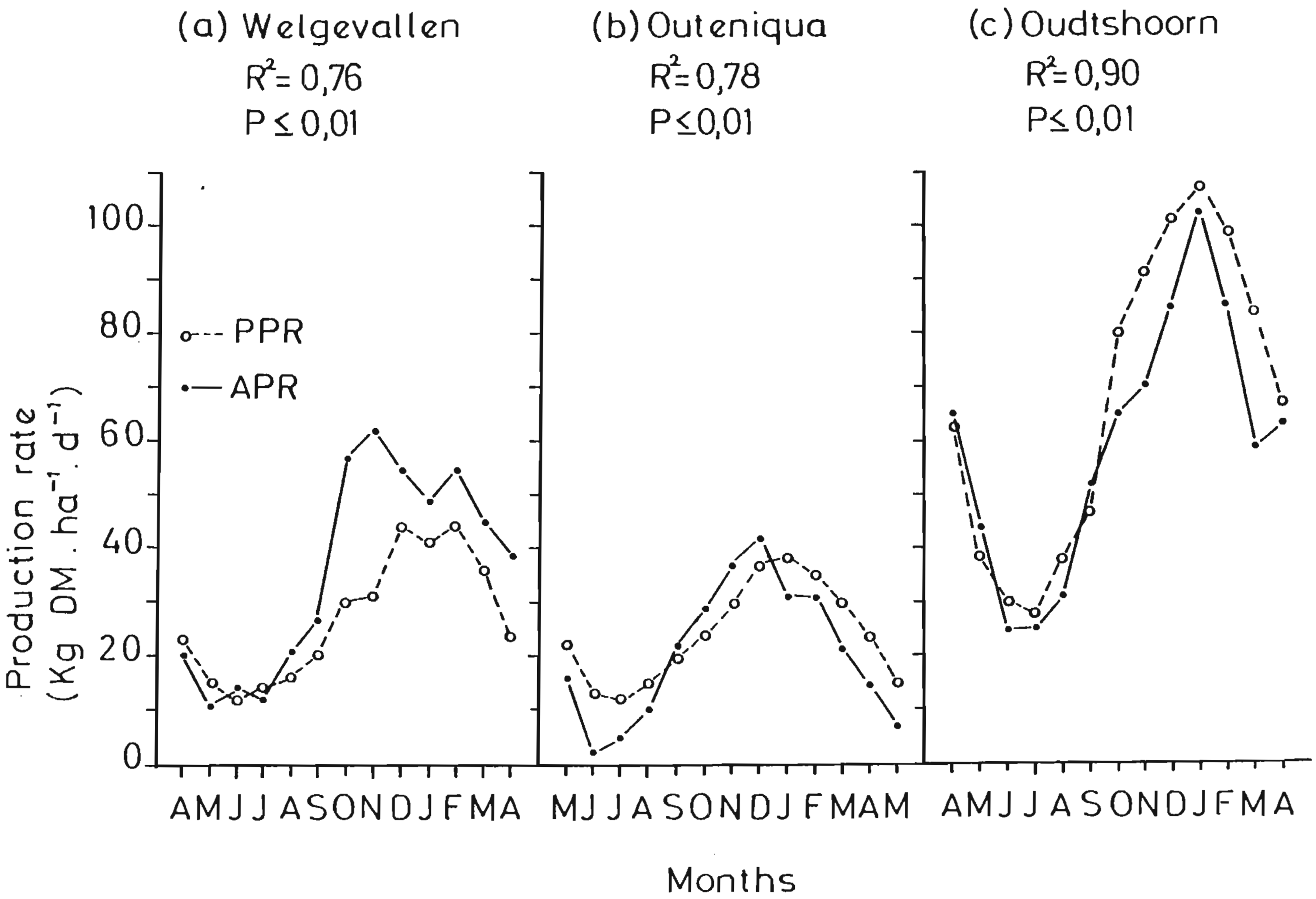


Figure 3.8 Comparison of the actual (APR) and predicted potential production rate (PPR) under irrigation at Welgevallen (1980-81), Outeniqua (1982-83) and Oudtshoorn (1983-84), using data which had not been utilised during the development phase

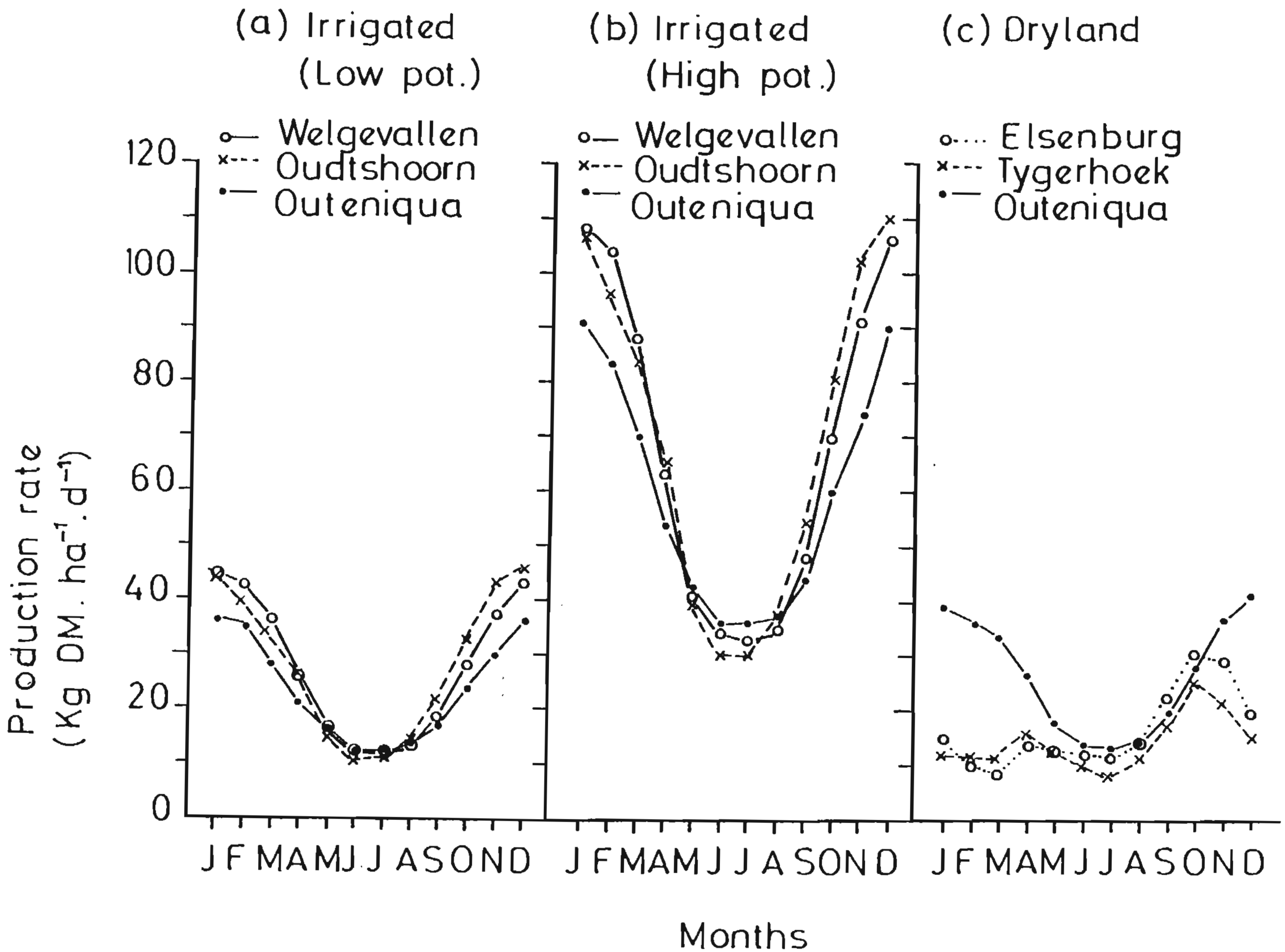
the possible use of a separate relationship between GI and PPR at these two sites. In spite of the large apparent deviation at Langkloof, the R^2 was, however, similar to that at Outeniqua.

The results found at the irrigated sites (figure 3.8) were even more satisfactory than those on dryland sites and generally the R^2 values were higher under irrigation than under dryland. This once again indicates that the MI was not as successful an estimator of soil moisture effects as TI and RI are of temperature and radiation effects. The R^2 values at the sites Outeniqua (irrigated) and Oudtshoorn were, however, slightly lower than those for the long-term means (figure 3.6). The R^2 values were highest at Oudtshoorn and lowest at Welgevallen. A large deviation occurred at the latter site during the late season when PPR underestimated the APR.

Using the derived functions, the long-term seasonal PPR of lucerne was calculated at each site, using long-term monthly climatic means. The derived curves are depicted in figure 3.9. The seasonal PPR under dryland was practically the same at Tygerhoek and Elsenburg, although it was slightly lower during spring and early summer at Tygerhoek. During the period November to April, the PPR at Outeniqua (dryland) was much higher than at these two sites.

Under irrigation the effect of soil potential was again apparent. The high potential soil was represented by the relationship developed at Oudtshoorn and the low potential soil by that developed at Outeniqua (irrigated) and Welgevallen. At each site the two relationships were, therefore, applied to the climatic data. This made possible the separation of soil and climatic factors and resulted in long-term mean curves expressing only the effect of seasonal

Figure 3.9 Long-term potential production rates (PPR) predicted, using the derived functions and long-term mean climatic data



climatic variations at the different sites of either high or low potential.

Under irrigation, differences due to soil potential and to monthly climatic variations were much larger than differences between sites with the same soil potential during the same month. This indicates that differences in climatic potential between the different sites were negligible under irrigation. Generally, however, the PPR under irrigation for the period September to April was slightly lower at Outeniqua than at the other two sites. During June and July the PPR at Oudtshoorn was again lowest. These differences were, however, negligible compared to the variation in monthly climatic potential and in soil potential.

3.3.1.4 Discussion and conclusions

The cutting frequency trials indicated that site, i.e. soil and climatic differences, have a far greater influence on the mean production rate of lucerne than cutting frequency. The form and degree of response to cutting frequency differed at the different sites, although it seems that the highest production rates were attained when lucerne was cut every six to eight weeks.

The most important feature of the production curves of lucerne under irrigation, was the large variation in production rates through the year. The curves indicated a high summer and very low winter production rate. Lucerne seems to be very sensitive to soil differences and this was reflected in the large differences in production recorded under irrigation at respectively the sites with low potential soils (Welgevallen and Outeniqua) and the site with a high potential soil (Oudtshoorn).

Under dryland the summer production rate of lucerne was also limited by soil moisture at Elsenburg and Tygerhoek and the highest production rates were, therefore, recorded during spring and early summer at these two sites. At Outeniqua, however, a more favourable soil moisture supply resulted in higher production rates occurring during summer.

The objective of the extrapolation of production rates was to determine long-term potential production rates (PPR), using long-term climatic data. With this objective in mind, the GI concept gave very satisfactory results, although the deep rooting system of lucerne reduced the accuracy of MI as a determinant of GI under dryland conditions. It should, however, be possible to improve results by collecting more data at each site.

Due to the deep rooting system of lucerne, soil potential had a very great influence on the seasonal PPR under irrigation. This is largely reflected in the difference between PPR at Outeniqua and Welgevallen (low potential soil) on the one hand and Oudtshoorn (high potential soil) on the other, and also in the steeper slope and higher abscissa of the PPR to GI relationship at the latter site. Under dryland conditions, however, soil differences were not as important and seasonal variation in pasture production was more closely correlated with GI. The latter fact can be attributed to the large influence of MI on the GI.

The use of the GI concept, in order to predict the seasonal production rate was more successful under irrigation than under dryland. This indicated that the MI, in spite of its large influence, was not as useful a function in estimating GI than were TI and RI. This can largely be attributed to the problem of accommodating soil moisture storage, even though an attempt was made to account for storage by calculating the mean MI for three consecutive months.

The large influence of soil potential on the PPR of lucerne under irrigation, resulted in the PPR for a particular month and a particular soil potential varying less between sites with the same potential, than between sites of different soil potential. The variation between months was, however, equally large and resulted in a substantial variation in the predicted PPR during the year.

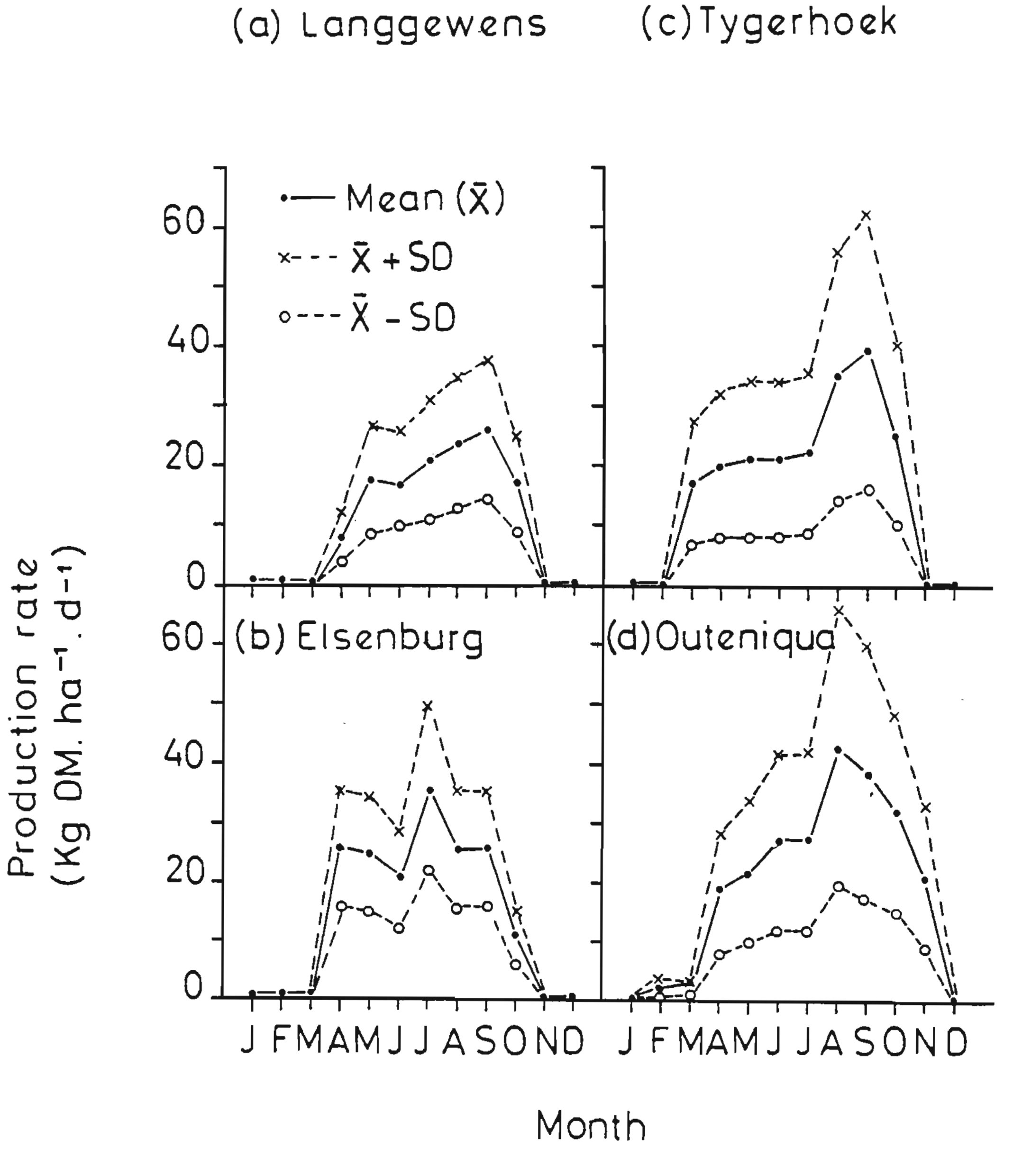
3.3.2 Medics

3.3.2.1 Seasonal production

The production rates of all medic cultivars, evaluated over a number of seasons at four sites, Langgewens, Elsenburg, Tygerhoek and Outeniqua, are depicted in figure 3.10. The seasonal variation in production, expressed as a standard deviation, is also indicated. Seasonal variation was clearly very large and could limit the usefulness of the data. The data, however, do indicate the differences in seasonal production rate at the different sites.

The data presented in figure 3.10 were obtained by sampling on a monthly basis in a different position in each plot each time, without defoliating the whole plot. The derived production rates may, therefore, be slightly higher than would have been the case had the plots been completely defoliated at each sampling. Also, due to this method of sampling, an arbitrary date had to be chosen for the start and the end of the growing season, indicating the points in time when seedling regeneration commenced and when growth ceased. Growth rates calculated for the first and last months of each growing season are not, therefore, as reliable as those for the intermediate months, although the errors made can be expected to be small.

Figure 3.10 The production rate over all medic cultivars under dryland at Langgewens (1977-80), Elsenburg (1978-83), Tygerhoek (1977-83) and Outeniqua (1977-83)



The general shapes of the production curves did not differ much at the different sites, though the late winter and spring production peak was more prominent at Outeniqua and Tygerhoek than at the other two sites. The largest differences were in the dates at which production commenced, peaked and terminated and Outeniqua seems to have had the longest and Langgewens and Elsenburg the shortest growing season. Production rates also tended to be lower at Langgewens than at the other three sites. The seasonal production rates were surprisingly uniform and relatively high through the whole winter growing season (April/May to September/October) at all sites.

The production rates of the three most important medic cultivars, Jemalong, Borung and Cyprus, which had been evaluated at all sites, were also calculated over the whole experimental period and are depicted in figures 3.11 to 3.14. The seasonal production rates of the three cultivars largely reflected the production pattern shown by the means already indicated in figure 3.10.

The three cultivars differ largely in terms of growing season length, i.e. the length of the period from regeneration to flowering and seed ripening, and also in production potential (Van Heerden & Wassermann, 1977). Jemalong has the longest growing season and the highest production potential and Cyprus the shortest growing season and the lowest production potential (Van Heerden & Wassermann, 1977). This, however, did not always reflect in the derived production rates.

The production rate of Jemalong was noticeably higher than that of the other two cultivars at Outeniqua and Tygerhoek. The other two cultivars, however, did not differ much, though Cyprus tended to have higher rates than Borung at Elsenburg. The slightly higher production rate of Jemalong,

Figure 3.11 The production rate of three medic cultivars under dryland at Langgewens (1977-80)

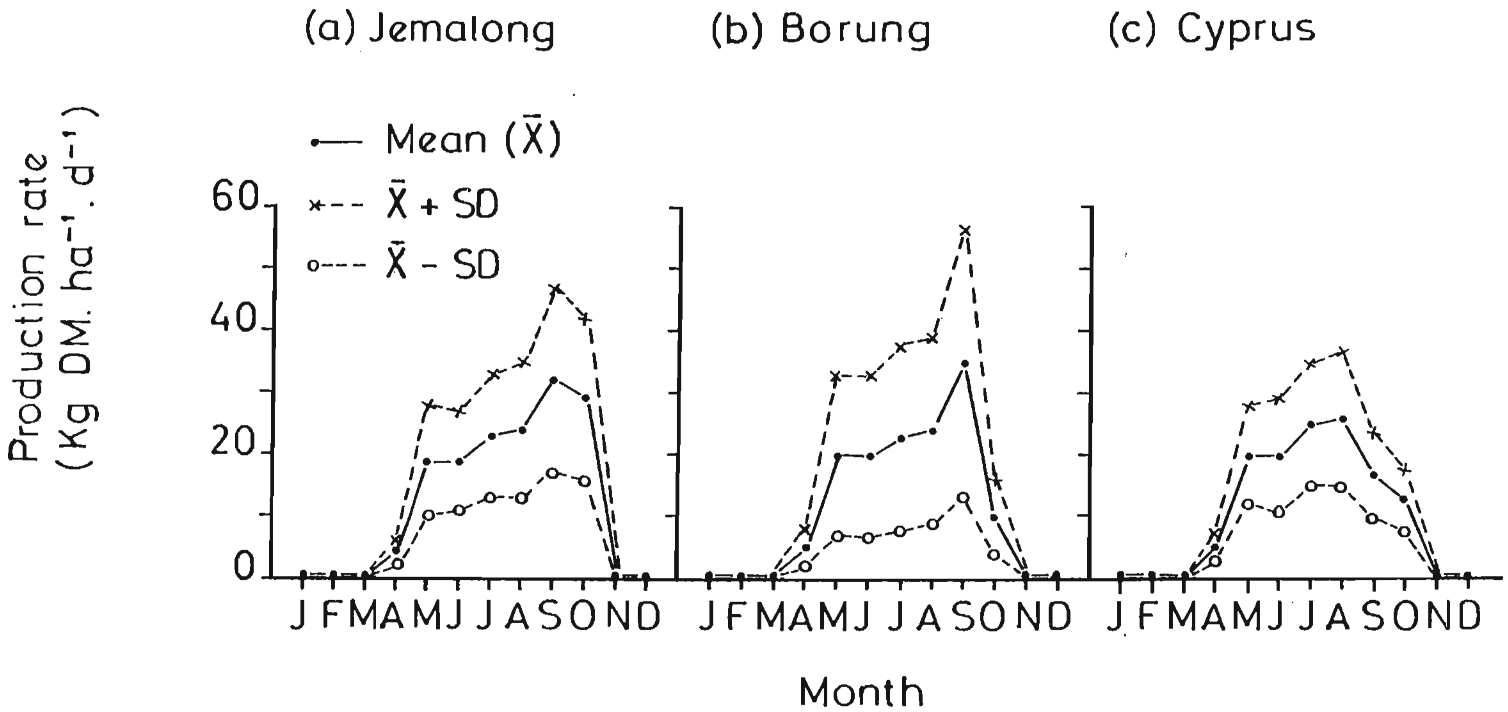


Figure 3.12 The production rate of three medic cultivars under dryland at Elsenburg (1978-83)

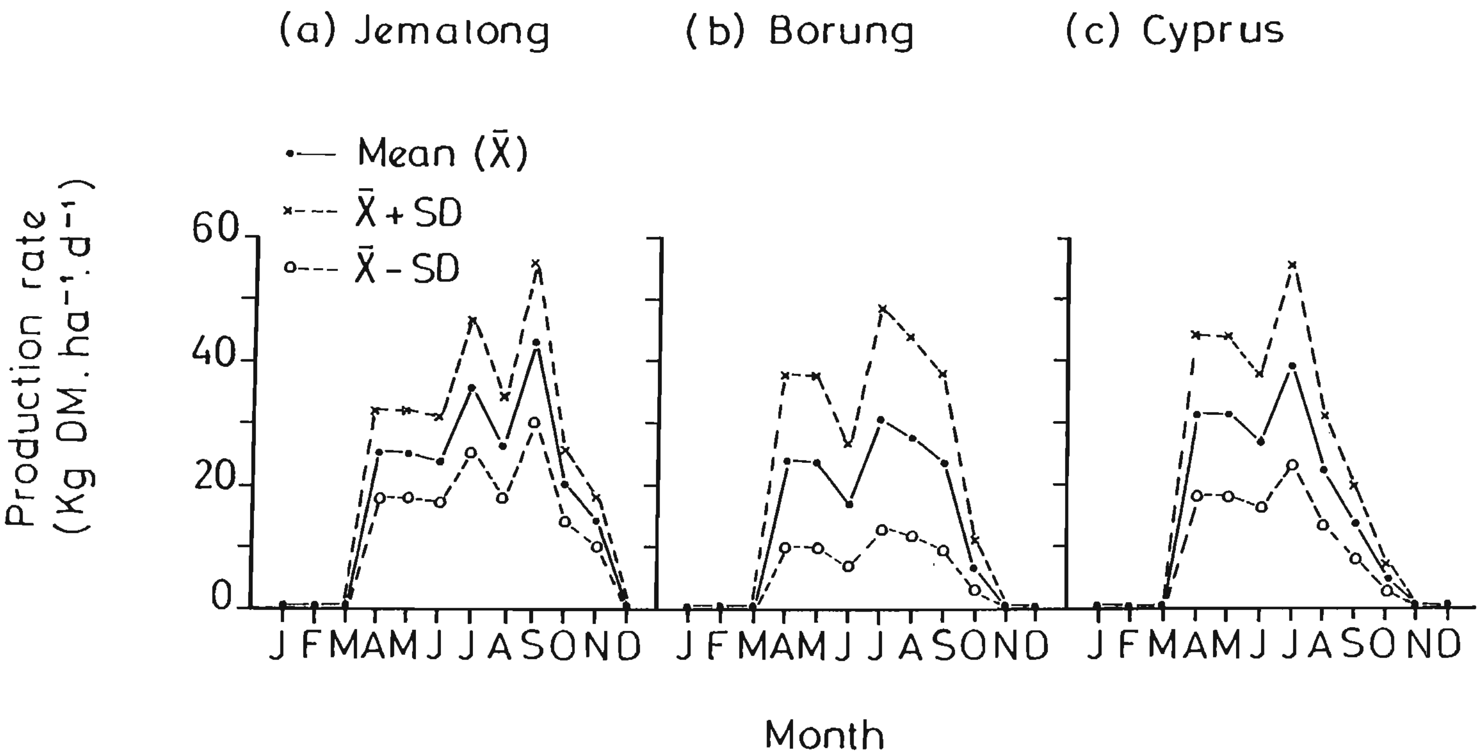


Figure 3.13 The production rate of three medic cultivars under dryland at Tygerhoek (1977-83)

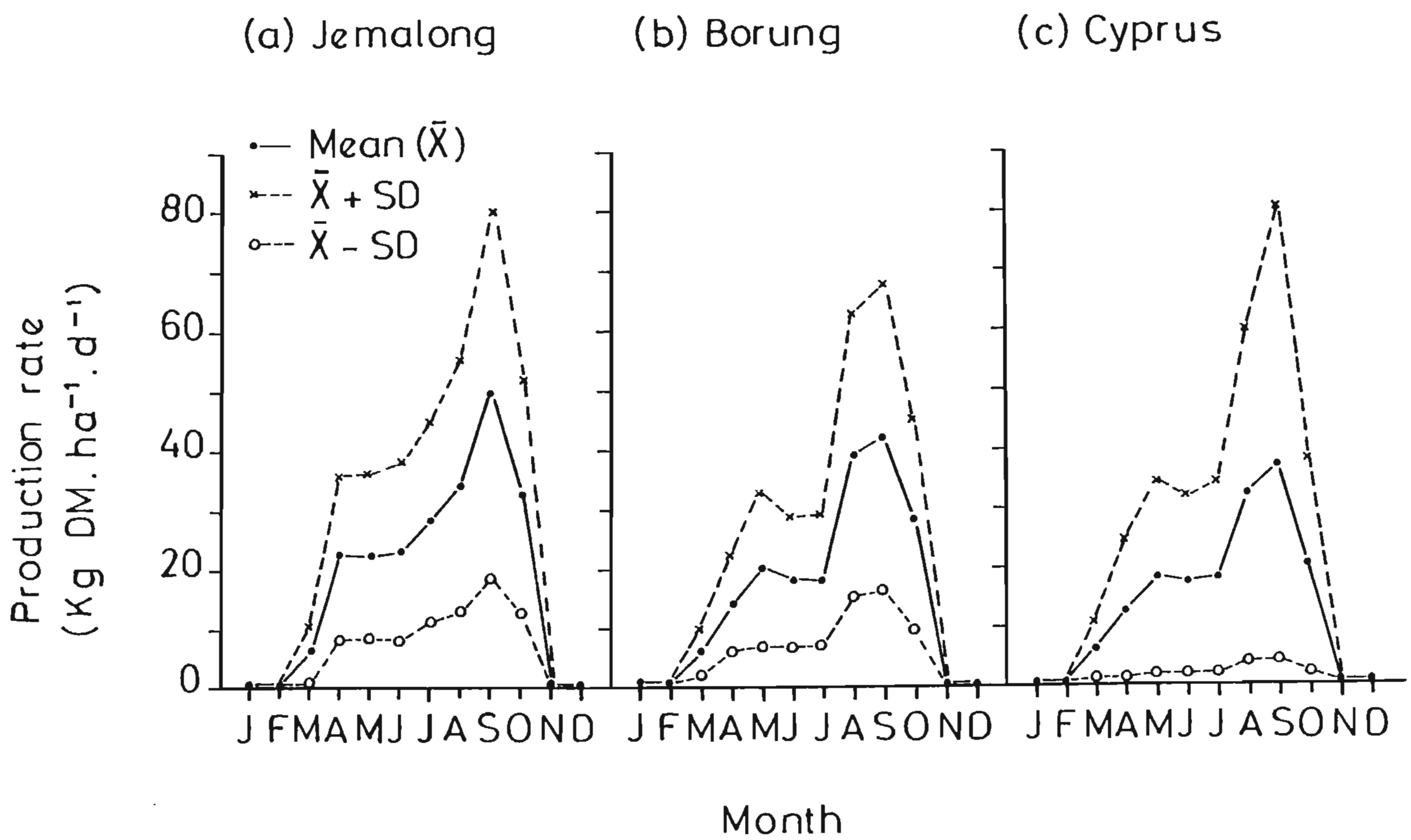
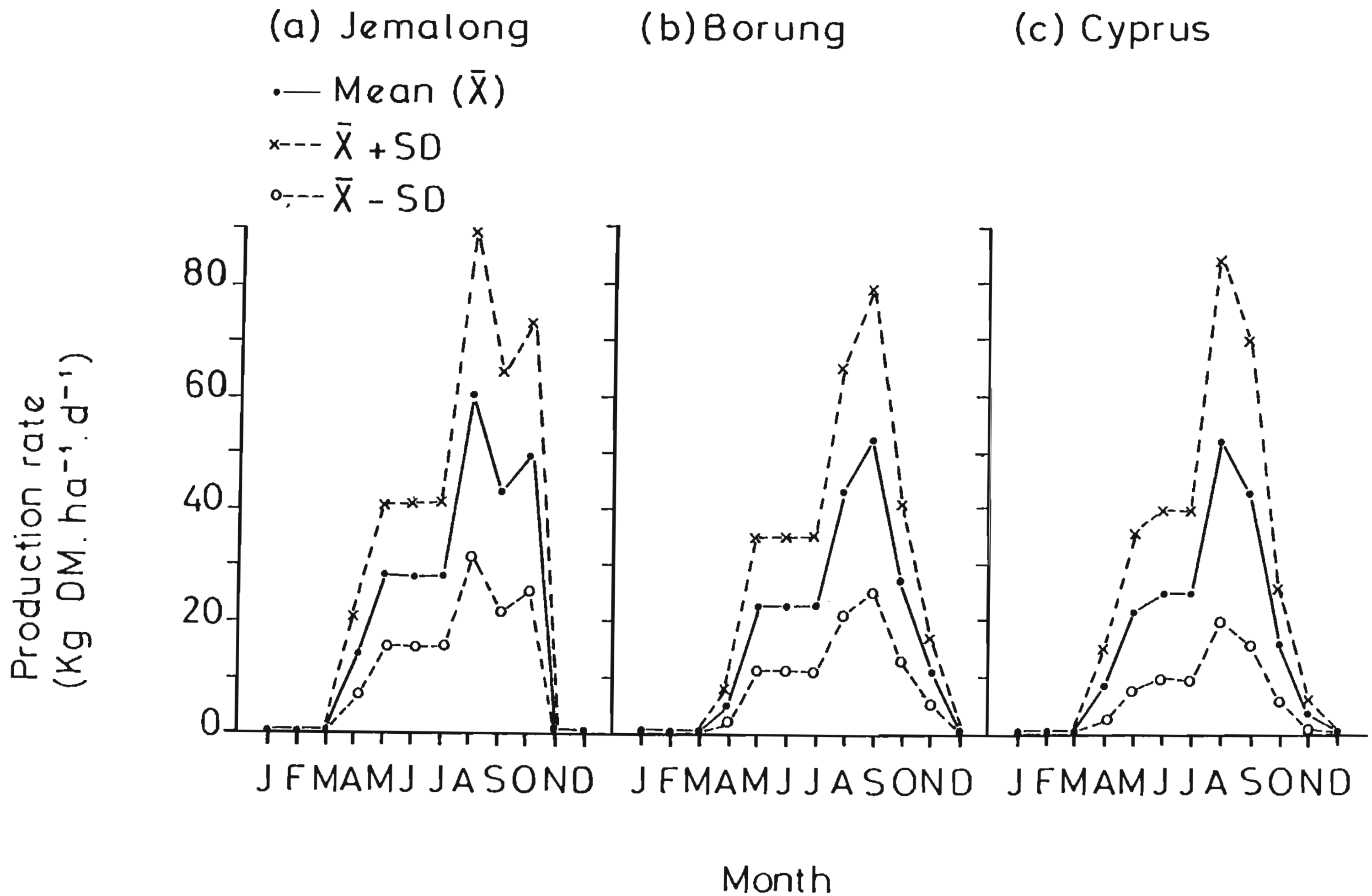


Figure 3.14 The production rate of three medic cultivars under dryland at Outeniqua (1977-83)



combined with its longer growing season, has resulted in it being the main medic cultivar recommended for and sown in practice throughout most of the region.

3.3.2.2 Extrapolation of production rate data

The seasonal production rate data, derived at Elsenburg, Langgewens, Tygerhoek and Outeniqua, were used for the development of functions for the extrapolation of the monthly production rates. The following functions were derived:

$MI = R.(0,5E)^{-1}$ (two-monthly means),
with R = total monthly rainfall (mm) and
E = total monthly class A pan evaporation (mm);

$TI = \exp(-(T-14)^2.86^{-1})$,
with T = mean monthly air temperature (°C);

$RI = Q_{TOT}.14^{-1}$,
for $Q_{TOT} \leq 14$ and

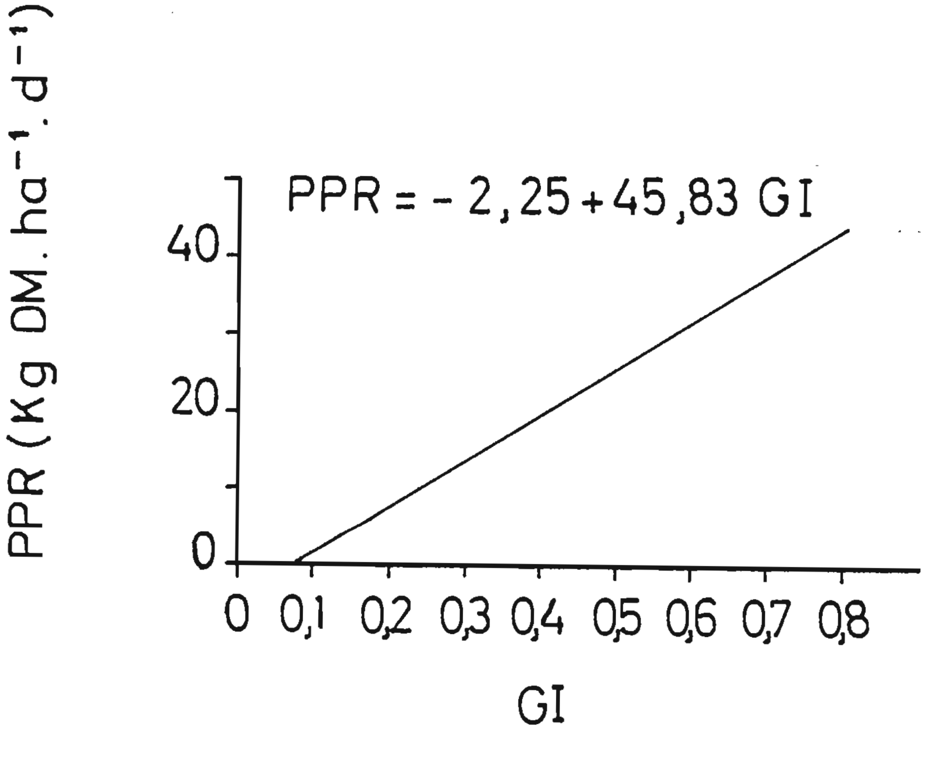
$RI = 14.{}_{QTOT}{}^{-1}$,
for $Q_{TOT} > 14$, with Q_{TOT} = total daily solar radiation ($MJ.M^{-2}.d^{-1}$);

GI = MI x RI x TI.

The relationship between the GI and the actual production rate (APR), used for the calculation of the potential production rate (PPR), is depicted in figure 3.15. Only one function was necessary, as the response at the different localities was very similar.

In the first instance the models were validated by comparing the PPR for the duration of the trials at each site with the

Figure 3.15 The relationship between the growth index (GI) and the potential production rate (PPR) for medics



APR of all medic cultivars over the same period. These results are depicted in figure 3.16. At Langgewens, Elsenburg and Tygerhoek the results were exceptionally good. At Outeniqua, however, the PPR deviated more from the APR, but was still significantly correlated with the latter. The deviation in mid winter (June to August), when the PPR was lower than the APR, is very difficult to explain. The deviation in summer can, however, be attributed to the fact that medics, being annuals, had to regenerate from seed every year. Rain during summer, associated with high temperatures capable of generating growth in a perennial, did not necessarily result in regeneration of the medics. This lead to an overestimation of the PPR during the summer period at Outeniqua, where a relatively high summer rainfall occurred.

For further validation of the models, data which had not been used during the development phase and had been derived at a separate locality, Sergeantsrivier, near Caledon, were used. The monthly PPR was compared with the APR over the whole experimental period (1977 to 1980). These results are presented in figure 3.17.

The PPR curve followed that of the APR curve reasonably well. The correlation between the APR and PPR was significant, largely due to the large number of degrees of freedom (n-2 = 46) involved. The method of predicting the PPR was, however, not intended to be used for the determination of the actual PPR, but for longer term prediction. The mean APR and PPR over the whole experimental period (1977 to 1980) was, therefore, determined and compared. These results are presented in figure 3.18.

The longer term PPR curve fits that of the APR very well and results in a very high correlation. These results, therefore, indicate that the functions used enable the reasonably

Figure 3.16 The comparison of the actual (APR) and the predicted potential (PPR) production rate at four sites over the whole trial period

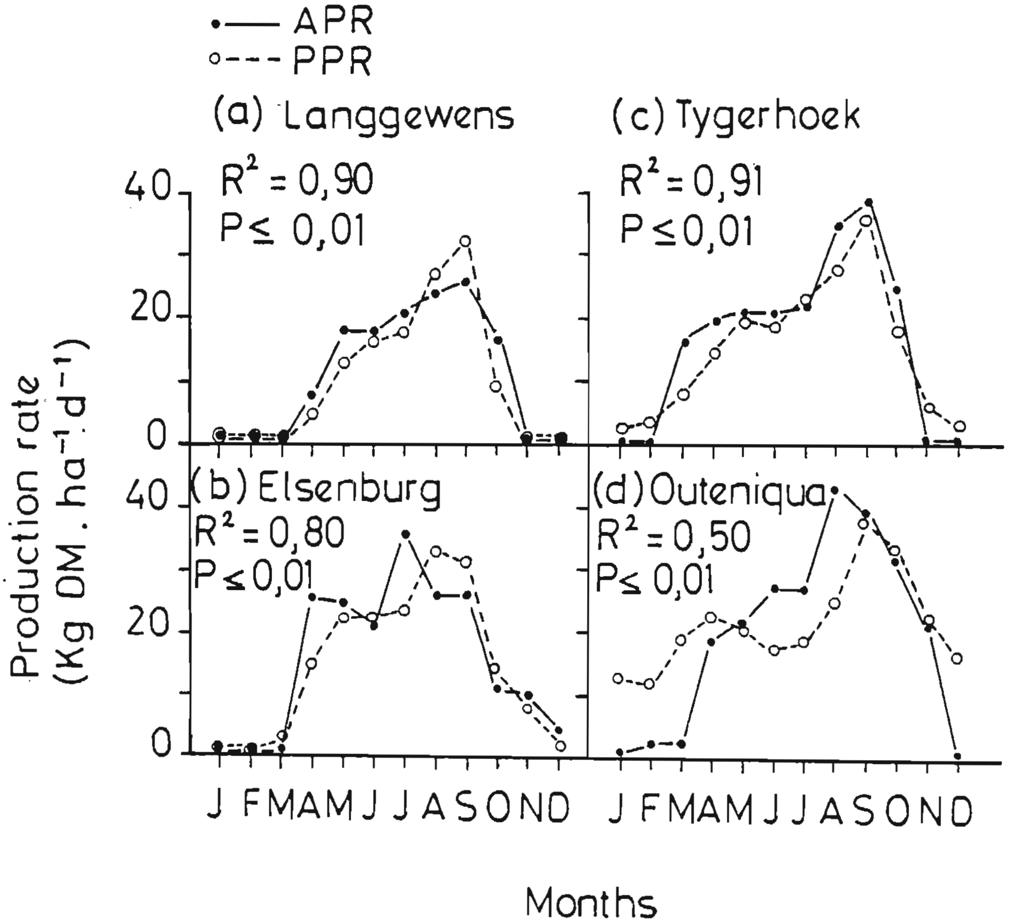


Figure 3.17 Comparison of the actual (APR) and the predicted potential (PPR) production rate at a validation site, Sergeantsrivier

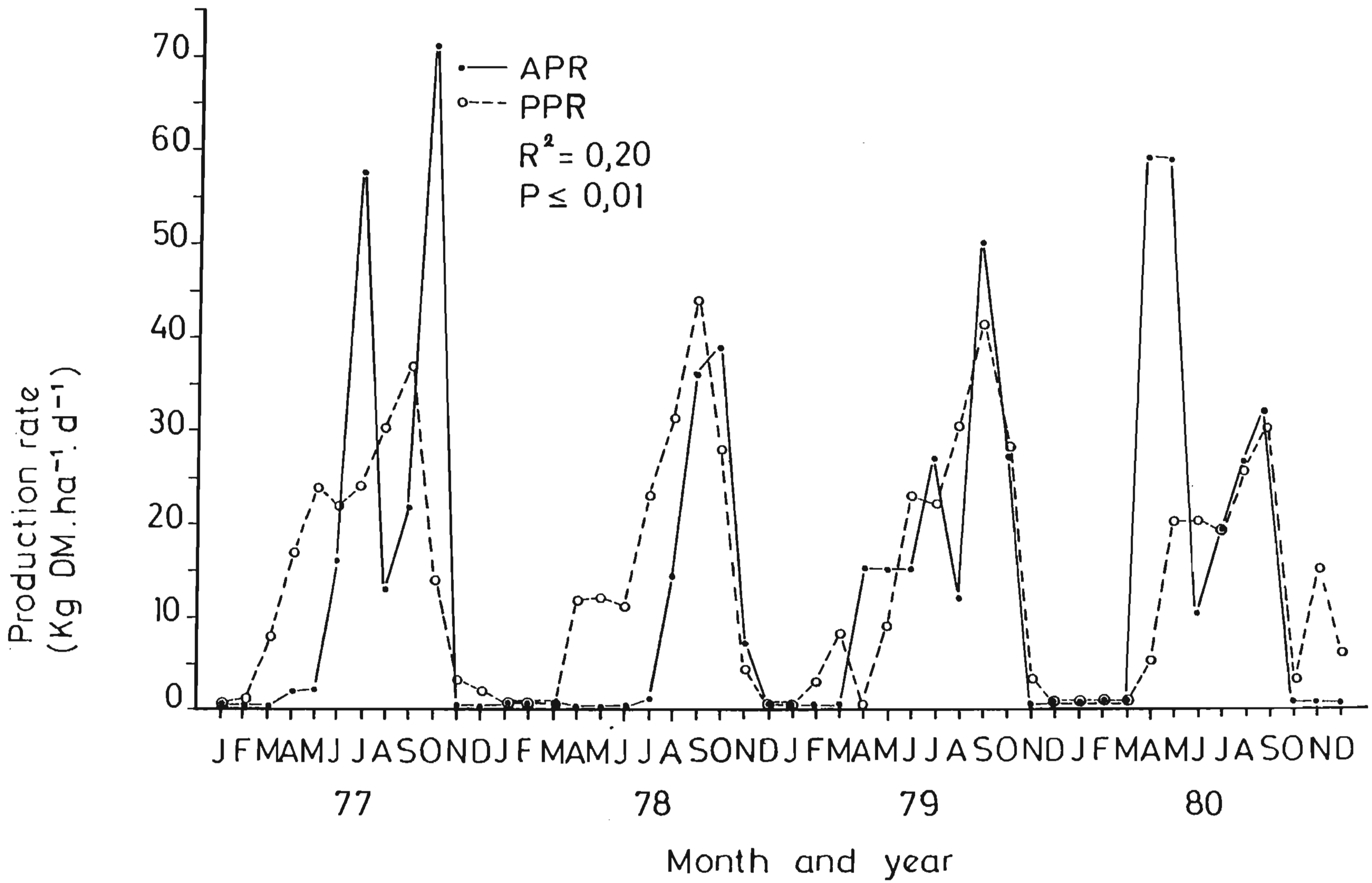
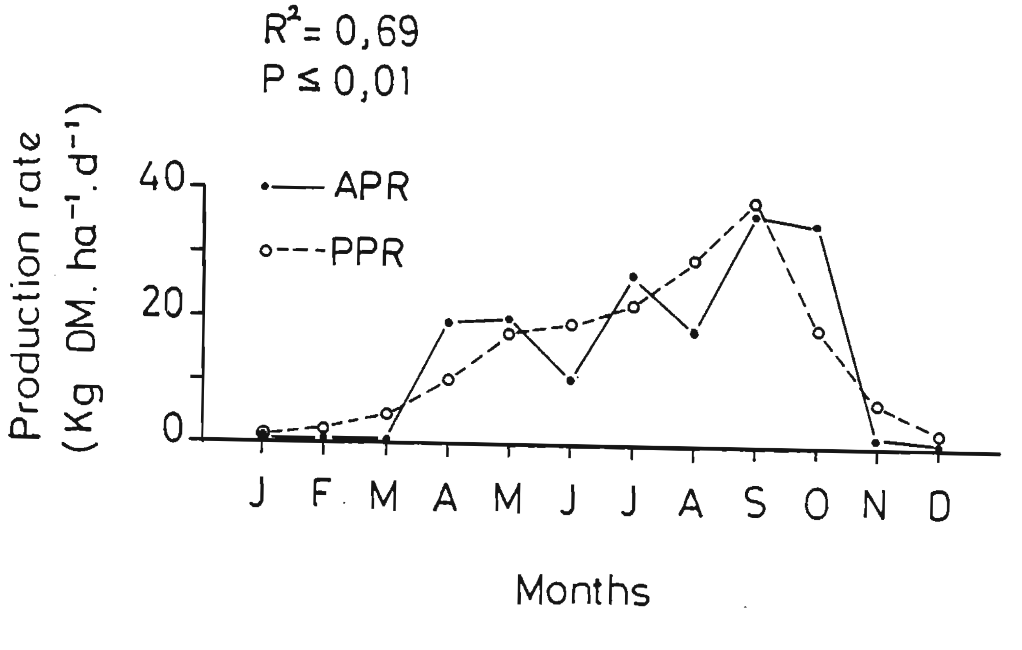


Figure 3.18 The comparison of the actual production rate (APR) for four seasons (1977 to 1980) with the mean predicted potential production rate (PPR) over the same period at Sergeantsrivier



accurate prediction of the long-term PPR at sites in the South Coast and the Swartland. Using long-term climatic data, the PPR was, therefore, determined for each of the above-mentioned four sites. These results are presented in figure 3.19.

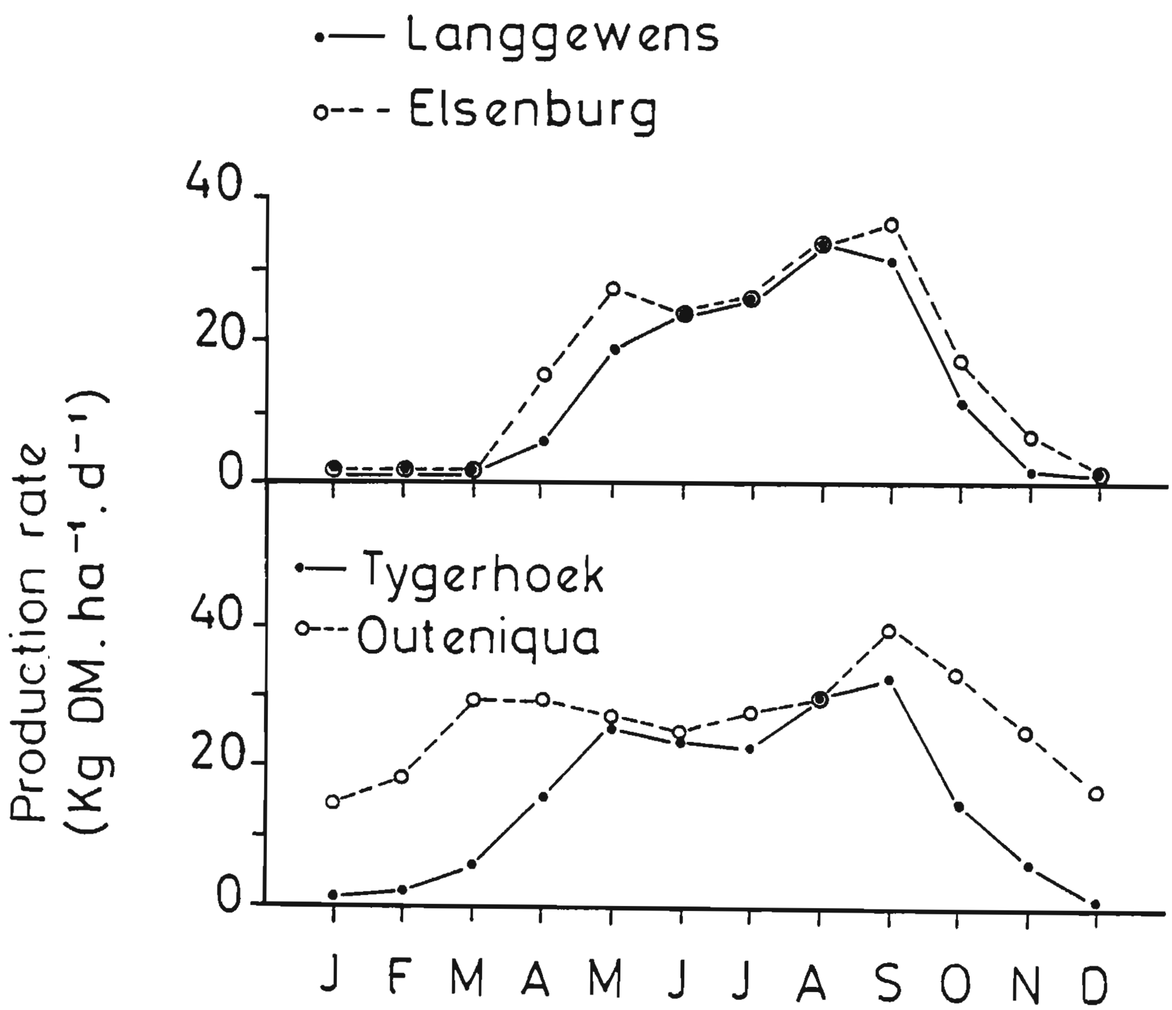
The four trial sites differ mainly in the length of their effective growing seasons, as reflected in their PPR curves. If the sites are placed in order of increasing growing season length, the ordering will be: Langgewens < Elsenburg < Tygerhoek < Outeniqua.

3.3.2.3 Discussion and conclusions

The method of sampling and the distance of most trials from the main centre, made the accurate determination of the advent and end of the growing season and, therefore, also the accurate determination of growth rates before the first and after the last harvest, very difficult. In spite of this problem, the potential production curves seem to be very good estimates of the actual potential production rates at each site. Another problem was that the method of sampling may have resulted in higher production rates than would have been the case under the lenient-grazing system normally applied to this crop.

The basic shape of the production curves and the production rates did not seem to differ much between the sites and the main differences were in the length of the growing season, as well as the month during which the highest production rates were attained. Outeniqua seemed to be the site with the longest and Langgewens and Elsenburg the sites with the shortest growing season. Of the individual cultivars evaluated, Jemalong seemed to have had the highest production rate at two sites, Outeniqua and Tygerhoek. The winter production of all cultivars was, however, very high and this

Figure 3.19 Long-term potential production rate (PPR) predicted, using the derived functions and long-term mean climatic data



is indicative of the generally high winter production potential of annuals during the time of the year when that of perennials is very low.

The extrapolation of the production rates was successfull and significant correlations were attained at Elsenburg, Langgewens and Tygerhoek, although the PPR curve deviated more from the APR at Outeniqua. The latter deviation was, however, attributed to the fact that annual legumes, such as medics, do not respond readily enough to favourable moisture conditions during summer, as they have to regenerate from seed. The further validation of the functions, using a new set of data derived at a different site and not utilised during the development phase, indicated that the functions were sufficiently good to enable extrapolation when using long-term mean climatic data.

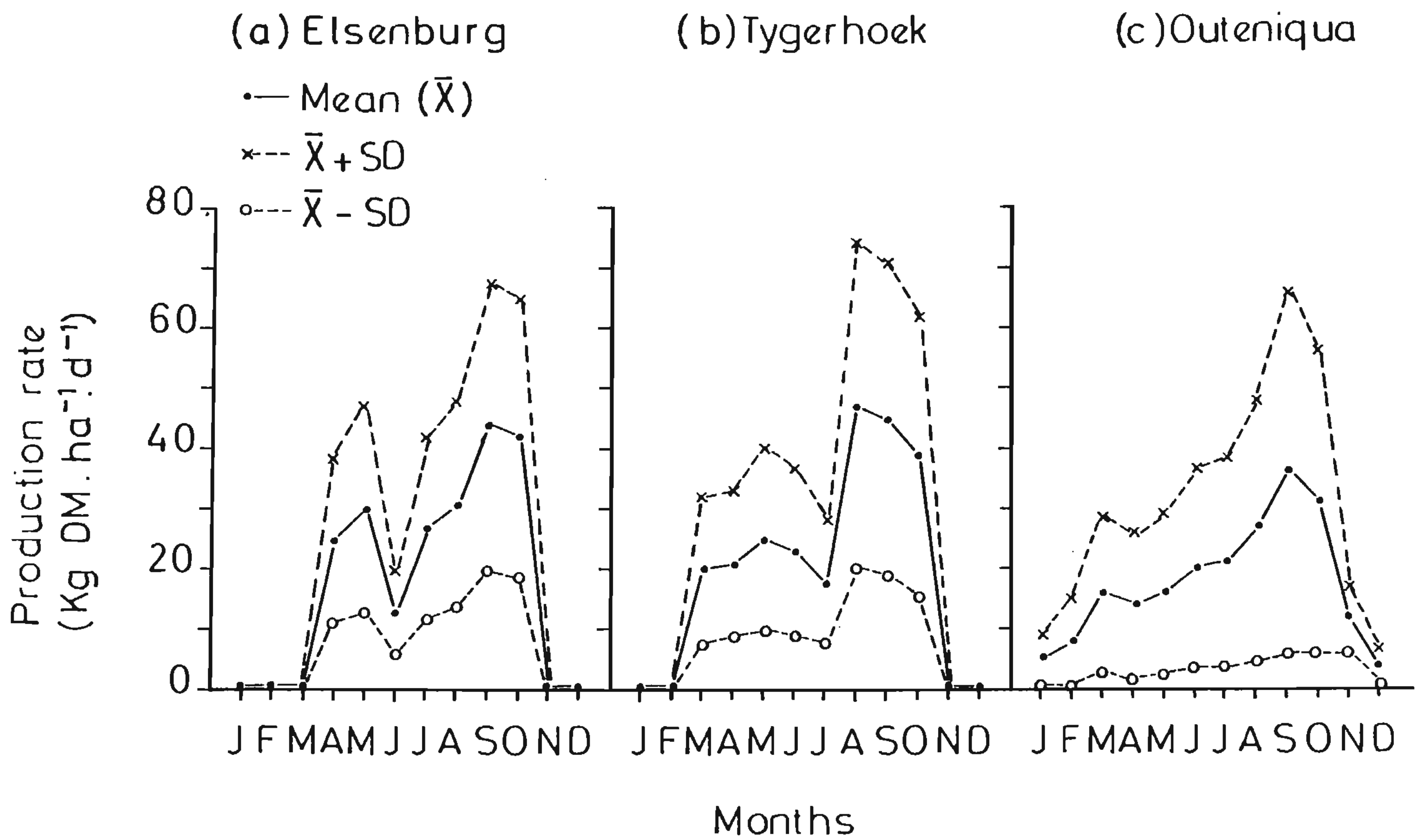
Using the functions to extrapolate long-term seasonal production rates at each site, based on long-term mean monthly climatic data, it was found that the trial sites did not differ much in potential production rate, but seemed to differ in the potential length of their growing seasons. Ranking the sites according to length of growing season, the following order seem to emerge: Langgewens < Elsenburg < Tygerhoek < Outeniqua.

3.3.3 Subterranean clover

3.3.3.1 Seasonal production

The mean production rates (kg $DM.ha^{-1}.d^{-1}$) of all the subterranean clover cultivars, evaluated under dryland conditions at three sites, Elsenburg, Tygerhoek and Outeniqua, as well as the standard deviation of the data, are presented in figure 3.20.

Figure 3.20 Production rate over all cultivars of subterranean clover evaluated under dryland conditions at Elsenburg (1978-83), Tygerhoek (1977-83) and Outeniqua (1977-83)



As in the case of the previous legumes, the variation in production was substantial. The curves, however, provided a definite indication of the seasonal trend in production rate at each site and so in differences in seasonal production between sites. The main differences were in the dates at which regeneration started and also the dates to which growth continued. At Outeniqua growth started during January, at Tygerhoek it started during February/March and at Elsenburg during March/April. The season ended during October/November at Tygerhoek and Elsenburg, but at Outeniqua growth continued until December. The production rates at Elsenburg tended to be slightly higher during April and May than at the other two sites. The winter trough in production rate was more prominent at Elsenburg (during June) than at Tygerhoek and Outeniqua.

The production rates of three of the most important cultivars, Mt Barker, Clare and Woogenellup, which had been evaluated at the above-mentioned three sites, are presented in figures 3.21 to 3.23. At Elsenburg, Woogenellup seemed to have had a longer growing season and a higher production rate, during the period August to December, than the other two cultivars Clare and Mt Barker. The production rate and growing season length of the latter two cultivars did, however, not differ much at this site. At Tygerhoek, Woogenellup and Clare outyielded Mt Barker. The growing season lengths of the three cultivars did, however, not differ much at this site. At Outeniqua also, Woogenellup had a longer growing season and a higher production rate than the other two cultivars during the latter half of the growing season (October to December). The production rates and growing season lengths of Clare and Mt Barker did not differ much at this site.

Figure 3.21 Production rate of three subterranean clover cultivars under dryland conditions at Elsenburg (1978-83)

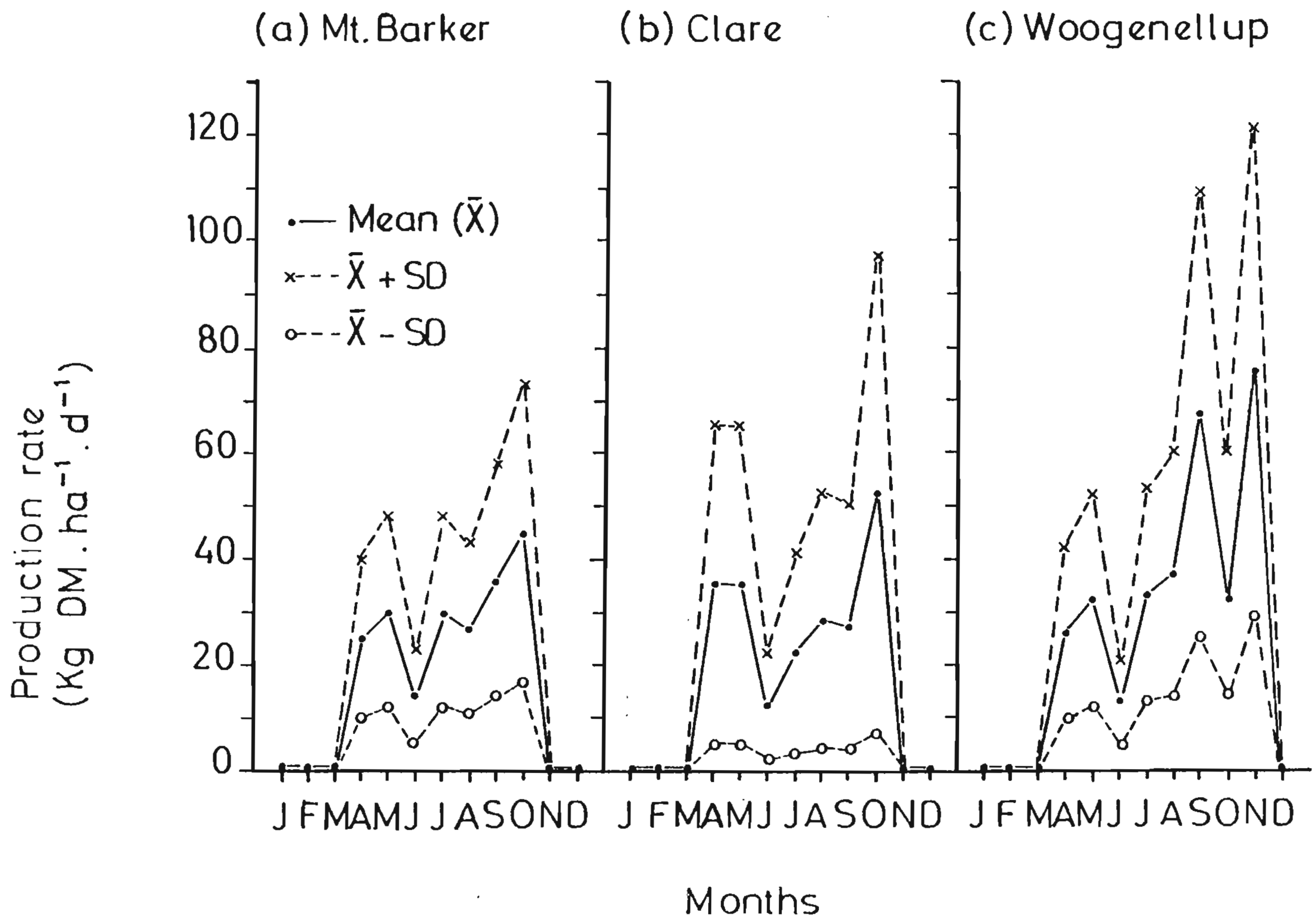


Figure 3.22 Production rate of three subterranean clover cultivars under dryland conditions at Tygerhoek (1977-83)

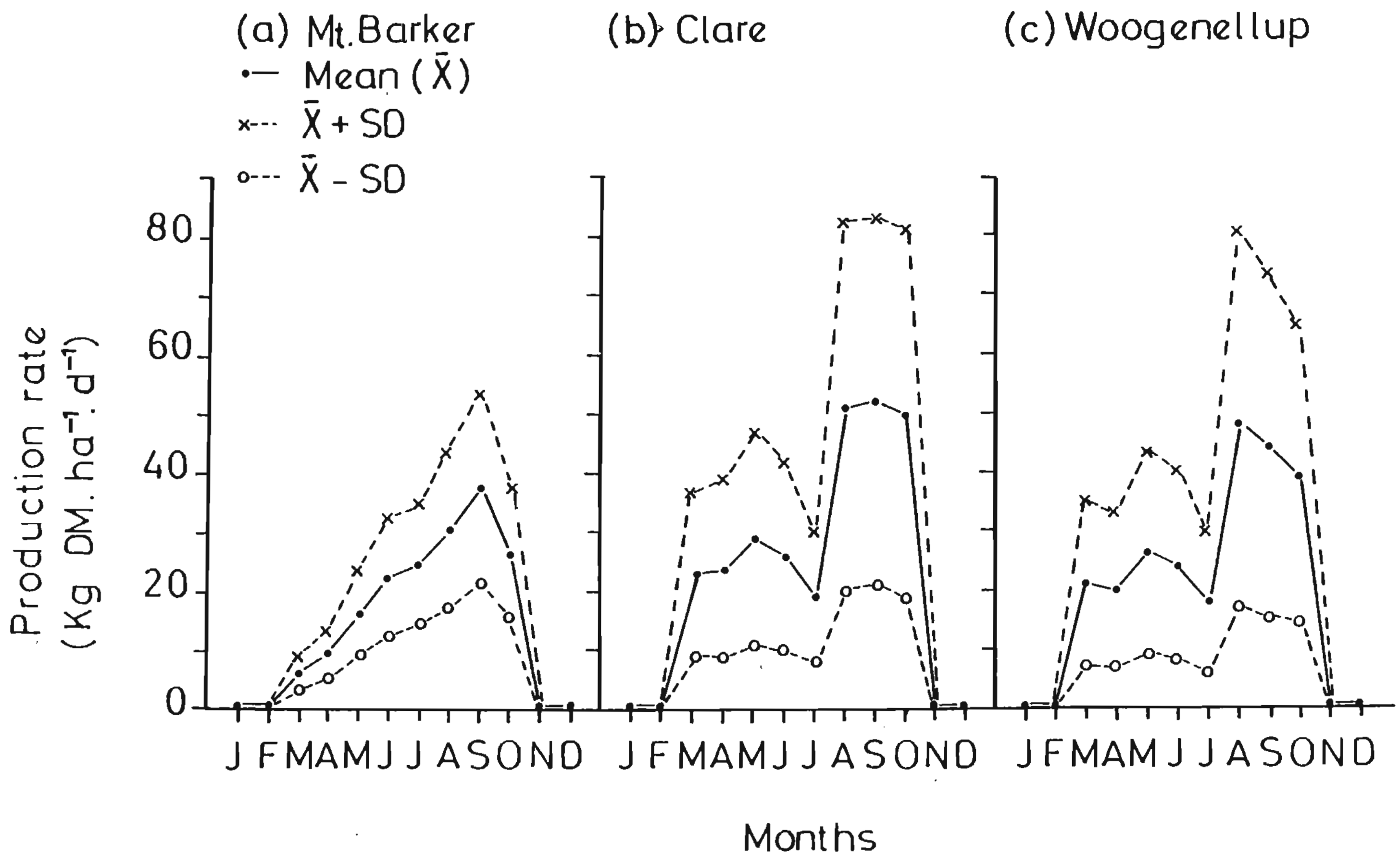
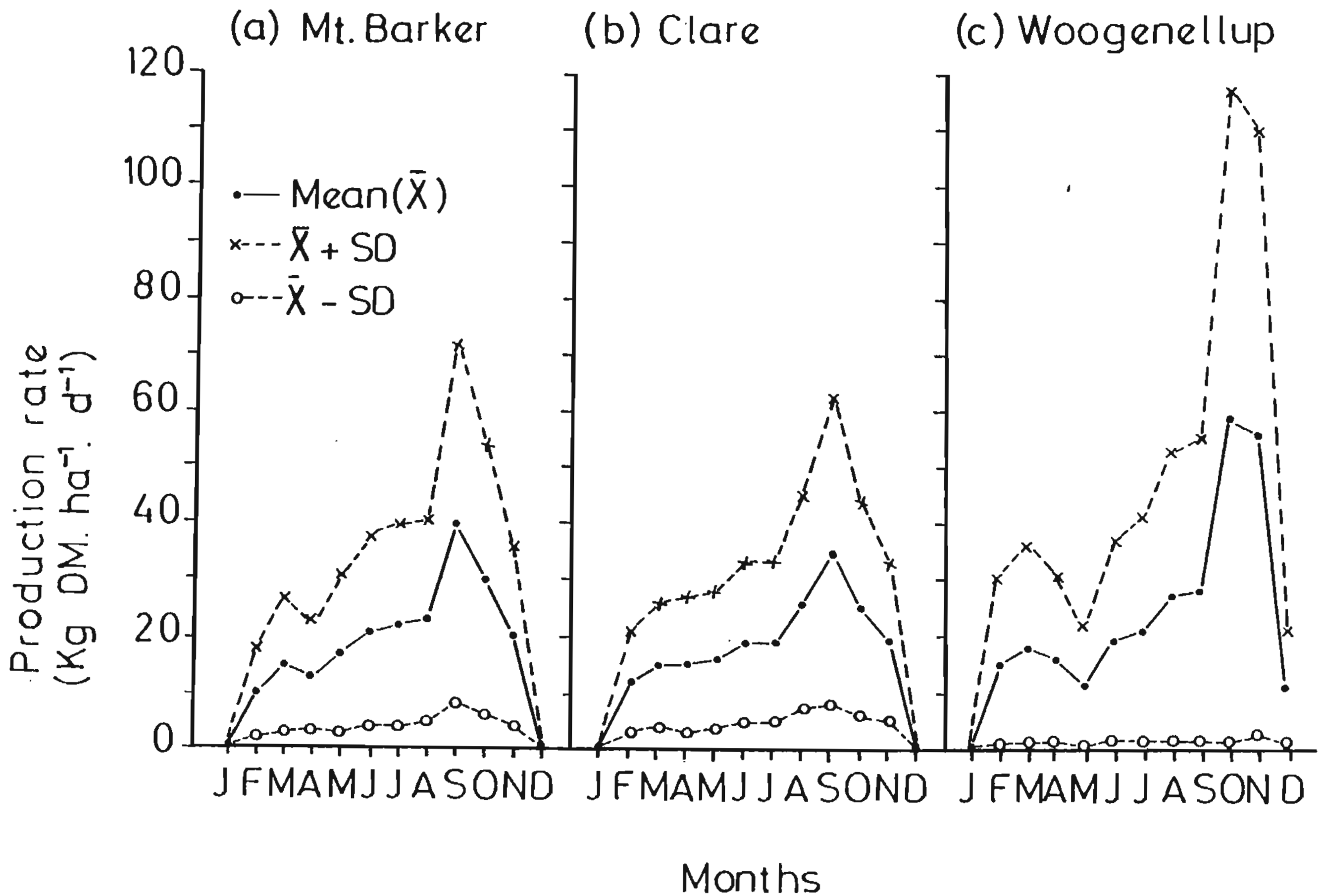


Figure 3.23 Production rate of three subterranean clover cultivars under dryland conditions at Outeniqua (1977-83)



3.3.3.2 Extrapolation of production rate data

The production rates, derived at the three experimental sites, were again used to develop mathematical models to define the relationship between the production rates and simple climatic factors. These relationships could be used for the extrapolation of yield data. The following functions were developed:

$MI = R.(0,5E)^{-1}$ (mean of two months),
with R = total monthly rainfall (mm) and
E = total monthly class A pan evaporation (mm);

$TI = \exp(-(T-14)^2.86^{-1})$,
with T = mean temperature (°C);

$RI = Q_{TOT}.14^{-1}$,
when $Q_{TOT} \leq 14$ and

$RI = 14.Q_{TOT}^{-1}$,
where $Q_{TOT} > 14$ and with Q_{TOT} = total daily radiation ($MJ.M^{-2}.d^{-1}$);

GI = MI x TI x RI.

A relationship was developed between GI and the actual production rate (APR), and used for the prediction of the potential production rate (PPR). This relationship is presented in figure 3.24. The above-mentioned functions were validated by comparing the mean monthly PPR with the mean monthly APR at each site over the experimental period. These results are presented in figure 3.25.

At all sites the PPR curve followed that of the APR very well, resulting in highly significant R^2 values. At Outeniqua, however, the PPR curve deviated from, and

Figure 3.24 Relationship between the growth index (GI) and the potential production rate (PPR) for subterranean clover under dryland at all sites

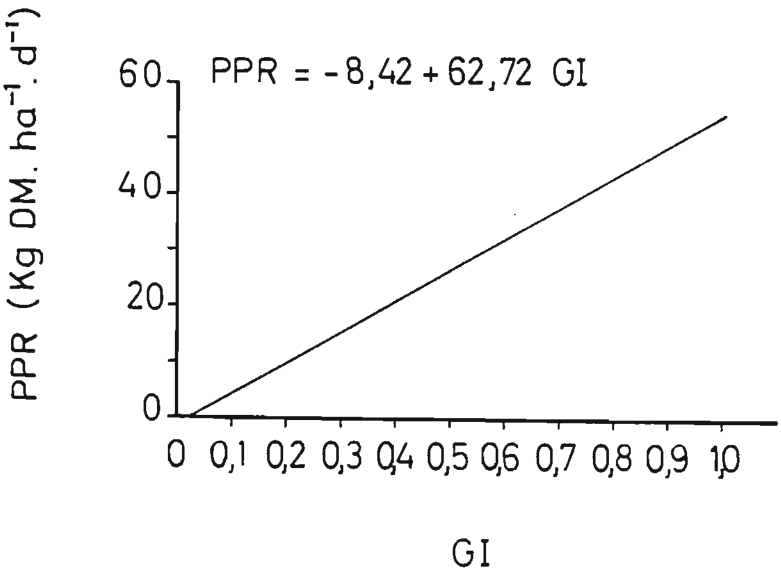
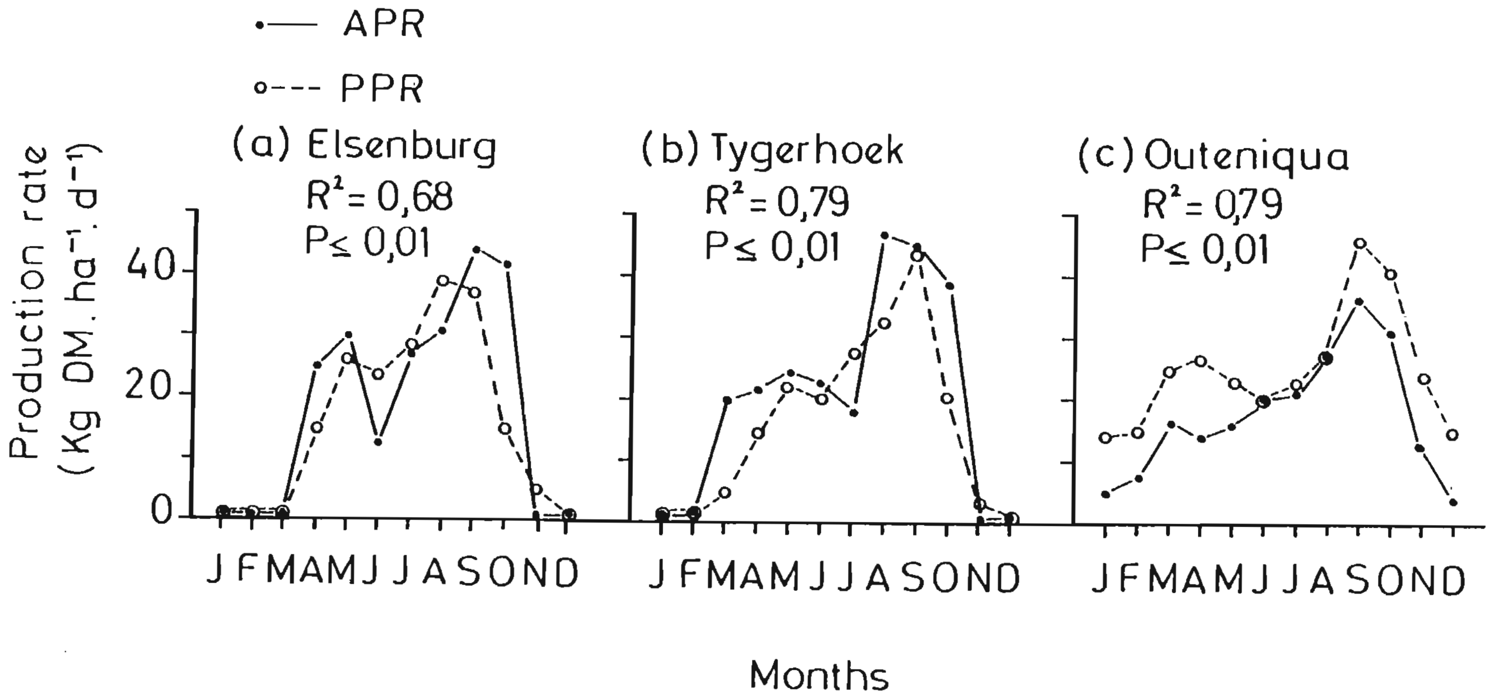


Figure 3.25 Comparison of the actual (APR) and predicted potential (PPR) production rate of subterranean clover at three dryland sites over the whole trial period



overestimated, the APR during almost all months of the year. The only time when the PPR values were similar to the APR was the period June to August. The overestimation during summer can be attributed to the fact that subterranean clover is an annual and has to regenerate from seed every year. A GI value which would have generated growth in a perennial pasture species, would not necessarily have resulted in regeneration from seed. The APR values at Outeniqua were also slightly lower during autumn and spring. This could perhaps be attributed to the lower potential soil at Outeniqua than at the other sites.

As a further validation of the models, the monthly APR over four seasons (1977 to 1980) at a site, Sergeantsrivier, of which the data had not been used during the development phase, was compared with the monthly PPR. These results are presented in figure 3.26. The PPR curve followed the APR curve reasonably well, resulting in a significant R^2. During certain periods the PPR, however, deviated quite sharply from the APR. This can possibly be attributed to the sampling method and, particularly the difficulty in defining both the start and the end of the growing season. Also, an aphid attack influenced the APR but could not be taken into account in determining PPR (in particular, refer to the March to June period in the 1978 season).

The aim of the exercise was, however, to develop a relationship which could be used to predict the long-term potential production rate (PPR), using only long-term mean climatic data. The comparison of APR with PPR values in this manner was, therefore, not quite in keeping with this aim. The mean APR over the experimental period at Sergeantsrivier was, therefore, subsequently compared with the mean PPR. This comparison is presented graphically in figure 3.27.

Figure 3.26 Comparison of the actual (APR) and predicted potential (PPR) production rate of subterranean clover at a validation site Sergeantsrivier

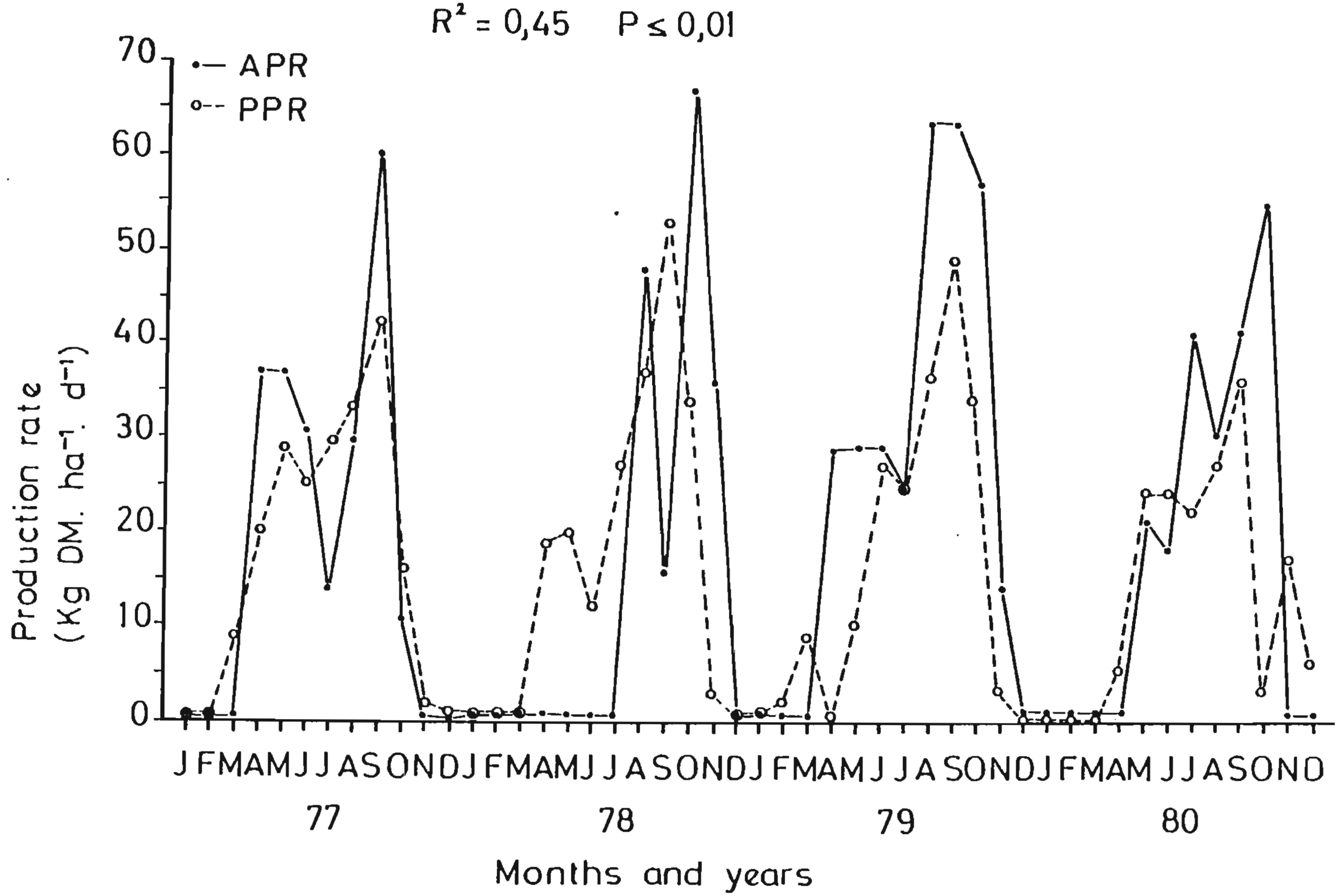
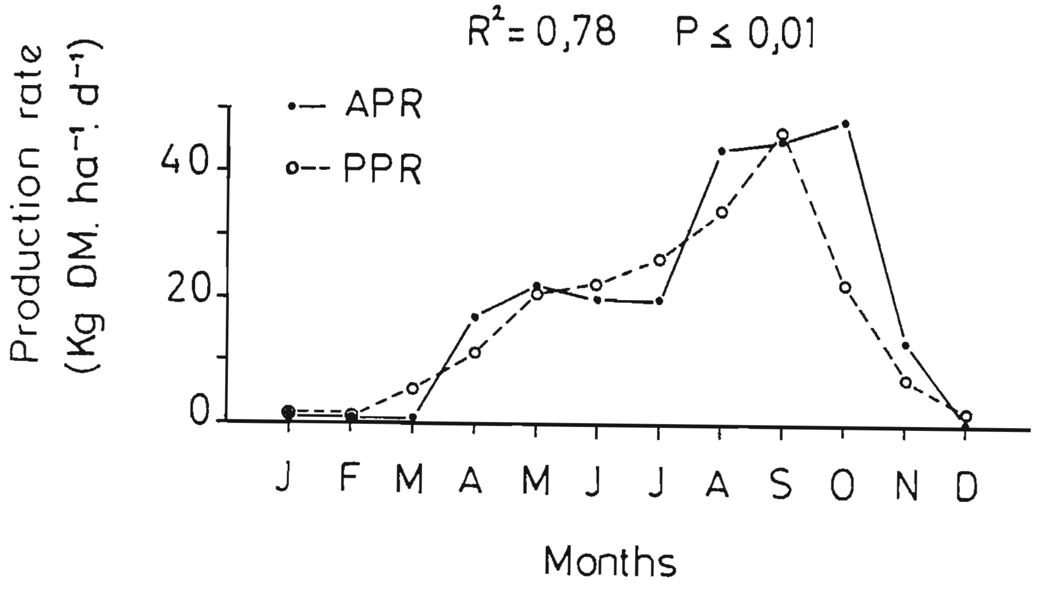


Figure 3.27 Comparison of the actual (APR) and potential (PPR) production rate of subterranean clover over the whole experimental period (1977 to 1980) at Sergeantsrivier



The two curves were clearly much more highly correlated than those in figure 3.26. This suggests that the functions are successfull in estimating the PPR, using long-term climatic data, and can, therefore, be reasonably safely used for extrapolation to sites not differing too much from those at which the trials were originally executed.

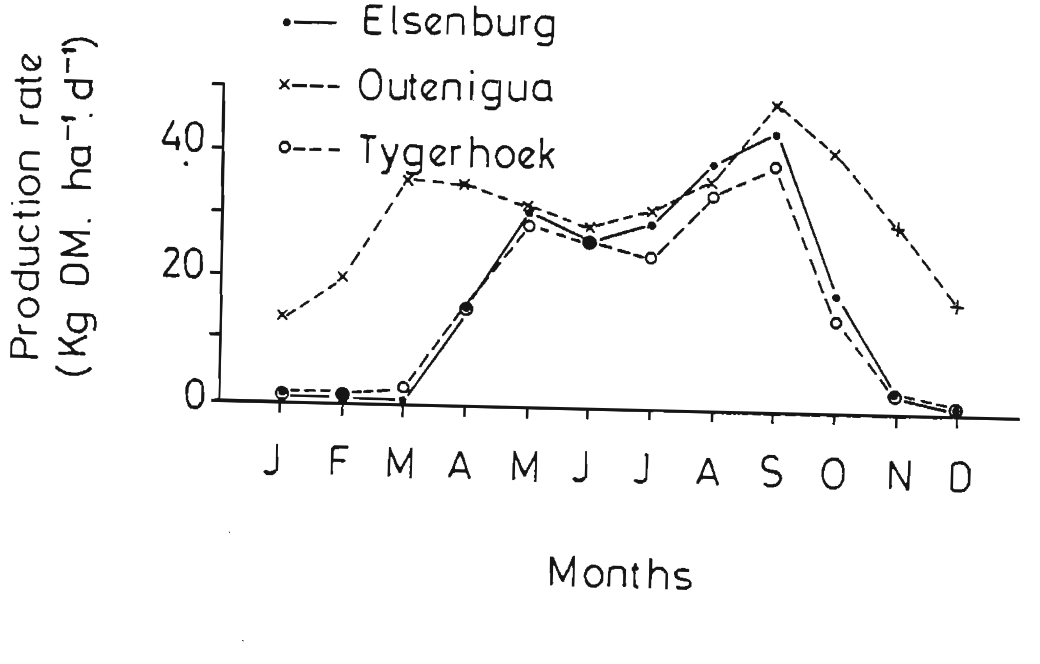
Based on the success of the methods used, the long-term monthly PPR was calculated for each of the above-mentioned sites, using long-term climatic data as input. These results are depicted in figure 3.28. The predicted PPR at Elsenburg and Tygerhoek is practically the same. During the period September to April the predicted monthly PPR is, however, much higher at Outeniqua than at the other two sites. During the winter months (May to August) the long-term PPR is very much the same at all three sites. The higher potential during summer at Outeniqua must, however, be interpreted in the light of the indicated overestimation of the PPR during this period.

3.3.3.3 Discussion and conclusions

The three trial sites differed largely in the length of their effective growing seasons. According to the APR data, Outeniqua had the longest and Elsenburg the shortest growing season. In comparing the production curves of the three cultivars evaluated, it was found that Woogenellup had the longest growing season. This cultivar is also the only one which is at present recommended, as all other cultivars, including Clare and Mt Barker, which had also been evaluated, are very susceptable to root diseases (Fusarium spp.).

The extrapolation of the production rates was very successful and correlations between monthly APR and PPR values over the experimental period, were significant in all

Figure 3.28 Long-term potential production rate (PPR) of subterranean clover predicted, using the derived functions and long-term mean climatic data



cases. Using new data, not utilised during the development phase and derived at a different site, Sergeantsrivier, a reasonably good fit was found between the actual monthly PPR and APR values, but an even better fit was found when longer term means were used over the whole experimental period. This, therefore, indicates that the functions are well suited for the estimation of the long-term PPR at a particular site; which is indeed what they were intended for.

The functions could, therefore, reasonably safely be used for long-term prediction at the experimental sites, using long-term climatic means as input. The only locality at which a measure of doubt was evident, is Outeniqua, where the PPR overestimated the APR only during summer when rains did not necessarily result in regeneration from seed.

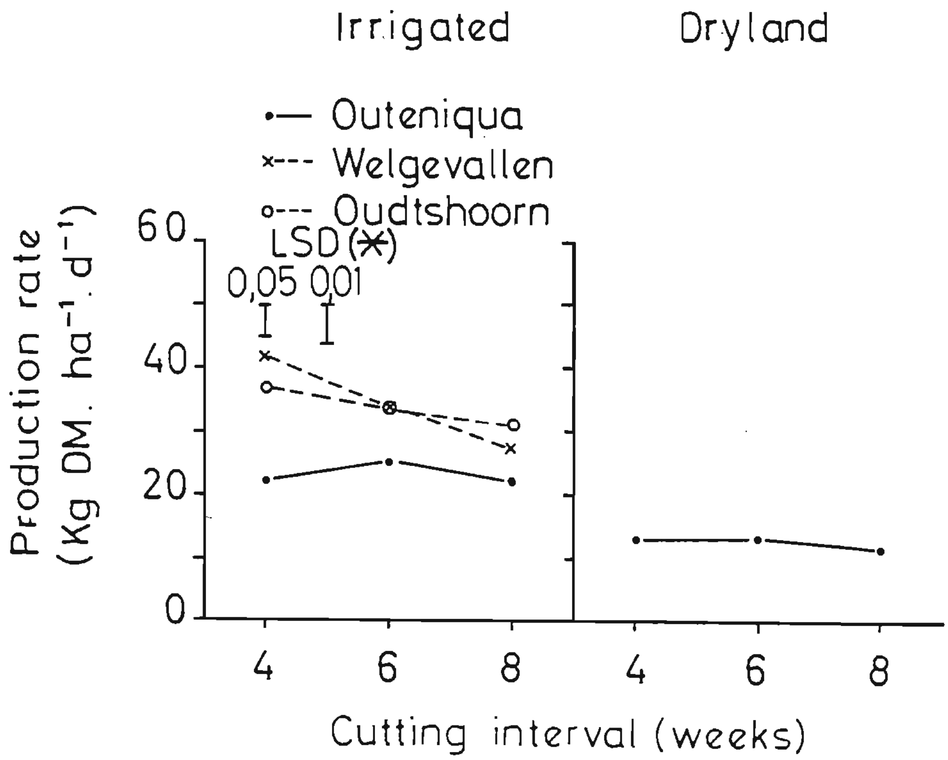
The long-term extrapolation of the PPR, using long-term mean climatic data, indicated that Elsenburg and Tygerhoek tend to have very similar potential production rates (PPR). At Outeniqua the potential growing season, however, extends into the summer period. These results also indicate that subterranean clover has a substantial production potential during winter, when most perennial species have a very low production rate.

3.3.4 White clover

3.3.4.1 Influence of cutting frequency

The mean production rates of all white clover cultivars evaluated under dryland and irrigation in four trials at three localities, Welgevallen, Outeniqua and Oudtshoorn, and cut at three different frequencies (four-, six- and eight-weekly), are depicted in figure 3.29.

Figure 3.29 Influence of cutting frequency on the production rate of white clover under irrigation and dryland at Outeniqua (1981-83), Welgevallen (1979-81) and Oudtshoorn (1981-84) (* LSD's for dryland and irrigated trials)



The influence of cutting treatment was significant only at Welgevallen. Yields at both this site and at Oudtshoorn, decreased with a decrease in cutting frequency. Under dryland, at Outeniqua, there was no significant response to treatment, but in the irrigated trial at the same site, the yields tended to be highest at the six-weekly cutting frequency. The results generally indicated that white clover is not very sensitive to cutting frequency. Results differed at the different sites, depending on growing conditions, but it can generally be accepted that white clover would maintain the highest rates of dry matter production when cut every four or at least every six weeks.

3.3.4.2 Seasonal production

The production rates (kg $DM.ha^{-1}.d^{-1}$) of all the white clover cultivars, evaluated over a number of seasons in cutting trials under irrigation at three sites, Welgevallen, Outeniqua and Oudtshoorn and at one dryland site, Outeniqua, are depicted in figures 3.30 and 3.31, respectively.

The seasonal variation in the production rates is also indicated as a standard deviation. The variation is very large, but does not prohibit the use of the results as an indication of the production potential during the trial periods at the respective sites.

The seasonal production patterns under irrigation (figure 3.30) varied between the different sites, but also varied quite substantially through the year at the same site. At Welgevallen and Outeniqua the production rates tended to fluctuate very similarly through the year, reaching a peak some time during summer and a trough during the period May to July/August. An interesting feature of the data was the very low winter (May to August) production rates at Outeniqua.

Figure 3.30 The production rate over all white clover cultivars under irrigation at Welgevallen (1978-81), Outeniqua (1978-83) and Oudtshoorn (1978-84)

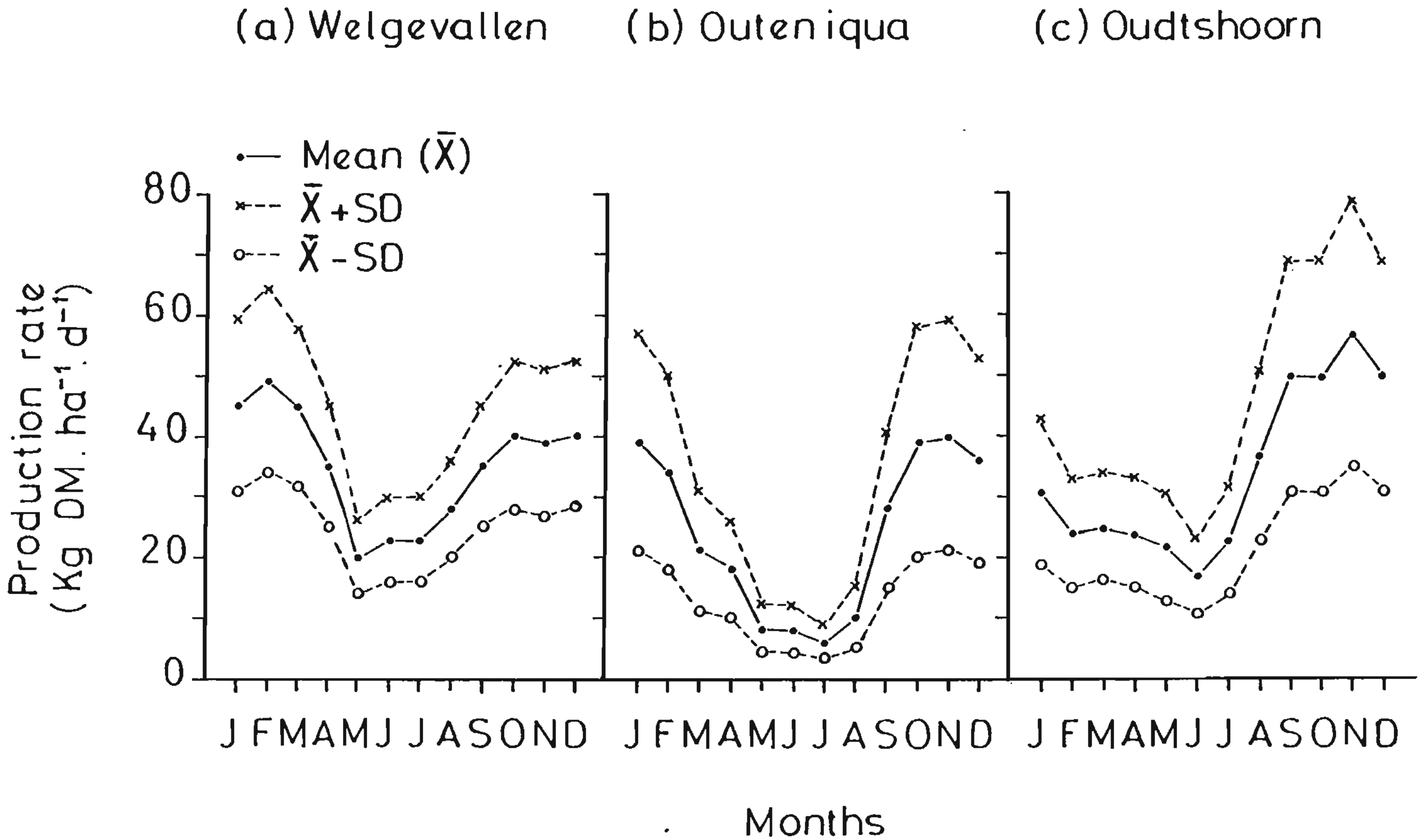
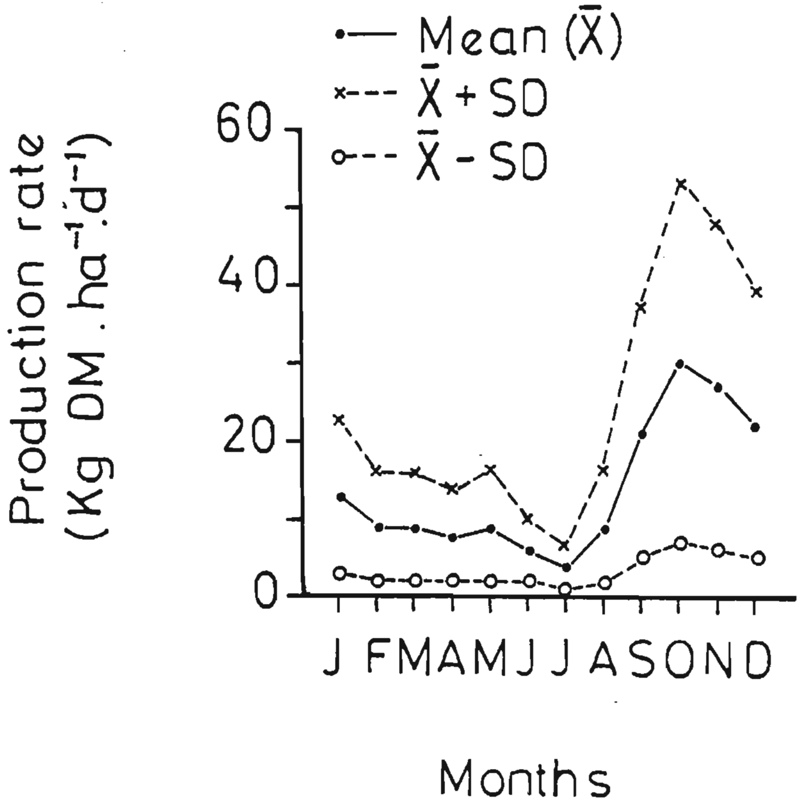


Figure 3.31 The mean monthly production rate over all white clover cultivars under dryland at Outeniqua (1978-83)



At Welgevallen the production rates seemed highest during January to March, while they were highest during October to February at Outeniqua. At Oudtshoorn, however, the production rates were very low during late summer (January to March) and decreased only slightly thereafter, to reach a minimum during June. During the subsequent months a sharp rise in production rates occurred at Oudtshoorn, reaching a peak during the period September to December.

The seasonal production rate under dryland conditions at Outeniqua (figure 3.31), differed quite substantially from that of the irrigated swards during certain months of the year. During winter, there was basically no difference between the irrigated and dryland swards, but during spring, summer and autumn (August to May), production was much lower under dryland conditions. Maximum production rate under dryland was attained during October/November, with a decrease in rate during subsequent months. The result was that production was not much higher during the late summer and autumn than during the winter.

Presented in figures 3.32 to 3.35 are the mean monthly production rates of two cultivars Ladino and Permanent Pasture, which had been evaluated at all sites. At Welgevallen and Outeniqua, under irrigation (figures 3.32 and 3.33), Ladino and Permanent Pasture had very much the same production pattern. The production rates of Ladino, however, generally seemed to be slightly higher than that of Permanent Pasture.

At Oudtshoorn, under irrigation (figure 3.34), however, the production pattern of the two cultivars tended to differ quite substantially. The production rates of Ladino were also generally much higher than those of Permanent Pasture,

Figure 3.32 The production rate of two white clover cultivars under irrigation at Welgevallen (1979-81)

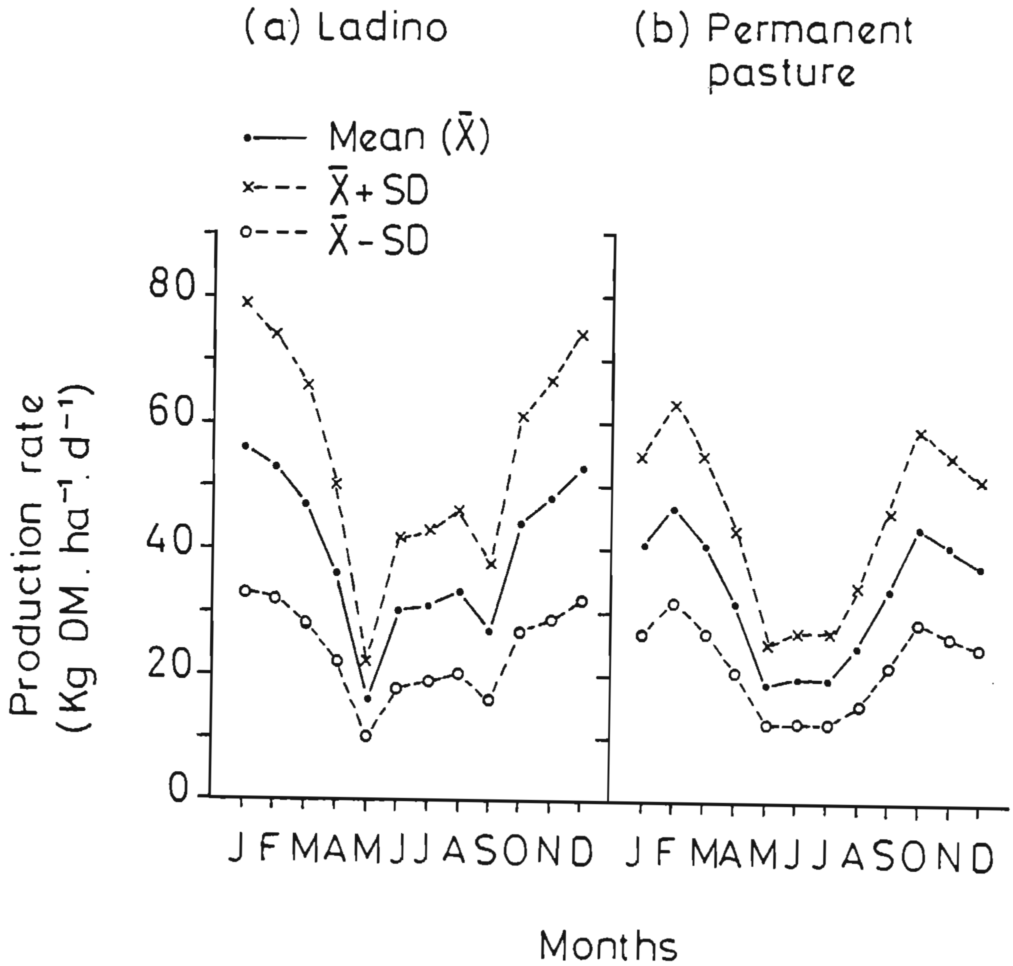


Figure 3.33 The production rate of two white clover cultivars under irrigation at Outeniqua (1978-83)

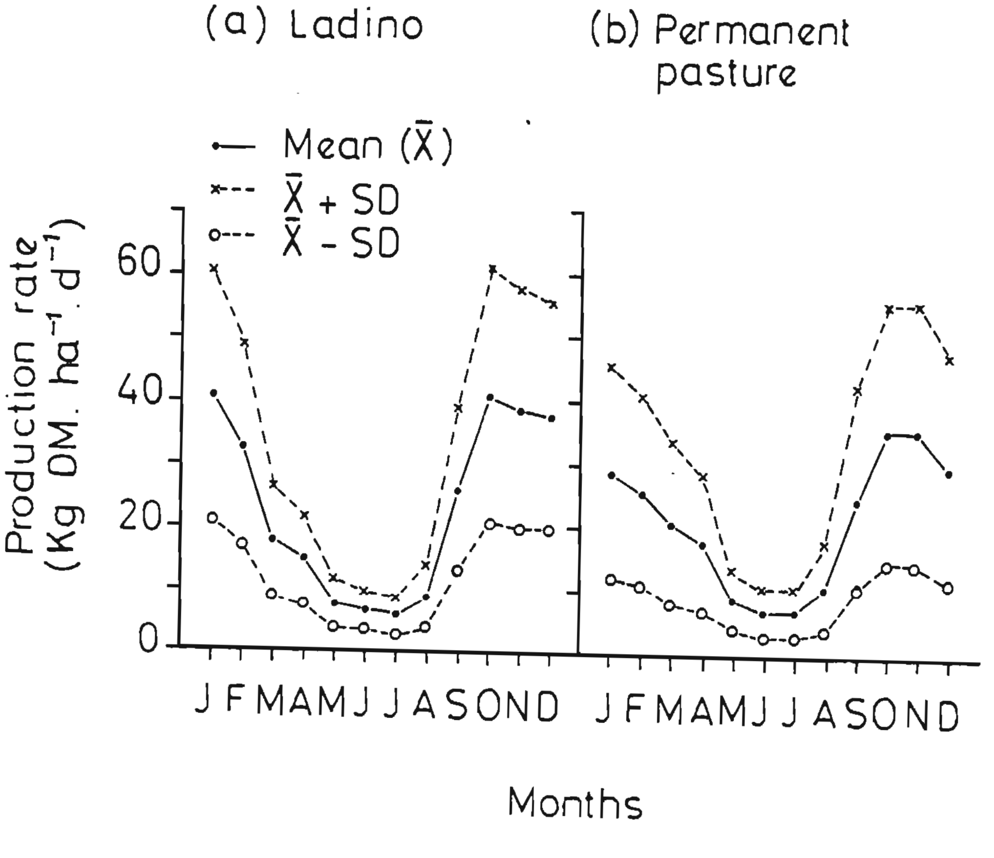


Figure 3.34 The production rate of two white clover cultivars under irrigation at Oudtshoorn (1978-84)

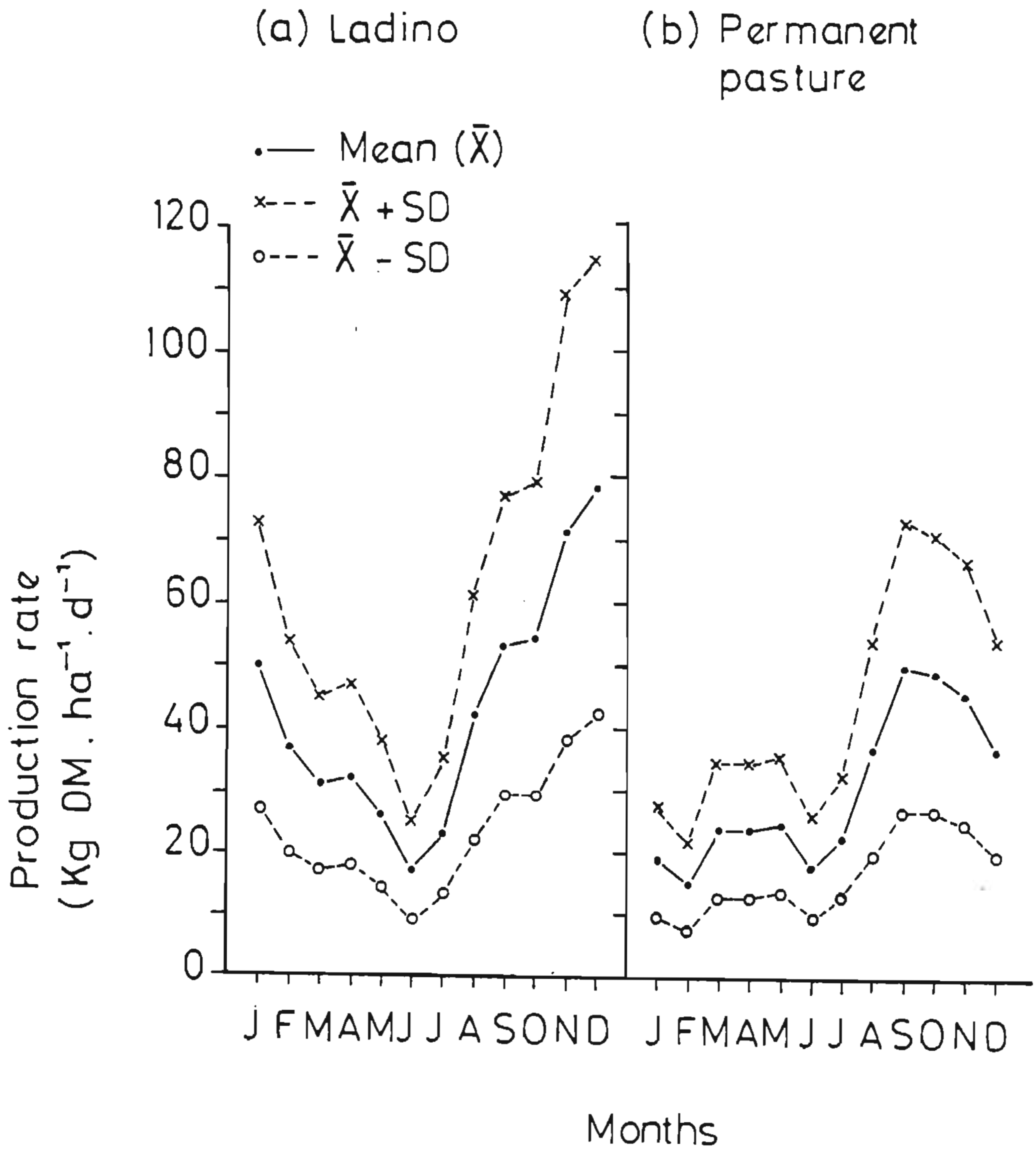
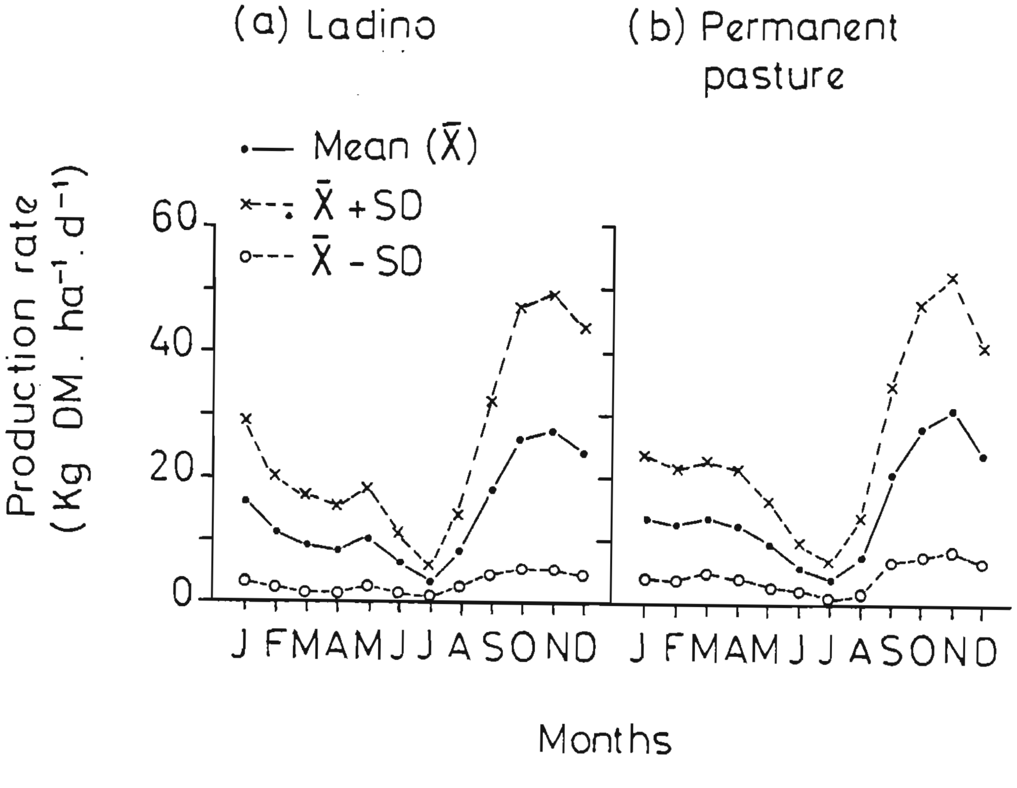


Figure 3.35 The production rate of two white clover cultivars under dryland at Outeniqua (1978-83)



with the greatest difference occurring during November to April.

Under dryland conditions at Outeniqua (figure 3.35) there was little difference between the seasonal production rates of the two cultivars.

3.3.4.3 Extrapolation of production rate data

The mean production rates, acquired at the dryland site at Outeniqua and the three irrigated sites at Outeniqua, Welgevallen and Oudtshoorn, were used to develop functions for the extrapolation of mean production rates. The functions are as follows:

$MI = R.E^{-1}$ (mean of two months),
where R = total monthly rainfall (mm) and
E = total monthly pan evaporation (mm);

$TI = \exp(-(T-15)^2.86^{-1})$,
where T = mean monthly air temperature (°C);

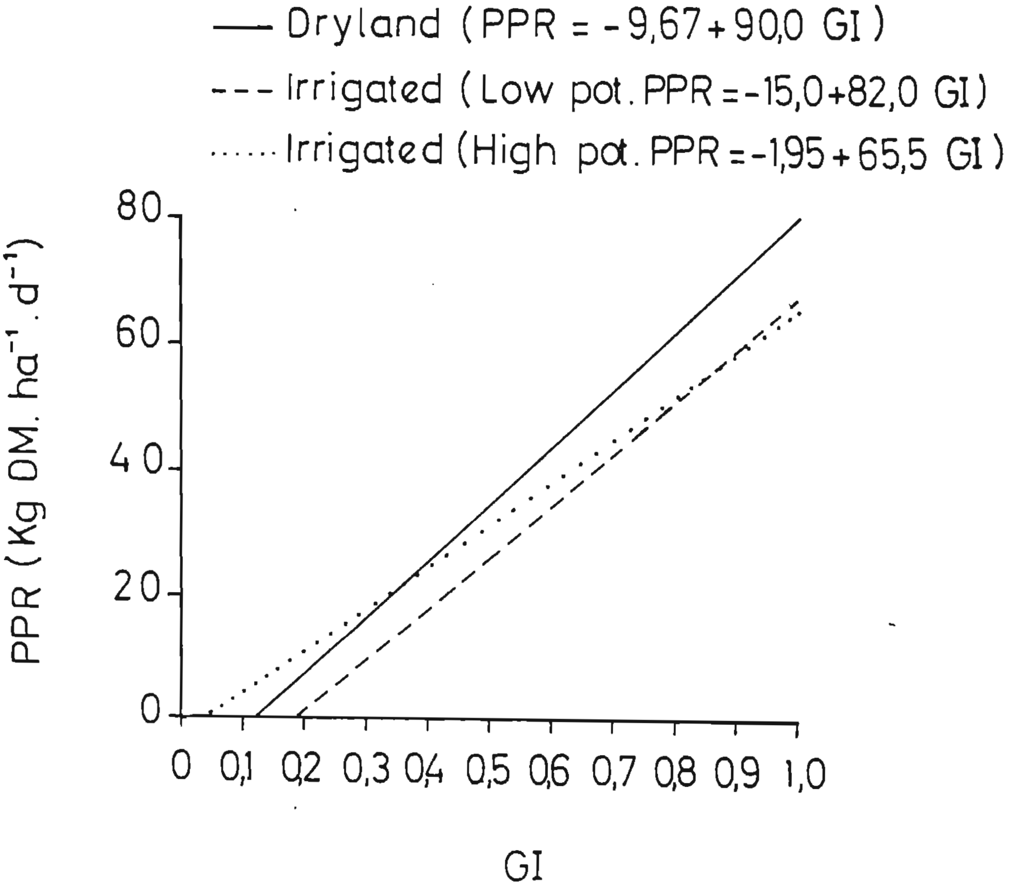
$RI = Q_{TOT}.23^{-1}$,
when $Q_{TOT} \leq 23$ and

$RI = 1$,
when $Q_{TOT} > 23$, where Q_{TOT} = mean monthly total daily solar radiation ($MJ.M^{-1}.d^{-1}$);

$GI = MI \times TI \times RI$.

Three different relationships were developed between GI and the actual production rate (APR) and used to predict the potential production rate (PPR). These functions are depicted in figure 3.36. Under dryland conditions soil differences could not be incorporated as only one trial site

Figure 3.36 Relationships between the growth index (GI) and the predicted potential production rate (PPR) for white clover under dryland and under irrigation



was used. Only one relationship was therefore developed, i.e.:

$$PPR = -9,67 + 90,0GI.$$

Under irrigation, however, a number of sites were used and, as soil did have a slight influence, two separate relationships were developed. One function was developed for a high potential soil, i.e.:

$$PPR = -1,95 + 65,5GI.$$

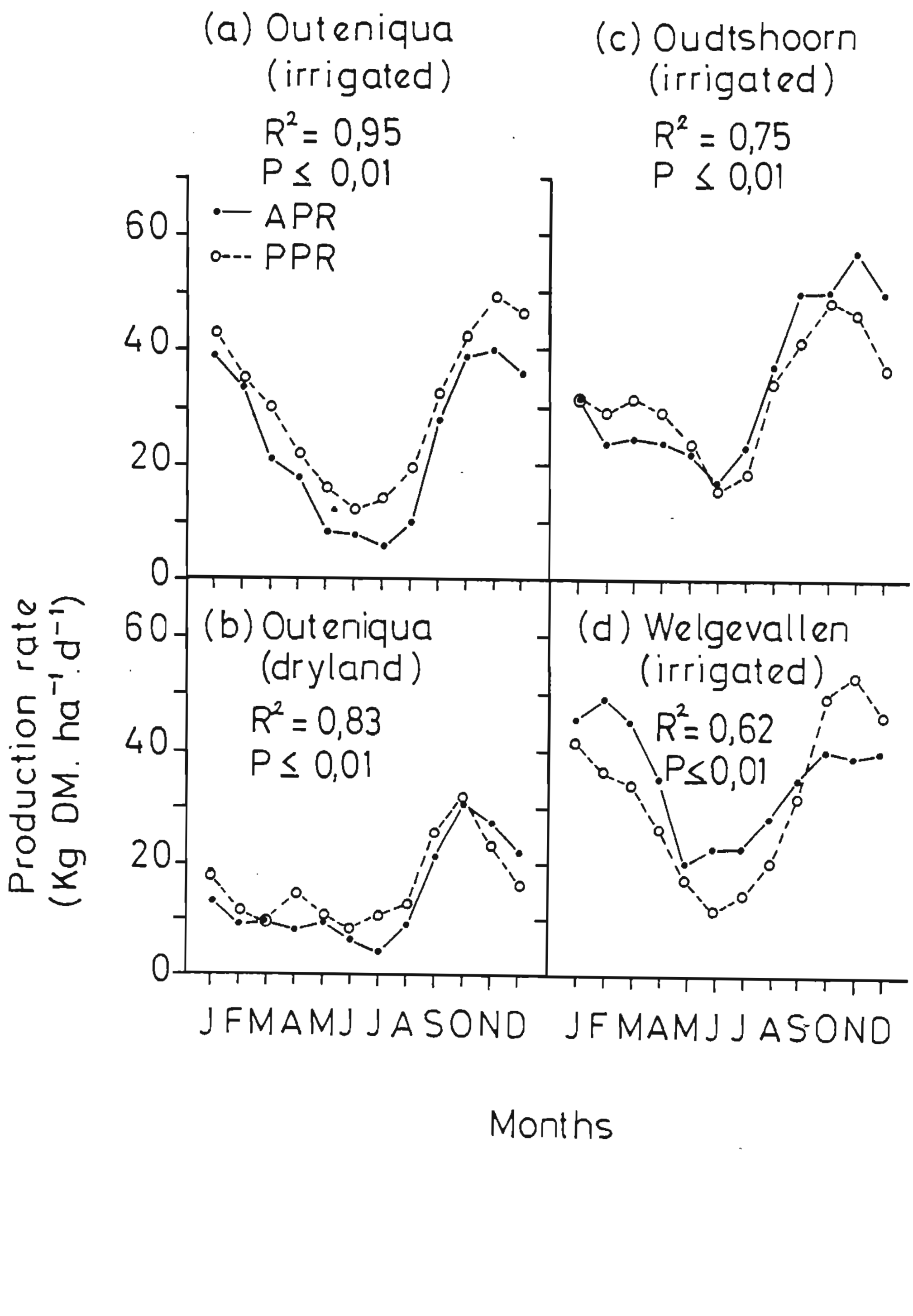
This relationship was derived using data acquired on an Oakleaf soil at Oudtshoorn. A second function was developed for a low potential soil, i.e.:

$$PPR = -15,0 + 82,0GI.$$

The last mentioned relationship was derived using data acquired on Sterkspruit and Estcourt soils at Welgevallen and Outeniqua. Figure 3.36 seems to indicate that the influence of soil potential on the production rate of white clover was not very large and also seemed to diminish as GI increased. Due to its shallow rooting depth, white clover would seem to be rather insensitive to differences in soil potential.

The above-mentioned functions were validated further before being used for extrapolation. With this in mind, all the available data were not used during the development phase and the last season's data at Outeniqua and Oudtshoorn were excluded and used for validation. As a first step, however, the mean PPR, for the whole experimental period, was compared at each site with the mean APR, derived during the same period. These results are presented in figure 3.37. With the exception of the data acquired at Welgevallen, the

Figure 3.37 Comparison of the actual (APR) and the potential (PPR) production rate at three irrigated and one dryland site over the whole experimental period



PPR curves followed the APR curves very well and the correlation was significant at all sites.

The functions were then validated further, using new data, which had not been utilised during the development phase. These results are depicted in figure 3.38. The PPR curve once again followed that of the APR fairly well, with correlations lower than those in figure 3.37, but still significant. The lower correlations are, however, to be expected, as the models are by no means sophisticated enough to enable the successful extrapolation on an actual monthly basis. They should, however, be sufficiently accurate to enable the long-term extrapolation of the seasonal production rates, using long-term mean climatic data for each site.

In figure 3.39 the long-term PPR, based on long-term climatic data gathered over a number of years, is depicted for each site. The PPR curves for high potential soils were calculated, using the function derived at Oudtshoorn, that of the low potential soil situation, by using the function derived at Outeniqua (irrigated) and Welgevallen and that of the dryland site (Outeniqua), using the curve derived there.

Once again the influence of soil potential seems to be almost negligible. During the period April to October there seems to be very little difference in the PPR at the different sites. At Welgevallen and Outeniqua (irrigated) this also seems to be the case during the rest of the year. At Oudtshoorn the monthly PPR is, however, much lower than at the other two sites during the period December to March.

The curve depicting the seasonal PPR at Outeniqua under dryland, indicates that the long-term PPR of white clover under dryland conditions at Outeniqua is very low. The

Figure 3.38 Comparison of the actual (APR) and the potential (PPR) production rate at two irrigated and one dryland site, using data which had not been utilised during the development stage

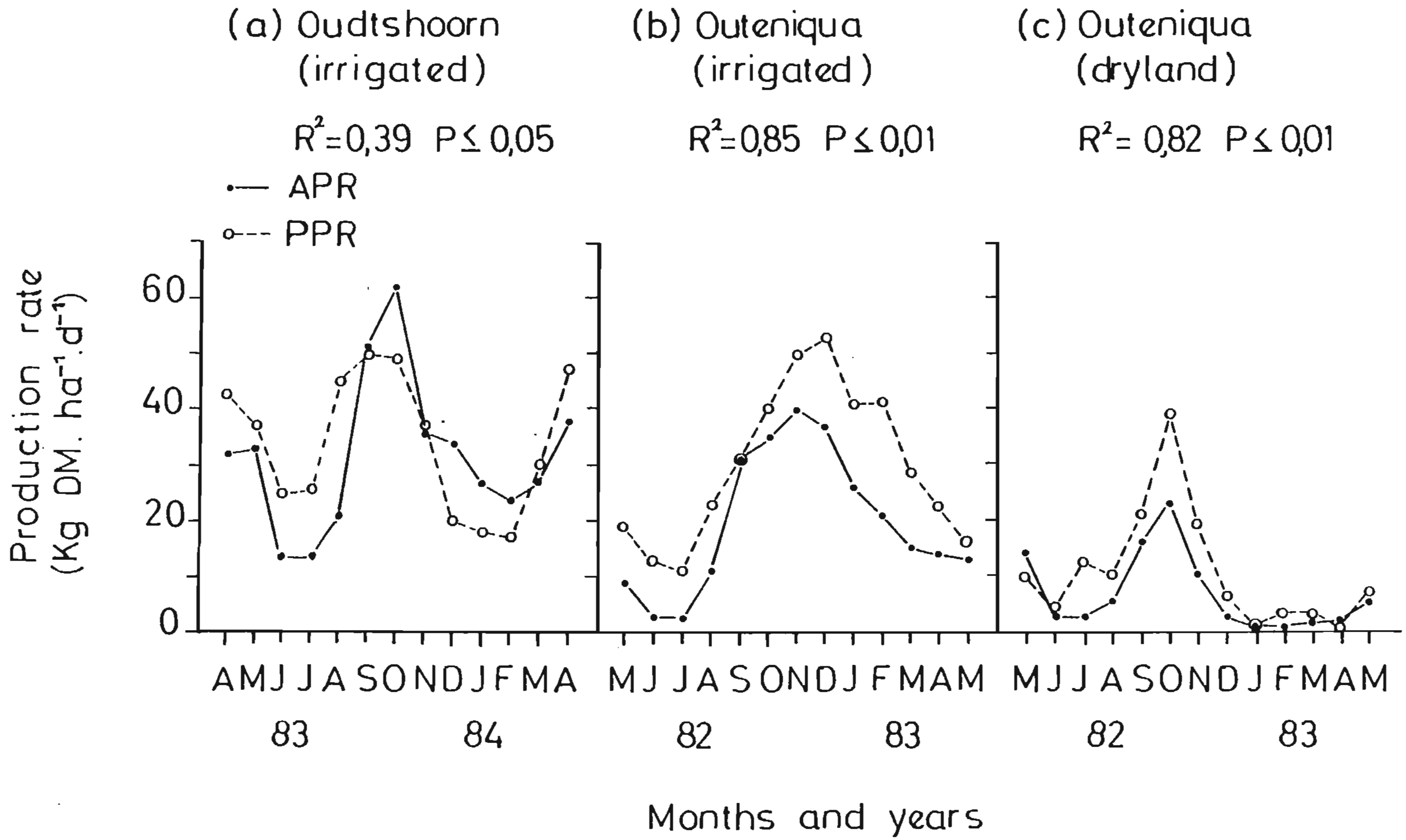
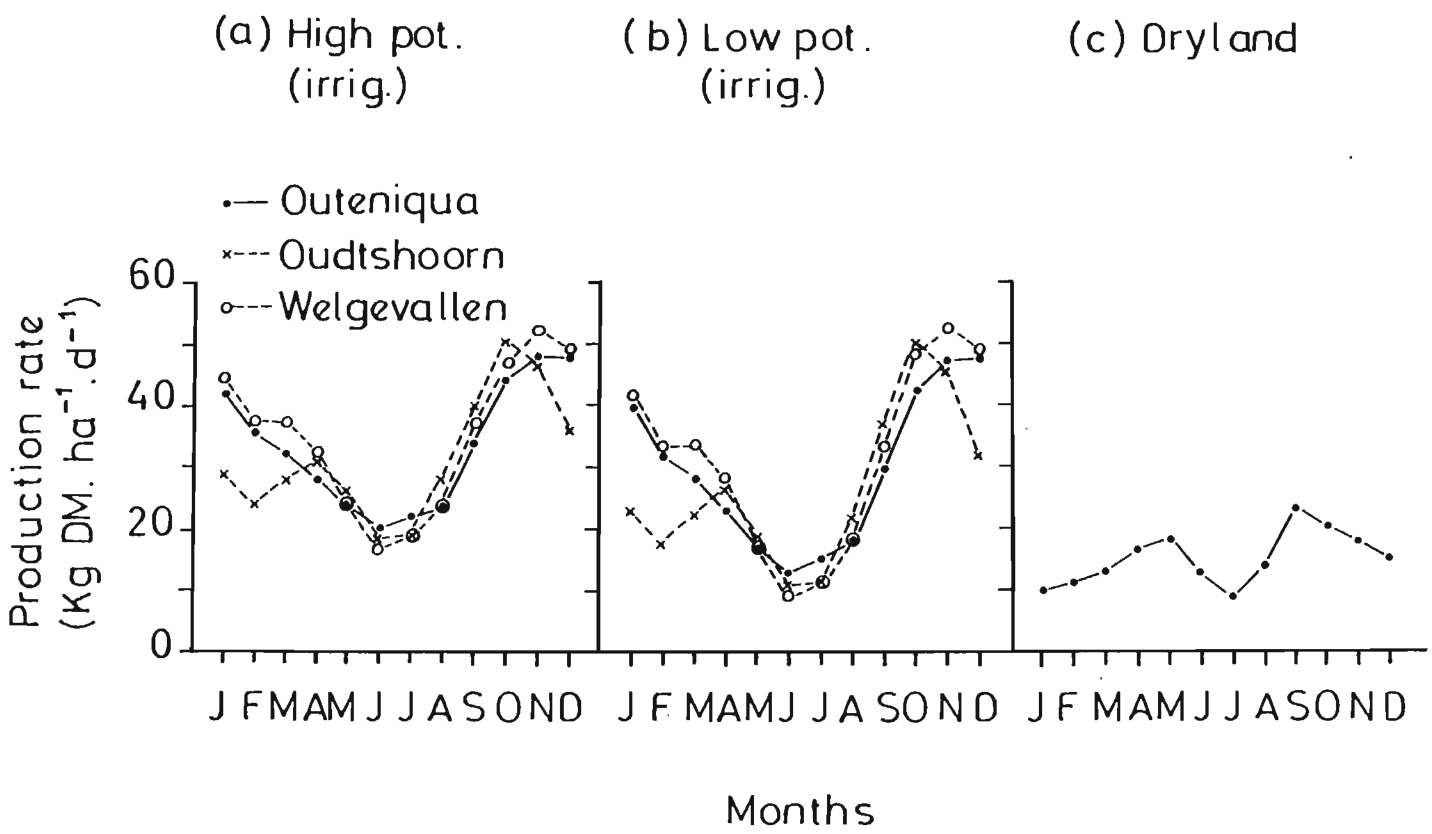


Figure 3.39   Long-term potential production rate (PPR) predicted, using the derived functions and long-term mean climatic data



highest potential occurs during spring (April/May) and autumn (September/October) and the lowest during summer (December/January) and mid winter (June to August).

3.3.4.4 Discussion and conclusions

The cutting frequency trials indicated that cutting frequency does not influence the production rate of white clover very much. The highest yields, however, tended to occur in the treatments which were cut very frequently, i.e. about four- to six-weekly.

The seasonal production rates varied between the different sites. The main differences were in the time during the year when minimum and maximum rates were attained and in the levels of production during different seasons. Under irrigation at Outeniqua and Welgevallen, the seasonal pattern of the production rates was very similar. Production was high during summer and low during winter. At Oudtshoorn, however, production rates were low during winter, as well as in late summer. This can be attributed to very high summer and very low winter temperatures at the last mentioned site. Under dryland at Outeniqua, the production rates were, however, also severely depressed by a low moisture regime during summer.

At Welgevallen and Outeniqua, under irrigation, the seasonal production patterns of the two cultivars, Ladino and Permanent Pasture, did not differ much, though Ladino tended to be higher producing. At Oudtshoorn the two cultivars also differed in their seasonal production pattern and the extreme summer temperature at Oudtshoorn seemed to depress the production rate of Permanent Pasture much more than that of Ladino. At the dryland site at Outeniqua, however, the seasonal pattern, as well as the rates of production of the two cultivars, did not differ and this indicated a very similar degree of sensitivity to soil moisture tension.

The extrapolation of yield data, using only mean monthly climatic data, was very successful. High correlations were found under dryland and irrigation when mean PPR and APR values were compared over the whole experimental period, as well as when monthly PPR values were compared with new APR data, not utilised during the development stage. The influence of soil potential under dryland could not be evaluated, but under irrigation its influence seemed to be negligible and although two separate functions were developed for use under irrigation, they did not differ very much. White clover, therefore, seems to be very insensitive to soil potential and the variation in PPR between months at the same site and during the same month between sites, induced by climatic differences, were much larger than those induced by differences in soil potential.

The detrimental influence of high summer temperatures and soil moisture tension on the production rate of white clover causes grave doubts as to the practicality of using white clover as a component of pastures under irrigation in parts of the Little Karoo sub-region, as well as under dryland in the South Coast sub-region. The results indicate that the use of white clover should be limited to the cooler and intensively irrigated areas of the Winter Rainfall Region.

3.3.5 Red clover

3.3.5.1 Influence of cutting frequency

The mean production rate (kg DM.ha-1.d^{-1}) of all red clover cultivars evaluated at one dryland (Outeniqua) and three irrigated sites (Welgevallen, Outeniqua and Oudtshoorn) and cut at three frequencies (four-, six- and eight-weekly), are presented in figure 3.40.

The mean production rate of red clover tended to increase at all the sites as the cutting frequency decreased from four- to eight-weekly. The increase was, however, only significant between the four- and six- and six- and eight-weekly frequencies at Oudtshoorn and between the four- and eight-weekly cuts at the latter site and at Outeniqua under irrigation.

3.3.5.2 <u>Seasonal production</u>

The mean production rates (kg $DM.ha^{-1}.d^{-1}$), of all red clover cultivars which had been evaluated at three irrigated (Welgevallen, Outeniqua and Oudtshoorn) and one dryland (Outeniqua) site, are presented in figures 3.41 and 3.42, respectively. The seasonal variation in production rate is also indicated as the standard deviation. The seasonal production patterns at Outeniqua (irrigated) and Welgevallen (figure 3.41) were very much the same. The only difference was that the highest production rates were attained during November at Welgevallen and during October at Outeniqua. Irrigated red clover produced very seasonally at these two sites. Production rates decreased during summer and autumn (January to May), reached a minimum during May to July and increased thereafter to peak during spring (October/November). At Outeniqua (irrigated) production rates were extremely low during autumn and winter (May to August).

At Oudtshoorn (figure 3.41), however, a different production pattern emerged. Production rates decreased much faster during late summer and autumn (January to May) than at the other sites and reached a minimum during June and July, after which the rates increased once again. This increase,

Figure 3.40 Influence of cutting frequency on the mean production rate over all red clover cultivars under irrigation and dryland at Outeniqua (1981-83), Welgevallen (1979-81) and Oudtshoorn (1981-84) (* LSD's for dryland and irrigated trials)

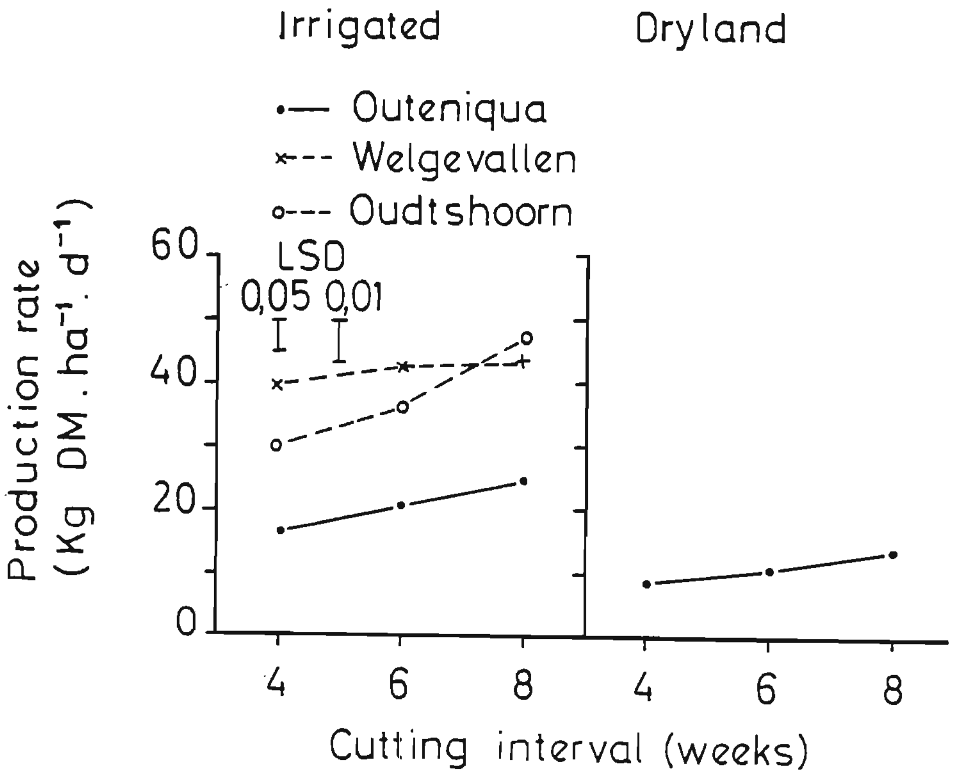


Figure 3.41 The production rate over all red clover cultivars under irrigation at Welgevallen (1978-81), Outeniqua (1978-83) and Oudtshoorn (1978-83)

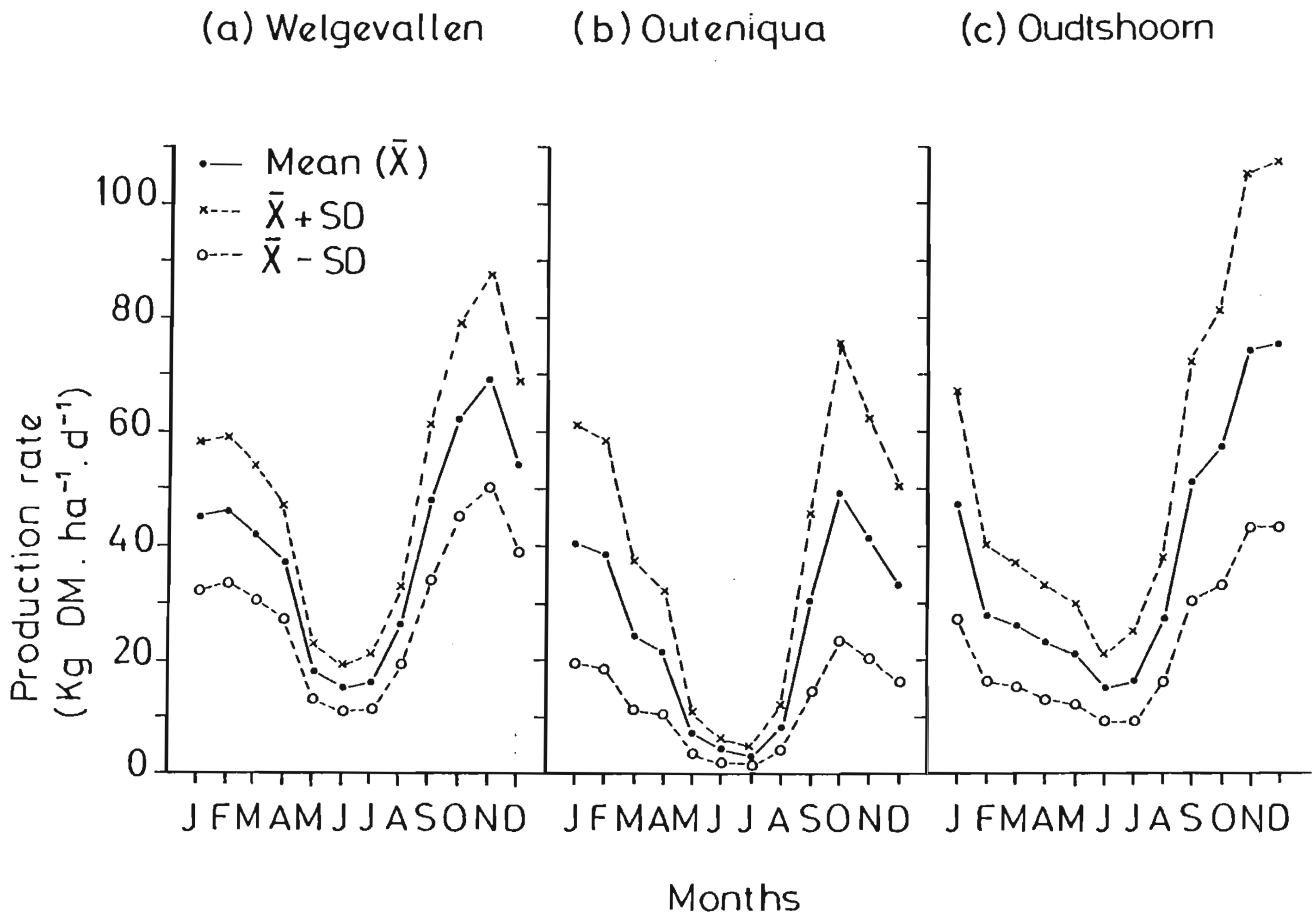
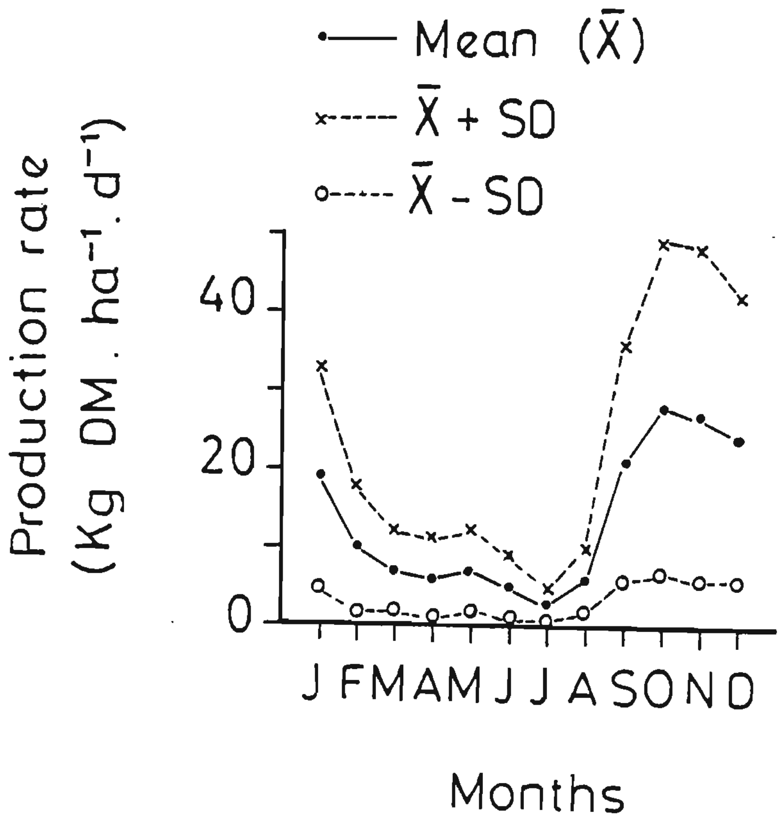


Figure 3.42 The mean monthly production rate over all red clover cultivars under dryland at Outeniqua (1978-83)



however, lasted much longer, i.e. until December, after which yield again decreased.

At the dryland site on Outeniqua (figure 3.42), production rates were low during late summer, as well as during autumn and winter (February to August). During the period September to November, a sharp increase in production rates occurred, but during December and January, the production rates once again tended to decrease sharply.

The production rates of two red clover cultivars, Kenland and Hamua, which had been evaluated at all sites, are depicted in figures 3.43 to 3.46. At Welgevallen (figure 3.43), the production rate of Kenland was about equal to that of Hamua during late summer (January and February), as well as in late winter (August), but tended to be slightly higher during autumn (March and April). During winter (May to July), spring and early summer (September to December) the production rates of Hamua, however, tended to be highest. At Outeniqua under irrigation (figure 3.44), and at Oudtshoorn (figure 3.45) and Outeniqua (dryland) (figure 3.46), the two cultivars also had basically the same production patterns, but the production rates of Kenland tended to be slightly higher than that of Hamua during some months.

3.3.5.3 Extrapolation of production rate data

For the extrapolation of the production rates, functions representing the relationships between mean climatic factors and production rates, were developed. The functions which were developed using the mean production rates acquired at three irrigated sites (Welgevallen, Outeniqua and Oudtshoorn) and one dryland site (Outeniqua), are as follows:

Figure 3.43 The production rate of two red clover cultivars under irrigation at Welgevallen (1978-81)

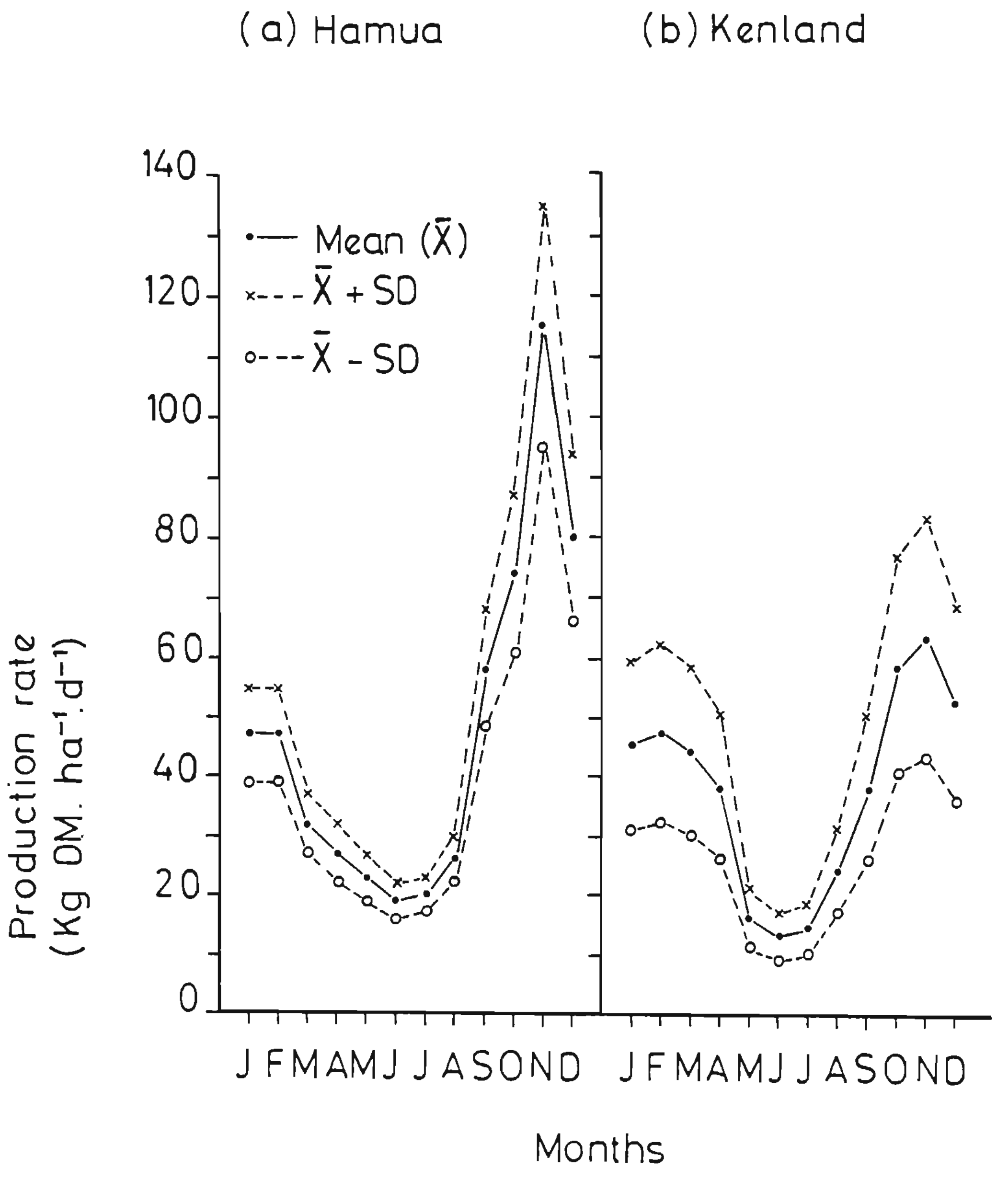


Figure 3.44 . The production rate of two red clover cultivars under irrigation at Outeniqua (1978-83)

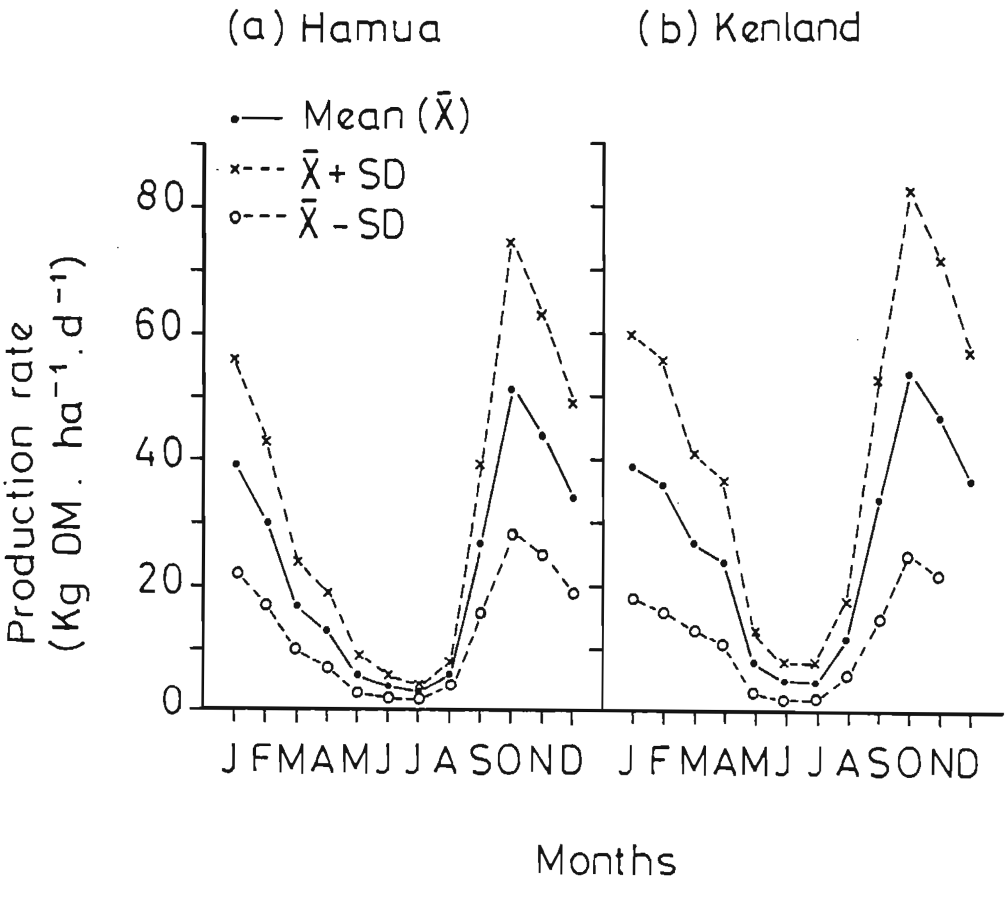


Figure 3.45 The production rate of two red clover cultivars under irrigation at Oudtshoorn (1978-84)

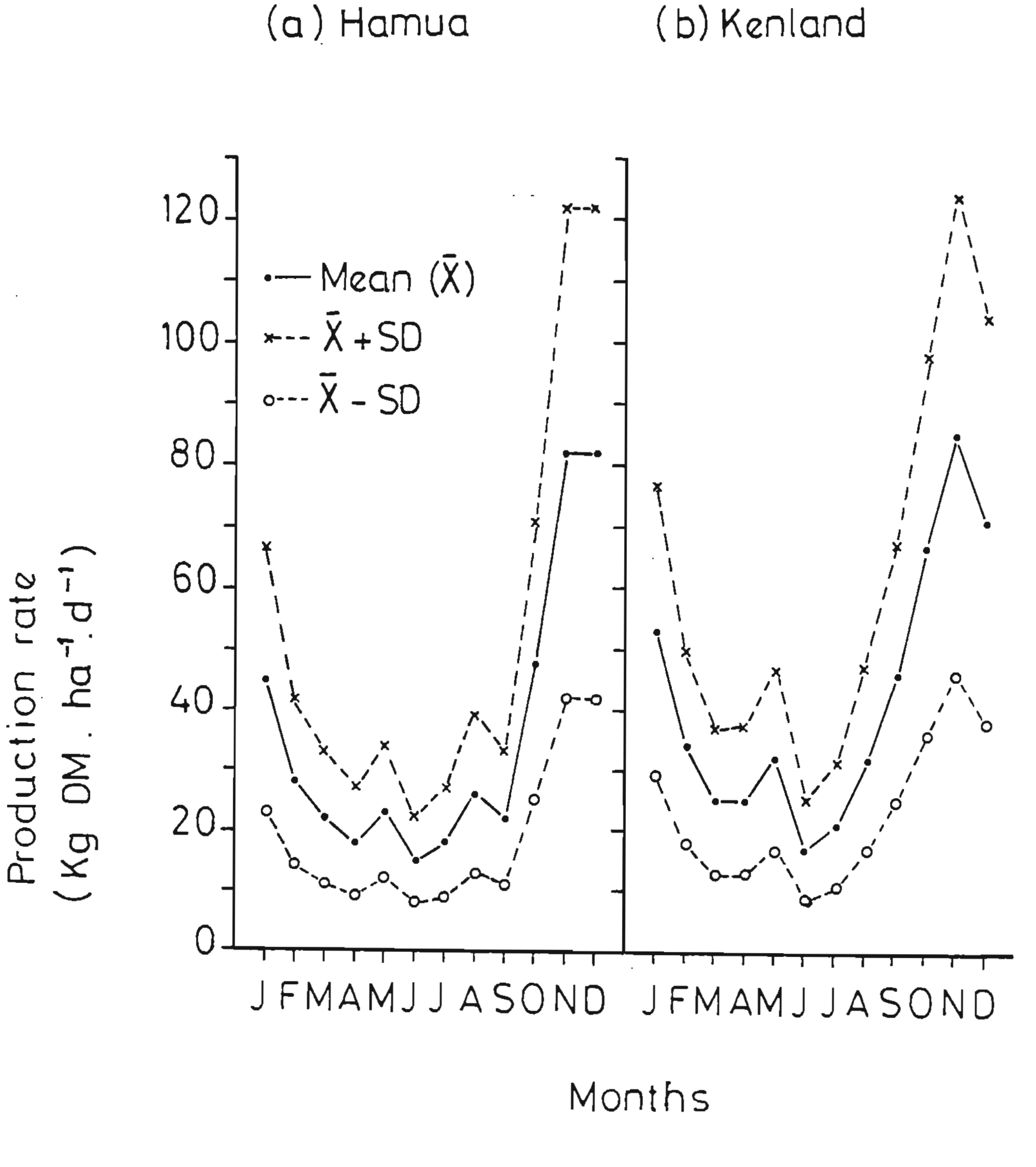
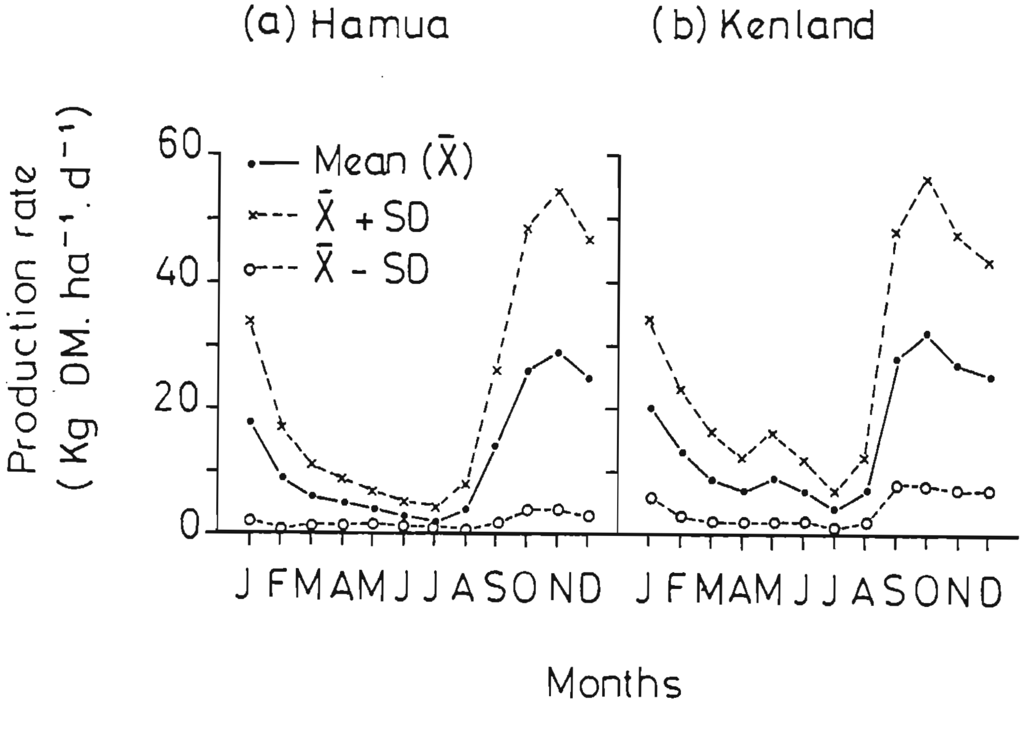


Figure 3.46 The production rate of two red clover cultivars under dryland at Outeniqua (1978-83)



$MI = R.(0,5E)^{-1}$ (mean of two months),
where R = total monthly rainfall (mm) and E the total monthly class A pan evaporation (mm);

$TI = \exp(-(T-18)^2.86^{-1})$,
with T = mean monthly air temperature (°C);

$RI = Q_{TOT}.17^{-1}$,
when $Q_{TOT} \leq 17$ and

$RI = 1$,
when $Q_{TOT} > 17$, where Q_{TOT} = total daily solar radiation ($MJ.M^{-2}.d^{-1}$);

$GI = MI \times TI \times RI$.

For the extrapolation of the data, relationships were developed between the actual production rate (APR) and the GI and used to predict the potential production rate (PPR) at the various trial sites. Under irrigation, the relationship for the high potential soil at Oudtshoorn (Oakleaf) differed from that of the low potential soils at Outeniqua (Estcourt) and Welgevallen (Sterkspruit), although the differences were not very large. The following two relationships were nonetheless used under irrigation:

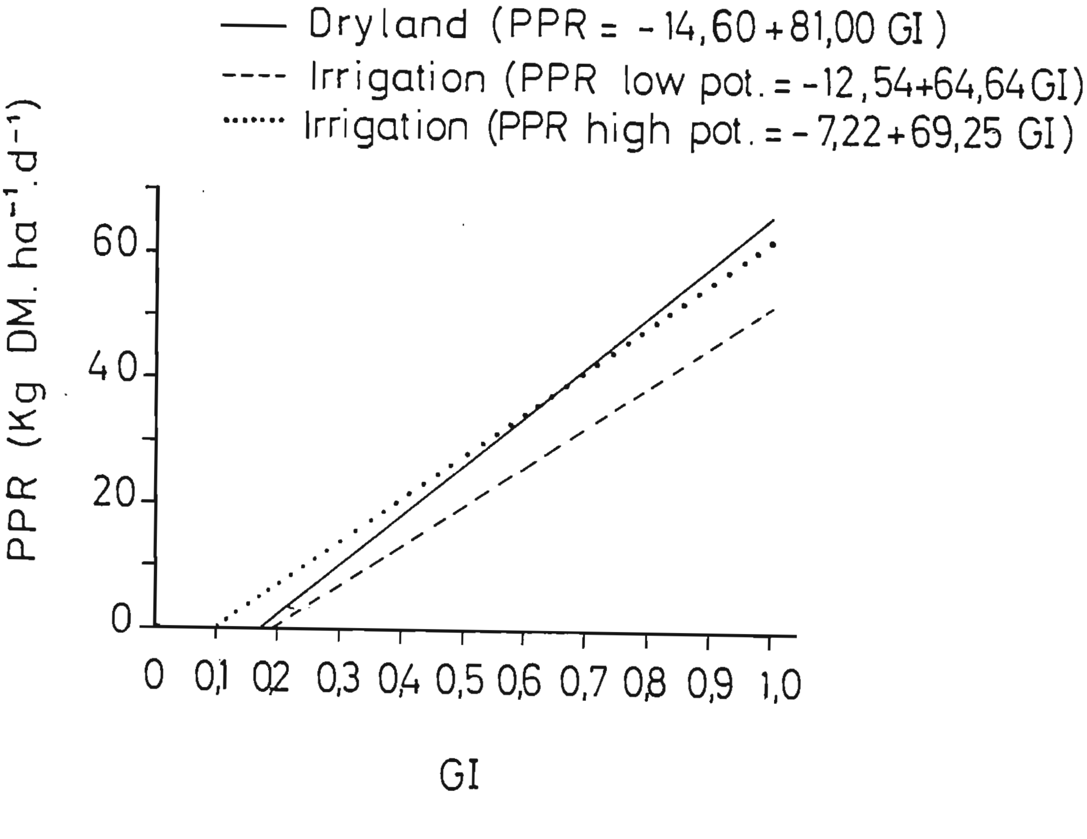
PPR (high potential soil) = -7,22 + 69,25GI and
PPR (low potential soil) = -12,54 + 64,64GI.

Under dryland conditions at Outeniqua only one relationship sufficed and is as follows:

PPR = -14,60 + 81,0GI.

The three relationships are depicted graphically in figure 3.47. The small difference in the abscissae and slopes of

Figure 3.47 Relationship between the growth index (GI) and the potential production rate (PPR) for red clover under irrigation and dryland



the two relationships used under irrigation, indicates that red clover is not very sensitive to soil potential. The differences are, however, larger than those which had been found for white clover.

The above-mentioned functions were validated in two phases. The first step was to compare the mean monthly APR values for the duration of the trials with the PPR values over the same period. These results are presented graphically in figure 3.48. Although deviations did occur, the PPR curves followed those of the APR very well and the correlations were highly significant.

The functions were, however, validated further by comparing the PPR values for one season at Outeniqua (irrigated and dryland) and Oudtshoorn with APR values acquired during the same period at the sites, but which had not been used during the development of the functions. These results are presented in figure 3.49.

The PPR curves deviated quite sharply from that of the APR at all the trials. The PPR values deviated from APR during 1983 and 1984 at Oudtshoorn. Under irrigation at Outeniqua the largest deviations occurred during May to June 1982 and January to May 1984 and under dryland at Outeniqua the PPR curve overestimated the APR during all but two months (May and June, 1982). However, the patterns of the APR and PPR were generally very similar, and the R^2 values were highly significant in all cases.

In spite of these deviations, the results are as good as can be expected if the simplicity of the functions are taken into consideration. The method was also intended to be used only for the prediction of long-term PPR values, based on long-term mean monthly climatic data. Using them to predict

Figure 3.48 Comparison of the actual (APR) and the predicted potential (PPR) production rate of red clover at three irrigated and one dryland site, over the whole trial period

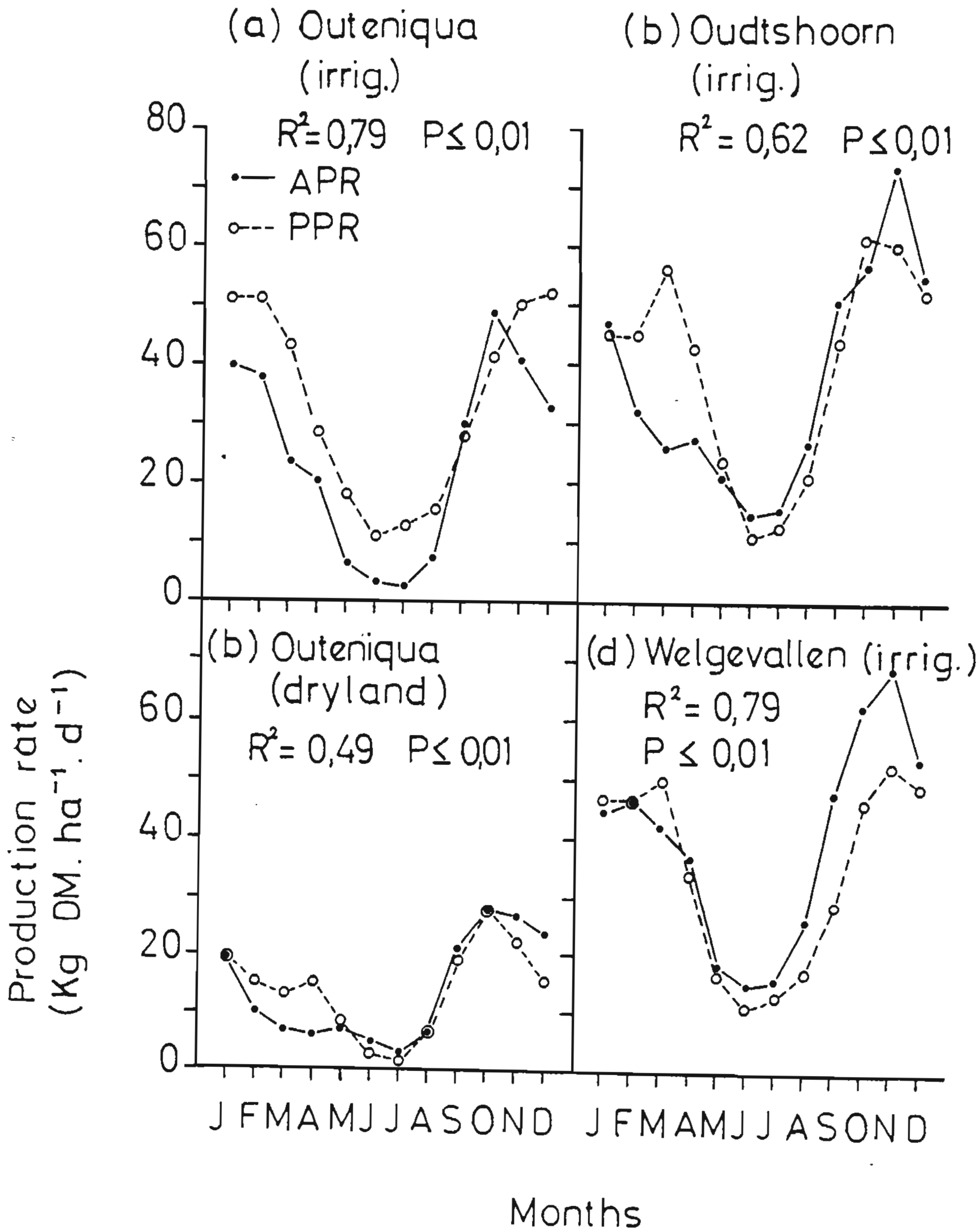
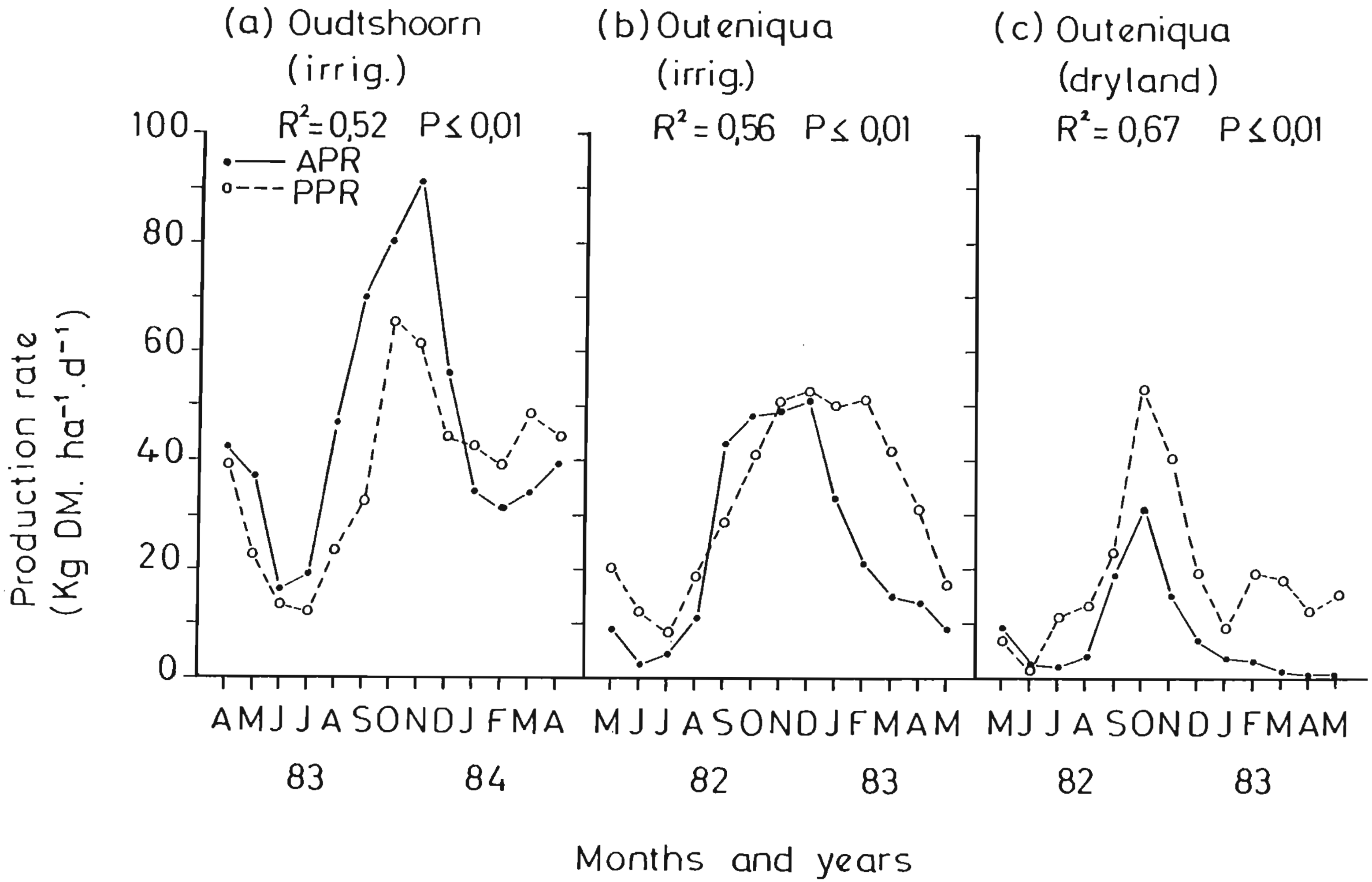


Figure 3.49 Comparison of the actual (APR) and the predicted potential production rate (PPR) at two irrigated and one dryland site, using data which had not been utilised during the development stage



actual monthly values for a specific season, was therefore somewhat optimistic.

The correlations between the APR and PPR values were successful enough to enable the use of the functions for the extrapolation of the data. The long-term mean PPR was subsequently calculated for each site, using long-term mean monthly climatic data as input. These results are presented in figure 3.50.

Under irrigation, there is not much difference between the low and the high soil potential curves at the different sites, although the differences are larger than those for white clover. The largest differences between the PPR at different sites, under irrigation, seems to occur during the periods June/July and December to February. During these months, the PPR seem to be highest at Outeniqua and lowest at Oudtshoorn.

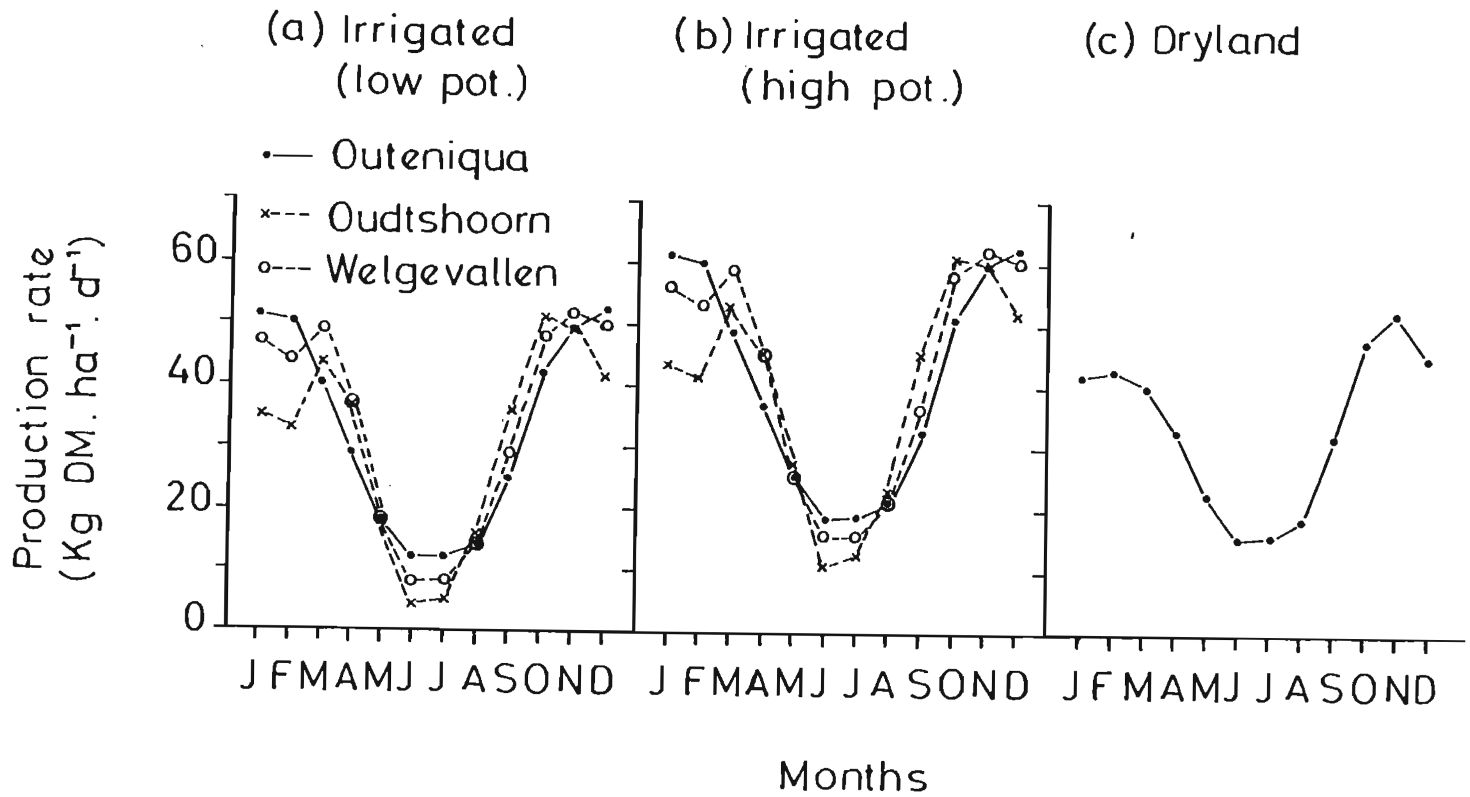
The long-term PPR, under dryland at Outeniqua, seems to be surprisingly high and attains a maximum during November, decreases slightly thereafter and levels off during December to March. Beyond March the PPR, however, again tends to decrease to reach a low during the period June to August.

3.3.5.4 Discussion and conclusions

The cutting frequency trials indicated that the seasonal production rate of red clover was not influenced much by cutting frequency. Generally, however, the results seemed to indicate that red clover would maintain the highest production rate when cut at the most every eight weeks.

At Welgevallen and Outeniqua (irrigated) the seasonal production of red clover was highest during spring. During summer and winter yields were, however, depressed and the

Figure 3.50 Long-term potential production rate (PPR) predicted, using the derived functions and long-term mean climatic data



lowest yields occurred during winter. At Oudtshoorn extreme temperature and at Outeniqua soil moisture tension depressed the production rate considerably during summer. Extreme water logging could also have resulted in a low production rate at Outeniqua (irrigated and dryland) during winter.

The production patterns of the two cultivars, Hamua and Kenland, differed most at Welgevallen. At the other sites, Outeniqua (dryland and irrigated) and Oudtshoorn, however, the production patterns of the two cultivars were practically the same. At the last mentioned sites Kenland, however, generally seemed to have had the highest production rate.

Under irrigation, two separate relationships between GI and the PPR were used to extrapolate mean monthly production rates, but under dryland, one function sufficed. The two functions used under irrigation, however, differed very little, indicating a general insensitivity of red clover to soil potential.

The validation of the functions was very successful when the mean PPR over the whole experimental period was compared with the APR values over the same period. However, when the PPR values calculated for one season at Outeniqua and Oudtshoorn, were compared with the APR values not used for the development of the functions, larger deviations occurred between the two sets of data. However, as the correlations were highly significant, it can be concluded that the functions can be used for tentative extrapolation.

Using the above-mentioned functions to extrapolate the seasonal production rates at the different sites, it was found that differences in soil potential did not effect the PPR as much as differences in GI, attributed to climatic differences between sites and between months at the same site.

The PPR values tended to be lowest during summer and winter at Oudtshoorn and highest during winter at Outeniqua (irrigated). This suggested that high summer temperatures tend to depress the PPR values. Under dryland at Outeniqua, a very high PPR indicated that soil moisture was not such an important limiting factor as the APR values had suggested. This also indicated that red clover has a substantial potential as pasture legume under dryland in this part of the South Coast sub-region.

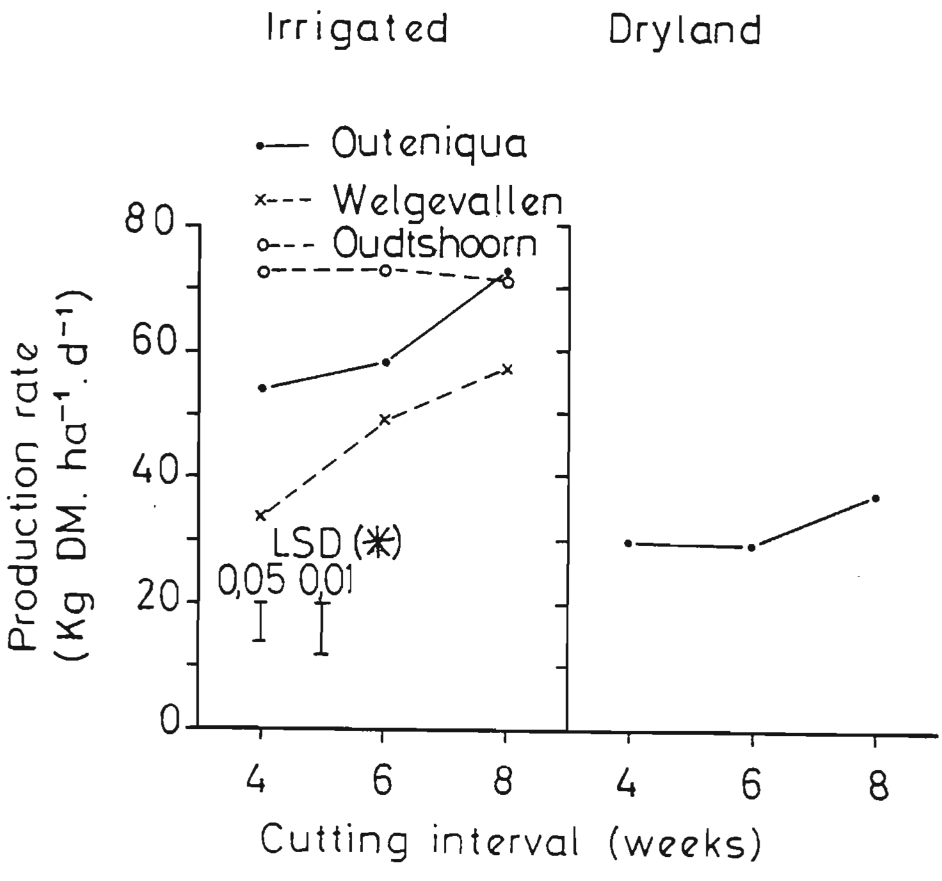
3.3.6 Kikuyu

3.3.6.1 Influence of cutting frequency

The mean production rate (kg $DM.ha^{-1}.d^{-1}$) of kikuyu in three irrigated (Welgevallen, Outeniqua and Oudtshoorn) and one dryland trial (Outeniqua), and cut at three frequencies (four-, six- and eight-weekly), is depicted in figure 3.51.

With the exception of the trial at Oudtshoorn, the highest yields were generally attained at the eight-weekly cutting frequency and the largest response between the six- and eight-weekly cutting frequency. The largest response was at Welgevallen and this was also the only site at which a significant response was attained between the four- and six-weekly cutting frequencies. The smallest response was recorded at Oudtshoorn, where no significant response was noted between any of the cutting frequencies. Yield, however, tended to decrease slightly between the six- and eight-weekly cutting frequencies at this site. At Outeniqua (dryland and irrigated) a significant response was recorded only between the six- and eight-weekly cutting frequencies.

Figure 3.51 Influence of cutting frequency on the production rate of kikuyu under irrigation and dryland at Outeniqua (1981-83), Welgevallen (1979-81) and Oudtshoorn (1981-84) (* LSD's for dryland and irrigated trials)



Under irrigation the highest growth rates were recorded at Oudtshoorn and the lowest at Welgevallen and this could perhaps have contributed to the differences in response attained at the two sites. As expected, higher yields were produced at a shorter cutting frequency at the site with the highest mean growth rate, while at the sites with the lowest growth rate, less frequent cutting produced the highest yields.

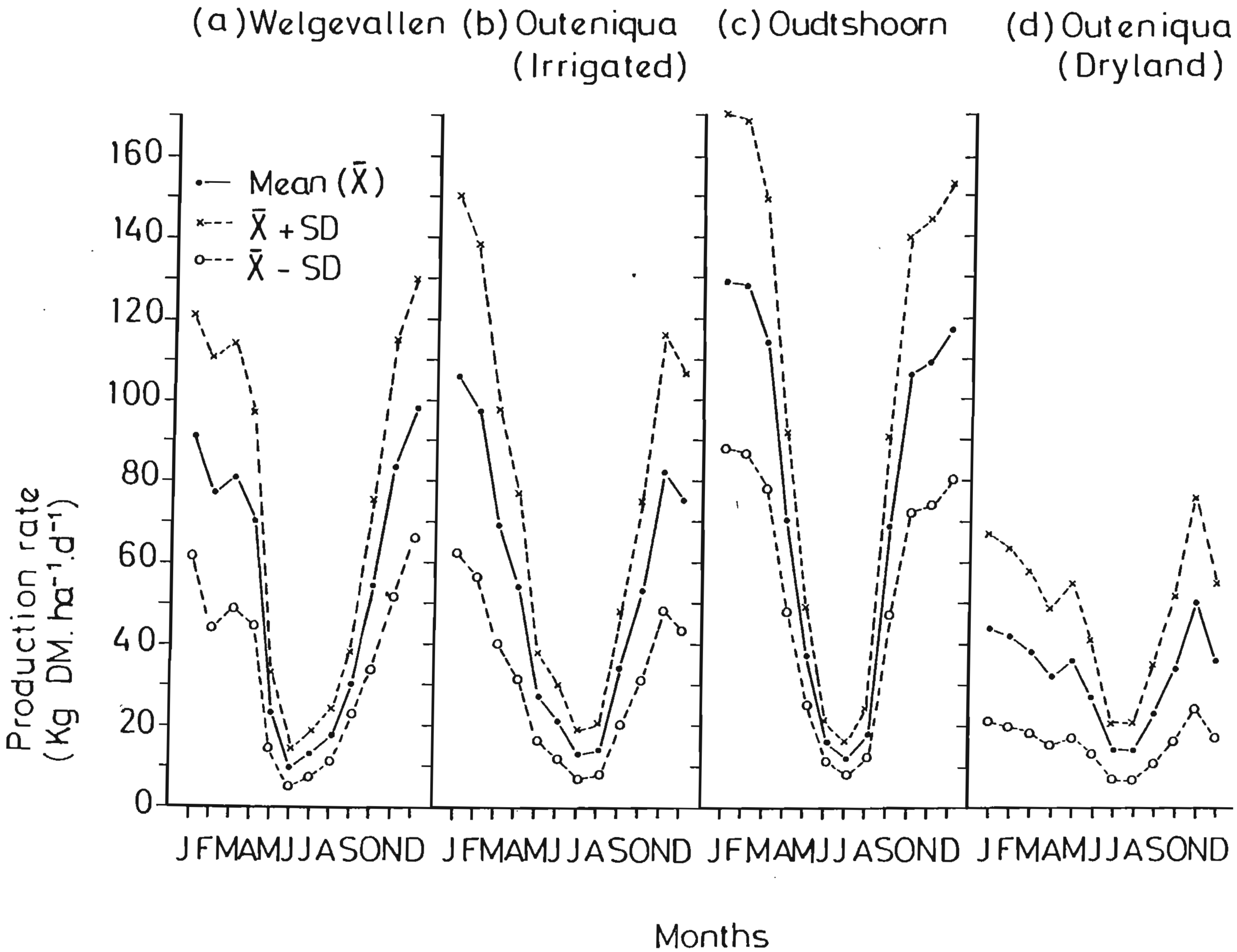
3.3.6.2 Seasonal production

The seasonal production rate (kg $DM.ha^{-1}.d^{-1}$) of kikuyu was determined for a number of seasons at three irrigated (Welgevallen, Outeniqua and Oudtshoorn) and one dryland site (Outeniqua). The production rates, calculated over cutting frequencies and strains at each site, are depicted in figure 3.52.

Also indicated in figure 3.52 is the seasonal standard deviation of the production rates. The most striking feature under irrigation, was the extreme seasonality of the production rates, i.e. a very high summer production rate with a very low winter trough. Under irrigation the lowest production rates occurred during the period June to August at all three sites. The period of peak production was, however, longer at Oudtshoorn than at Outeniqua or Welgevallen.

Under dryland at Outeniqua, the amplitude of the production rate curve was greatly depressed by soil moisture tension during summer. The peak production rate at this trial occurred during November, after which a gradual decrease in production rate occurred, reaching a minimum during July and August, and increasing again thereafter.

Figure 3.52 The production rate of kikuyu under irrigation and dryland at Welgevallen (1978-81), Outeniqua (1978-83), Oudtshoorn (1978-84)



At Welgevallen only one strain was evaluated, i.e. the local kikuyu strain which has to be propagated vegetatively. At the other two sites, however, this strain was compared with the only commercially available cultivar, Whittet. These results are presented in figures 3.53 to 3.55.

At the two irrigated (Outeniqua and Oudtshoorn), as well as at the dryland site, there was generally very little difference in the production patterns of the two strains. The production rate of Whittet was, however, slightly higher than that of the local strain during the period November to January at the two irrigated sites (figures 3.53 to 3.54). At the dryland site at Outeniqua (figure 3.55) the summer production rate of Whittet also tended to be highest, but the reverse occurred during the period April to June.

3.3.6.3 Extrapolation of production rate data

Seasonal production rate data derived at the three irrigated (Welgevallen, Outeniqua and Oudtshoorn) and one dryland (Outeniqua) site, were used for the development of functions for the extrapolation of the seasonal production rates to different seasons. The following functions were derived:

$MI = R.(0{,}5E)^{-1}$ (two-monthly means),
where R = total monthly rainfall (mm) and E = total monthly class A pan evaporation (mm);

$TI = \exp(-(T-32)^2.233^{-1})$,
where T = mean monthly air temperature (°C);

$RI = Q_{TOT}.17^{-1}$,
when $Q_{TOT} \leq 17$ and

$RI = 1$,

Figure 3.53 The production rate of two kikuyu strains under irrigation at Outeniqua (1978-83)

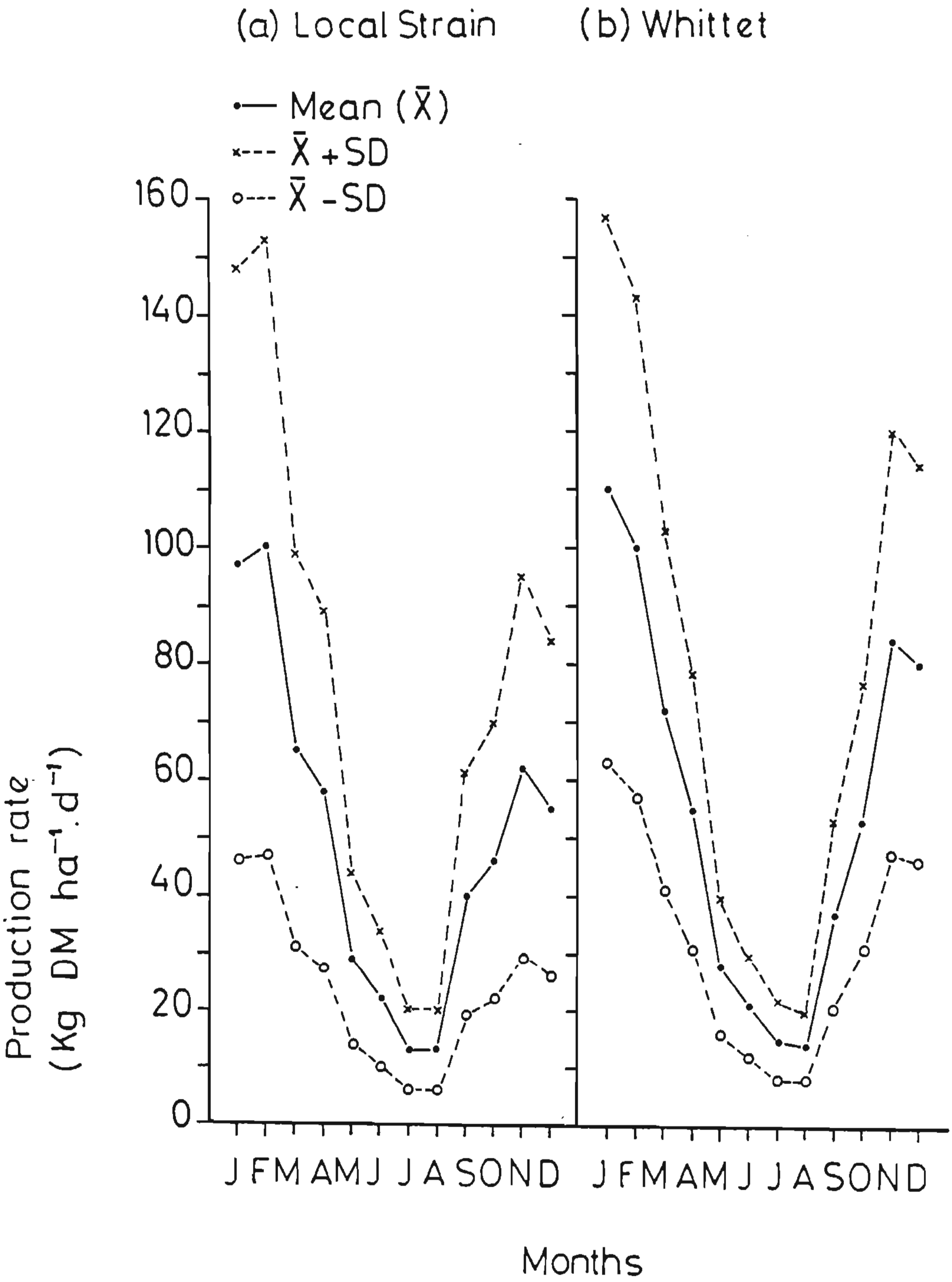


Figure 3.54 The production rate of two kikuyu strains under irrigation at Oudtshoorn (1978-84)

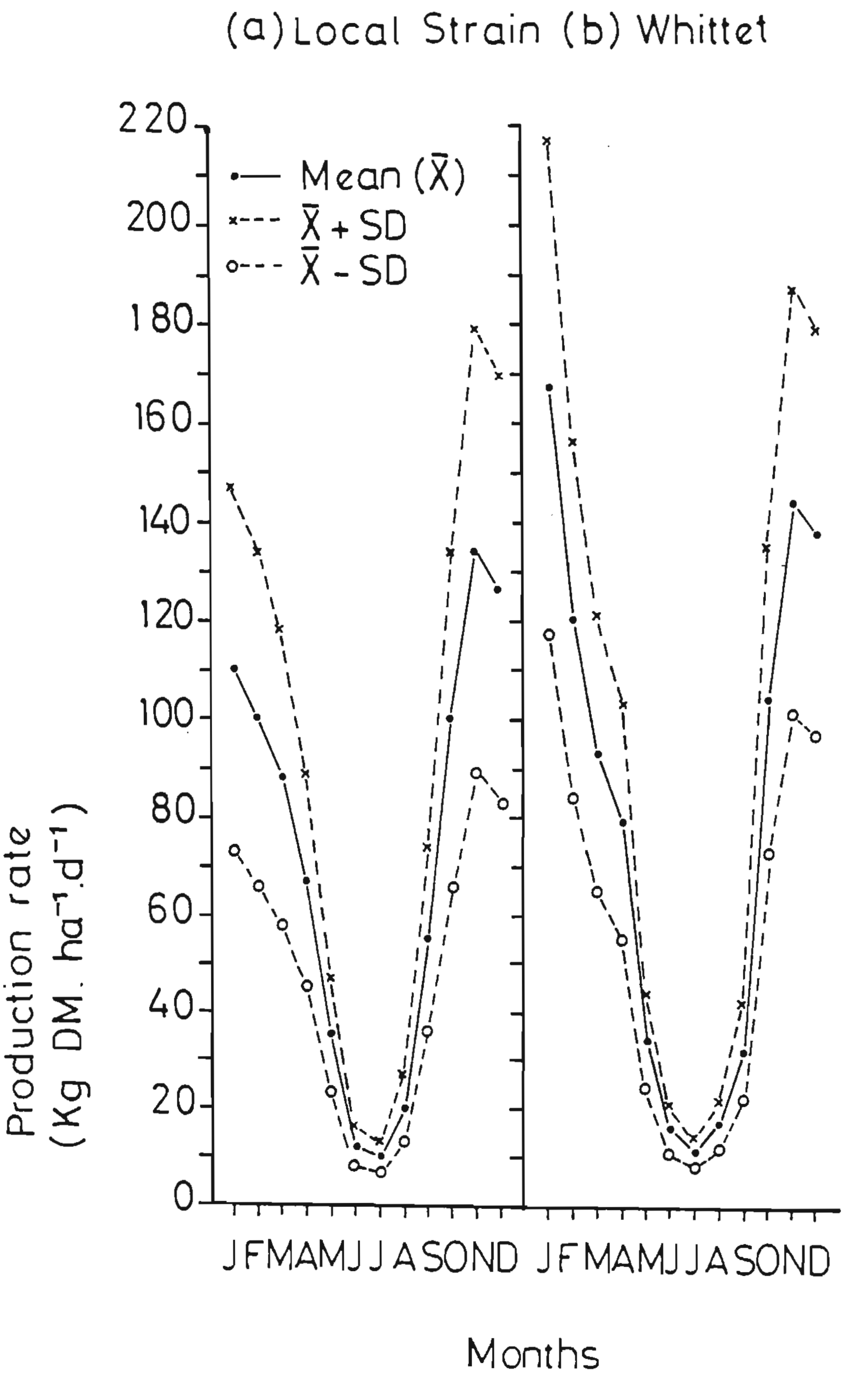
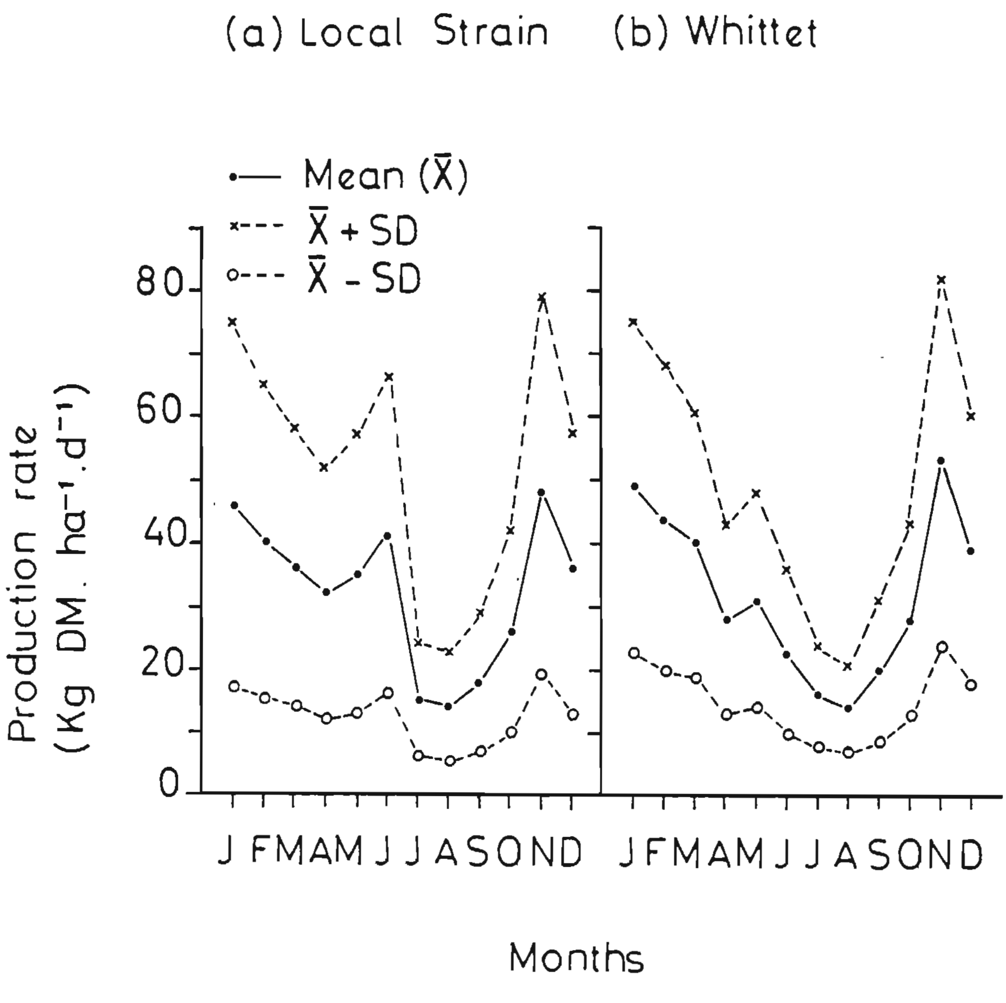


Figure 3.55 Production rate of two strains of kikuyu under dryland at Outeniqua (1978-83)



when $Q_{TOT} > 17$, with Q_{TOT} = total daily solar radiation ($MJ.M^{-2}.d^{-1}$);

GI = MI x TI x RI.

Two relationships were developed between GI and the APR for the calculation of the potential production rate (PPR) under dryland and irrigation respectively. A single function was, therefore, sufficient for each situation to respectively describe the relationship under dryland, as well as under irrigation, as soil played no role in the determination of the seasonal production rate of kikuyu. The following functions were used:

PPR (dryland) = 16,33 + 65,10 GI
PPR (irrigated) = 6,10 + 181,00 GI.

The two relationships are depicted in figure 3.56. For the derivation of the above-mentioned functions, data acquired during the last season at Outeniqua (dryland and irrigated) and Oudtshoorn, were excluded. These data were used to validate the models. As a first step, the PPR and APR for the whole trial period are compared at each site. These results are presented in figures 3.57 and 3.58. At all three irrigated sites (figure 3.57), the PPR values followed the APR curve very well and resulted in highly significant R^2 values.

Under dryland conditions at Outeniqua (figure 3.58) the PPR values deviated somewhat from the APR curve. The correlation was, however, still highly significant. The fact that R^2 was higher, and that the PPR curve followed that of the APR more closely under irrigation than dryland, indicates once again that MI was a much less successful contributor to GI than TI and RI.

Figure 3.56 Relationships between the growth index (GI) and the potential production rate of kikuyu under dryland and irrigation

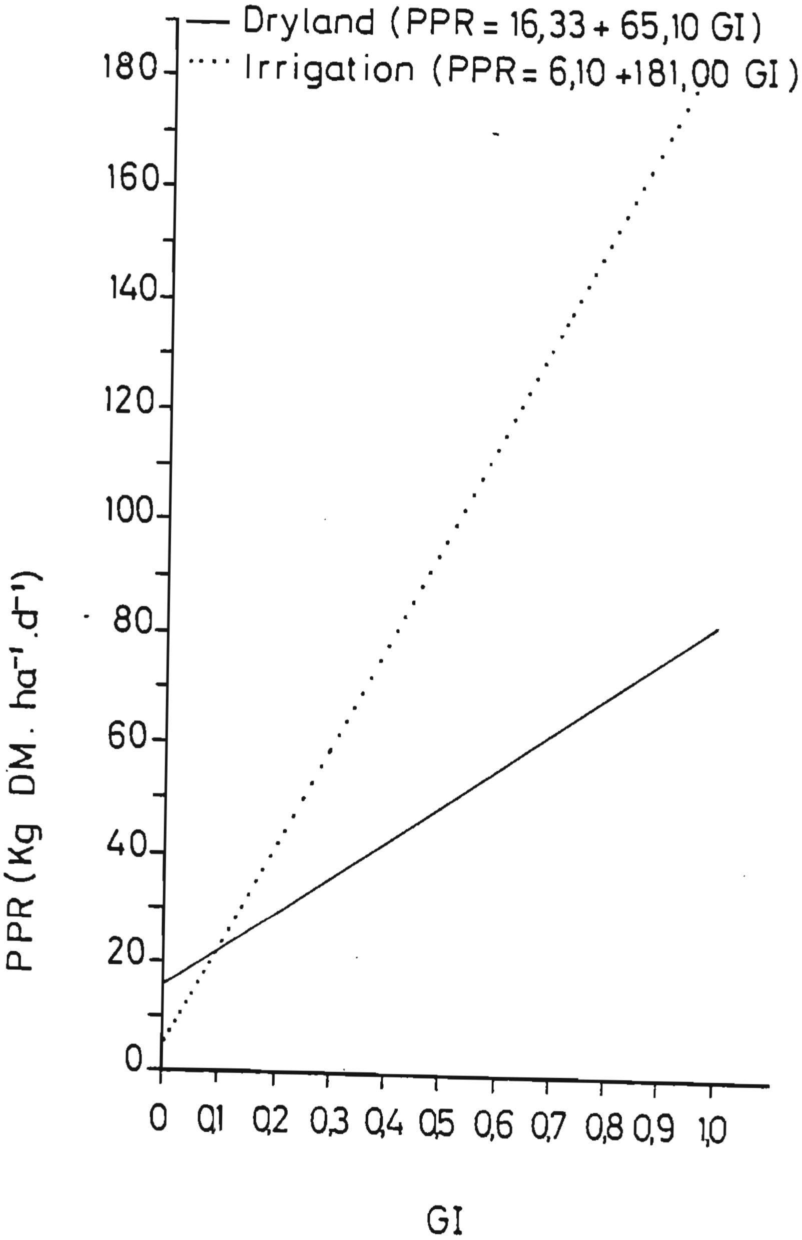


Figure 3.57 Comparison of the actual (APR) and the predicted potential (PPR) production rate at the three irrigated sites, over the whole experimental period

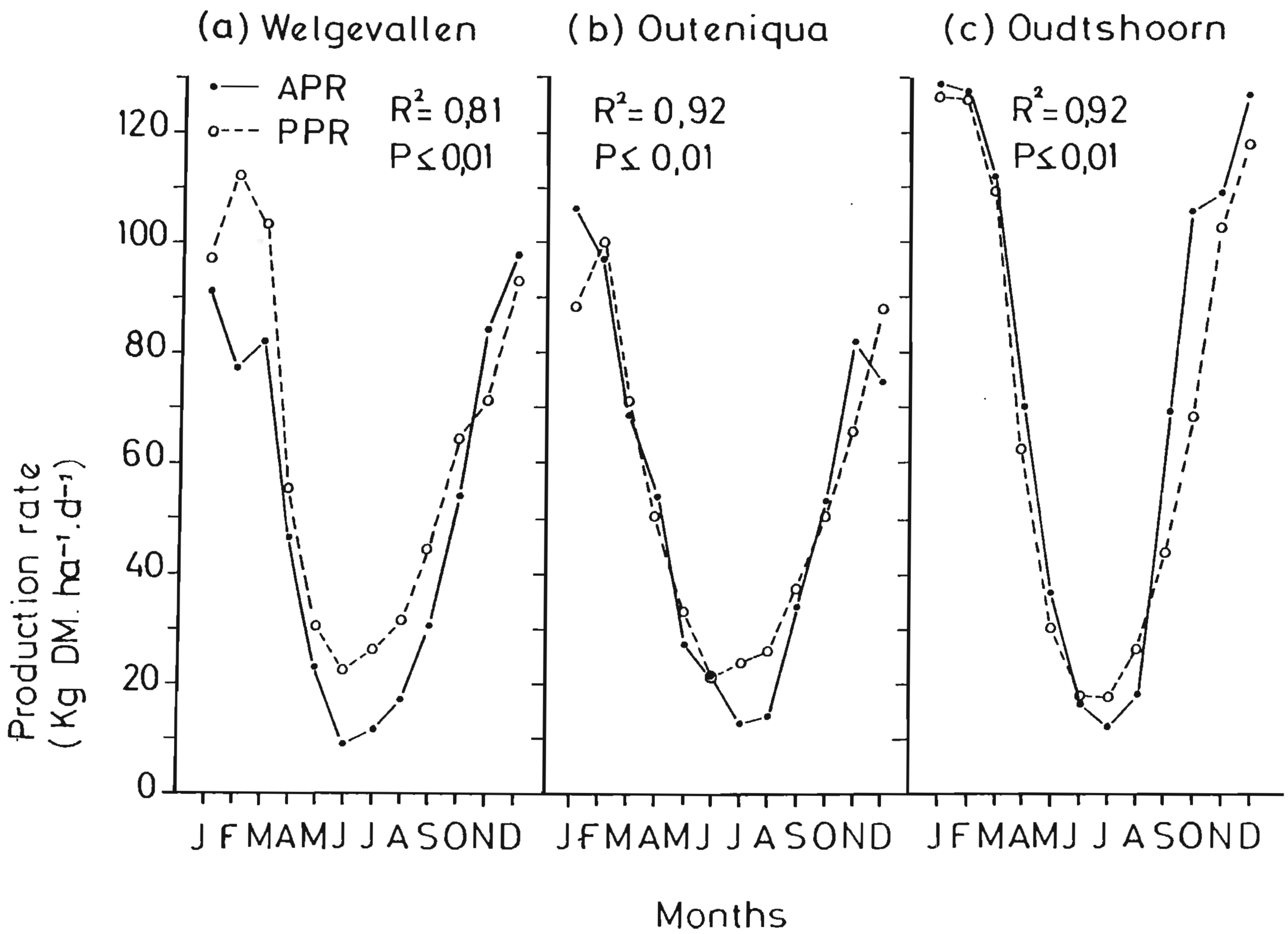
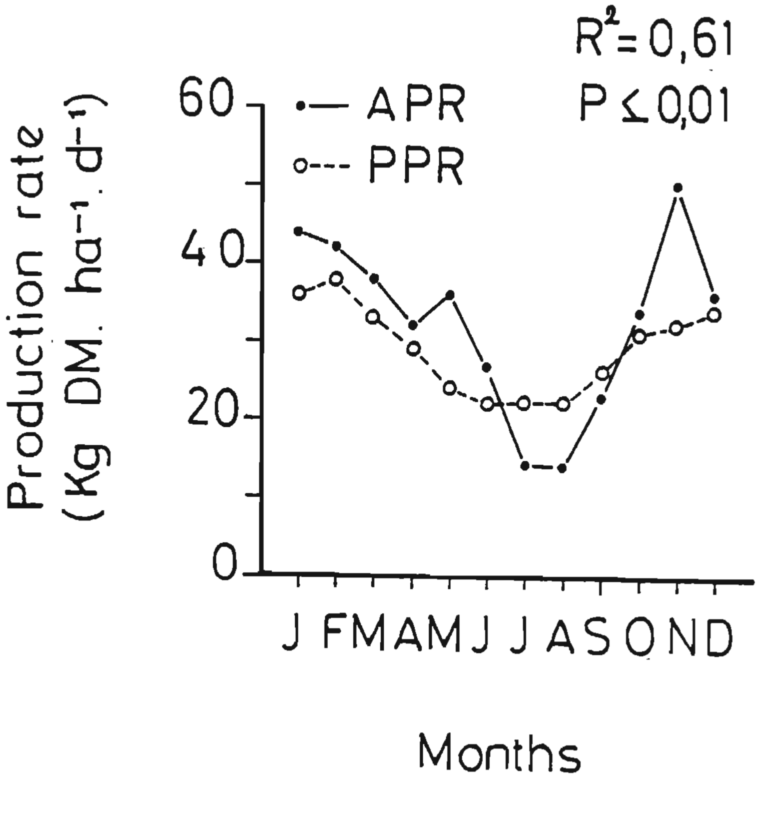


Figure 3.58 Comparison of the actual (APR) and the predicted potential (PPR) production rate over the whole experimental period at Outeniqua under dryland conditions



The models were validated even further by comparing the PPR and APR values for data not used during the development phase and obtained during one season in the trials at Outeniqua (dryland and irrigated) and Oudtshoorn. These results are depicted in figure 3.59. The PPR values followed those of APR very well at both Outeniqua (irrigated) and Oudtshoorn and the R^2 values were highly significant. Under dryland conditions (Outeniqua), the PPR curve again deviated from APR. The correlations were, however, still highly significant, indicating that the model was effective.

It can, therefore, be concluded that the models are successful enough under irrigation, as well as under dryland. The functions were subsequently employed to calculate the long-term potential production rates (PPR) of kikuyu at each experimental site, using long-term mean monthly climatic data as input. These results are depicted in figure 3.60.

The extreme seasonality of the production pattern of kikuyu under irrigation is again apparent. The PPR differs quite substantially at the different sites. During the period September to April the PPR is highest at Oudtshoorn and lowest at Outeniqua (irrigated). During June and July it is, however, the reverse, i.e. the highest PPR is estimated for Outeniqua and the lowest for Oudtshoorn. Under dryland conditions at Outeniqua, the amplitude of the PPR curve is much smaller, as the PPR values are depressed by the low MI values during summer.

3.3.6.4 Discussion and conclusions

The response of kikuyu to cutting frequency differed at the different sites. The largest response was measured at the lowest producing irrigated site, Welgevallen, and the

Figure 3.59 Comparison of the actual (APR) and the predicted potential production (PPR) rate at two irrigated and one dryland site, using data which had not been utilised during the development phase

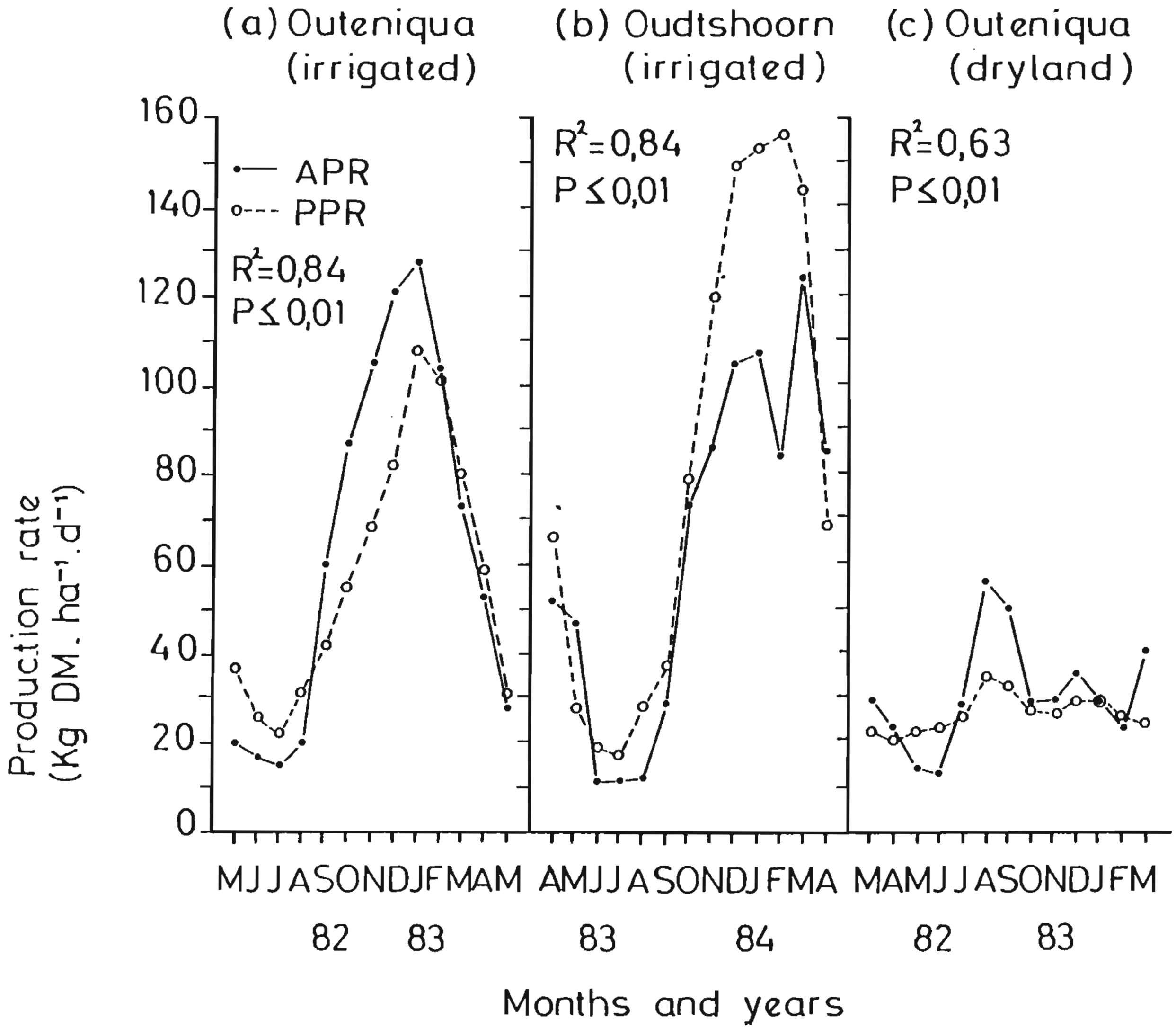
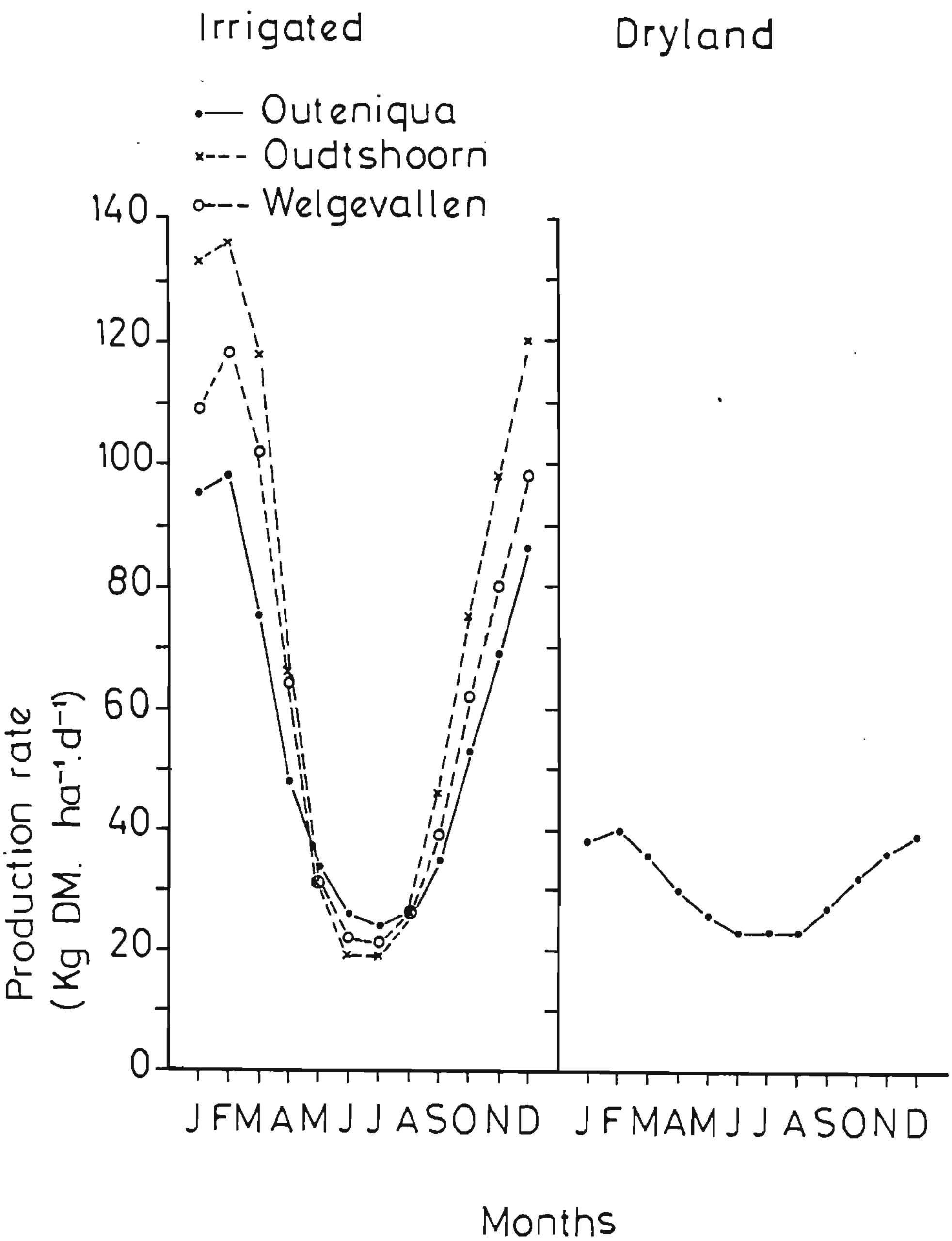


Figure 3.60 Long-term potential production rate (PPR) predicted, using the derived functions and long-term mean climatic data



smallest at the highest producing site, Oudtshoorn. The small response at Oudtshoorn could perhaps be attributed to the high production rate which could have shortened the optimum period between cuttings at this site. Generally, however, it seems that the highest production rates will be attained when kikuyu is cut at the most every eight weeks.

The most striking feature of the mean production rates at the three irrigated sites, was the extremely high summer rates, which generally peaked during December and January, as well as the very low winter production rates, generally at a low during June and July. Under dryland at Outeniqua, the production rate was, however, limited by low soil moisture supply during summer, but still rather high.

When the seasonal production rate of the local vegetatively propagated strain was compared with the commercially available cultivar Whittet, it was found that their seasonal production patterns did not differ much. Whittet, however, tended to have a slightly higher summer production rate than the local strain. The differences were, however, not large enough to indicate any significant advantage of Whittet. If one further considers the possibility of Whittet becoming a weed on fruit and vine farms, it is clear that the local strain is preferable.

The relationship between PPR and GI did not differ on soils with different potential. One function therefore sufficed for the dryland site and one for all the irrigated sites. This indicated that the seasonal production rate of kikuyu was influenced more by GI, i.e. climate, than by soil potential.

The models were validated by comparing estimated PPR values with APR values derived over the whole trial period, as well as with new data for one season only. Under irrigation, the

PPR values estimated the APR curve very well, but under dryland the estimation was slightly less successful. R^2 values were, however, highly significant in all cases and the deviations under dryland can mainly be attributed to the PPR curve being less sensitive than that of the APR. The models can, however, be reasonably safely applied, using long-term mean climatic data as input.

The results of the extrapolation emphasised the seasonality of kikuyu production and also indicate that climate has a much larger influence on the PPR than does soil potential. High summer temperature (TI) and solar radiation (RI) values result in a very high GI and PPR values under irrigation. Low winter temperature (TI) and solar radiation (RI) conditions, however, depress the PPR values just as much. This extreme seasonality of the PPR values of kikuyu is, therefore, one of the major factors limiting the use of kikuyu under irrigation in this region. Under dryland conditions in the high rainfall areas (Outeniqua), however, kikuyu may be of greater importance as a pasture, as it produces rather well during summer, although the production rates are depressed somewhat by the low moisture supply.

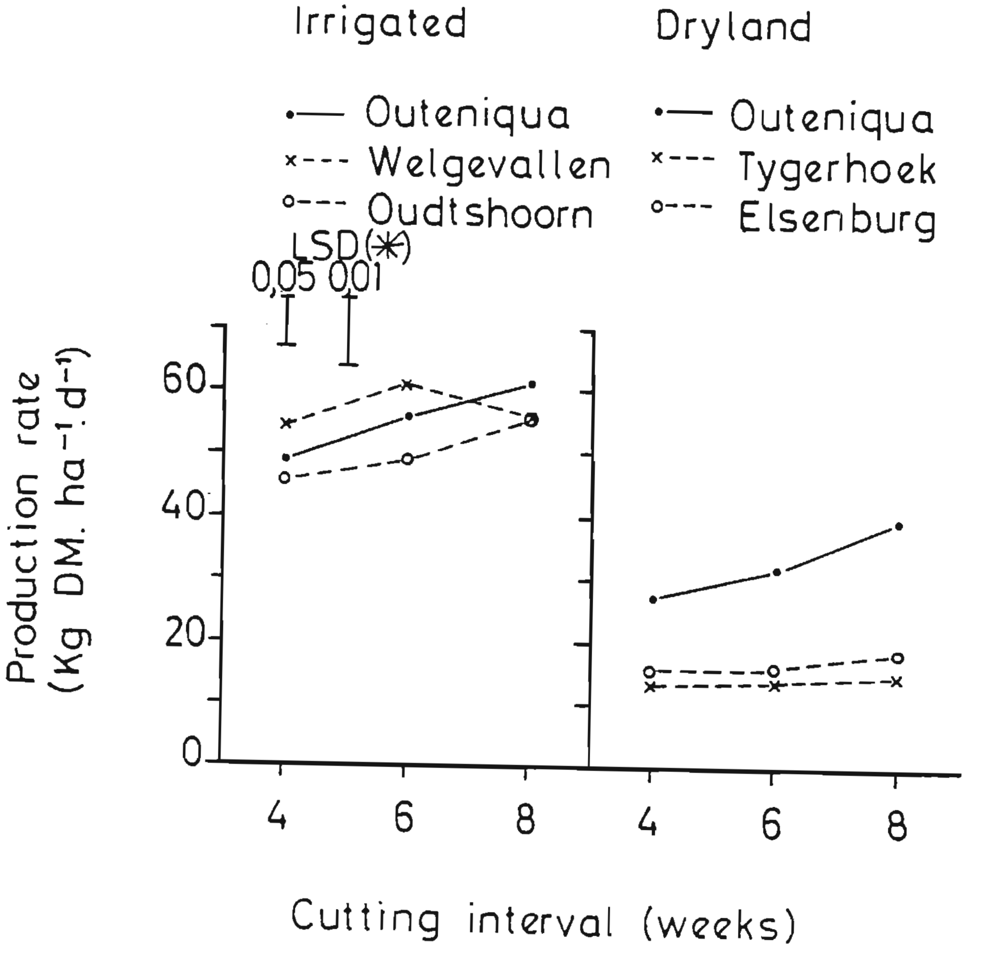
3.3.7 Fescue

3.3.7.1 Influence of cutting frequency

The mean production rate (kg $DM.ha^{-1}.d^{-1}$) of all fescue cultivars in three irrigated (Welgevallen, Outeniqua and Oudtshoorn) and three dryland trials (Elsenburg, Tygerhoek and Outeniqua), cut at three frequencies (four-, six- and eight-weekly), are depicted in figure 3.61.

The response of fescue to the cutting treatments was generally very small. With the exception of Welgevallen, the highest production rate tended to occur at the eight-

Figure 3.61 Influence of cutting frequency on the mean production rate of fescue under irrigation and dryland at Elsenburg (1981-84), Tygerhoek (1981-84), Outeniqua (1981-83), Welgevallen (1979-81) and Oudtshoorn (1981-84) (* LSD's for dryland and irrigated trials)



weekly cutting frequency at all the sites. At Welgevallen, as well as at two of the dryland sites, Elsenburg and Tygerhoek, the response was not significant between any of the treatments and at none of the sites was the response between the four- and six-weekly cutting treatments significant. At Oudtshoorn and Outeniqua (dryland and irrigated), however, a significant response was attained between the four- and eight-weekly frequency and at the dryland site at Outeniqua, also between the six- and eight-weekly frequencies.

3.3.7.2 Seasonal production

The mean production rates (kg $DM.ha^{-1}.d^{-1}$) of all fescue cultivars evaluated in cutting trials at three irrigated (Welgevallen, Outeniqua and Oudtshoorn) and three dryland sites (Elsenburg, Tygerhoek and Outeniqua), are depicted in figures 3.62 and 3.63 respectively.

The seasonal production pattern of fescue differed slightly at the three irrigated sites (figure 3.62). At all three sites the lowest production rates, however, tended to occur during June and July and the highest production rates during spring (October/November). At Welgevallen and Outeniqua, the production rates were very high during summer, but at Oudtshoorn, the late summer peak was non-existent. The production rates during the period February to May were subsequently about equal and not much higher than during winter (June and July) at the last mentioned site.

Under dryland the production pattern of fescue was less consistent at the different sites than under irrigation (figure 3.63). At Elsenburg and Tygerhoek, very low production rates during December to March were followed by an abrupt increase in production rate during June and subsequent months. At Tygerhoek a less defined peak

Figure 3.62 The production rate over all fescue cultivars evaluated under irrigation at Welgevallen (1979-81), Outeniqua (1978-83) and Oudtshoorn (1978-84)

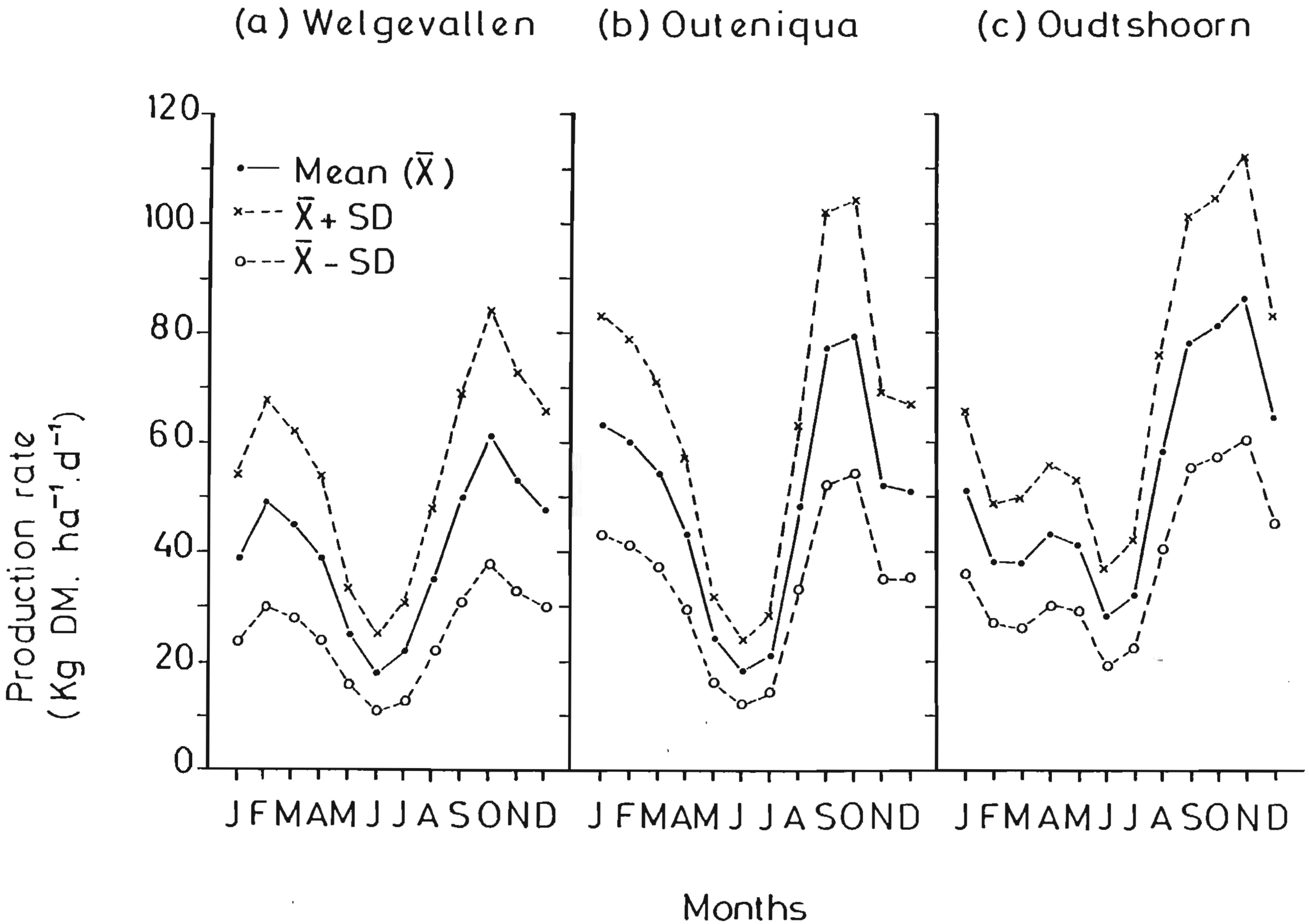
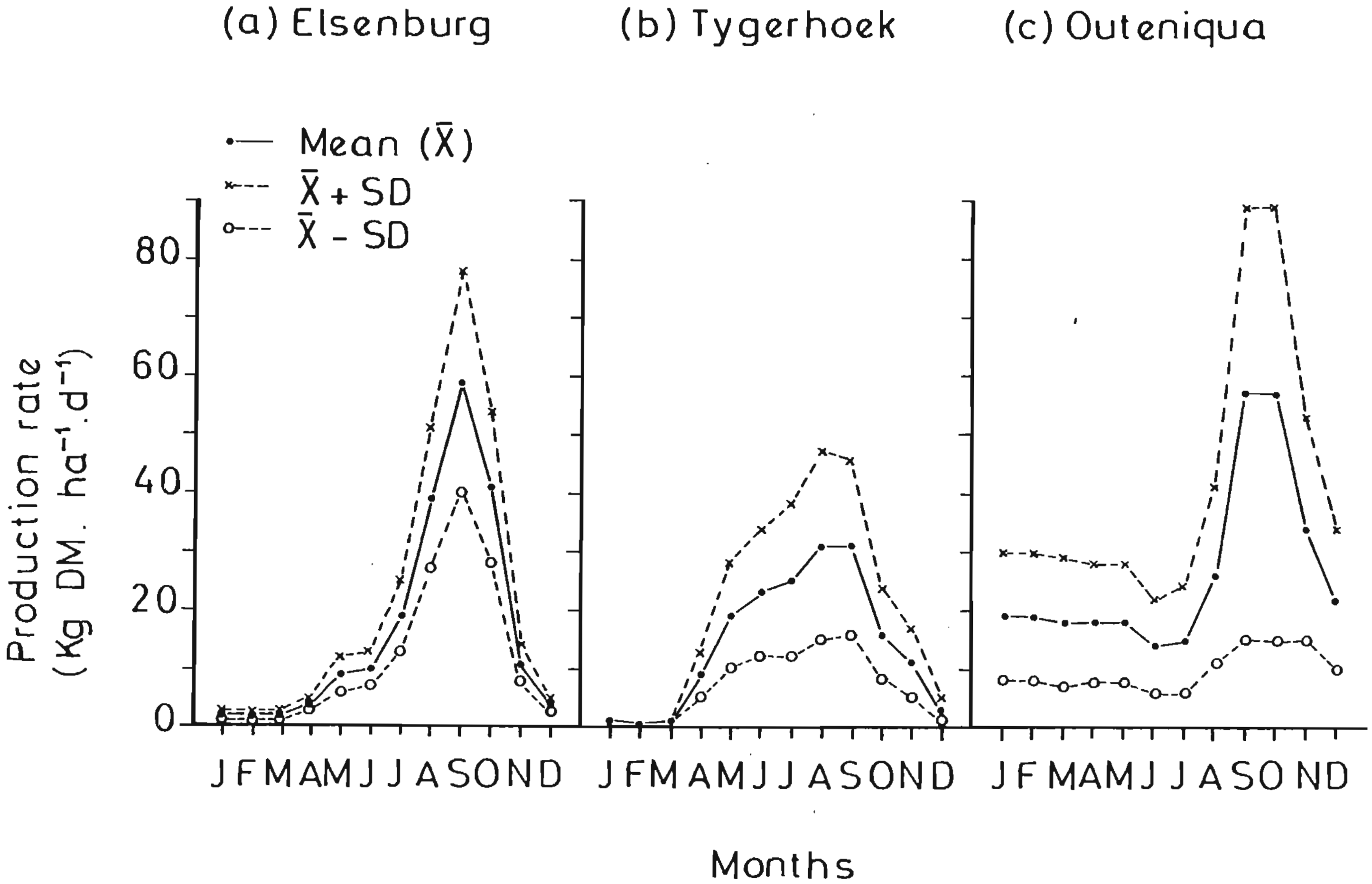


Figure 3.63 The production rate over all fescue cultivars evaluated under dryland at Elsenburg (1981-84), Tygerhoek (1981-83) and Outeniqua (1978-83)



occurred during September than at Elsenburg, but after September an equally sharp decline in the production rate occurred at both the last mentioned sites. At Outeniqua (dryland), the production rates were higher during summer than at the other two dryland sites and did not vary much during the period December to July. However, during August an increase in the production rate occurred at Outeniqua, which peaked during September and October and decreased again during subsequent months.

At each locality a number of cultivars were evaluated. Unfortunately, only two cultivars, Alta and Kentucky 31, were evaluated at Welgevallen, but at all the other sites three cultivars, Kentucky 31, Demeter and Kenhy, were evaluated. These results are depicted in figures 3.64 to 3.69.

Under irrigation at Welgevallen (figure 3.64) Kentucky 31 tended to have a higher production rate than Alta during the greater part of the year, although no differences occurred during the period May to August.

At Outeniqua (irrigated) (figure 3.65), the production patterns of the three cultivars, Kentucky 31, Demeter and Kenhy were very similar, but Demeter was highest producing during the period November to March. During the period March to August the production rate of Kenhy was much lower than that of the other two cultivars.

At Oudtshoorn (figure 3.66) Kenhy had a much more pronounced seasonal production pattern than Demeter and Kentucky 31, with two prominent peaks during autumn (March) and spring (November), as well as very low production rates during winter (June and July). Demeter tended to have the highest production rate during the greater part of the year, although Kenhy seemed to outyield the other two cultivars

Figure 3.64 The production rate of two fescue cultivars, evaluated under irrigation at Welgevallen (1979-81)

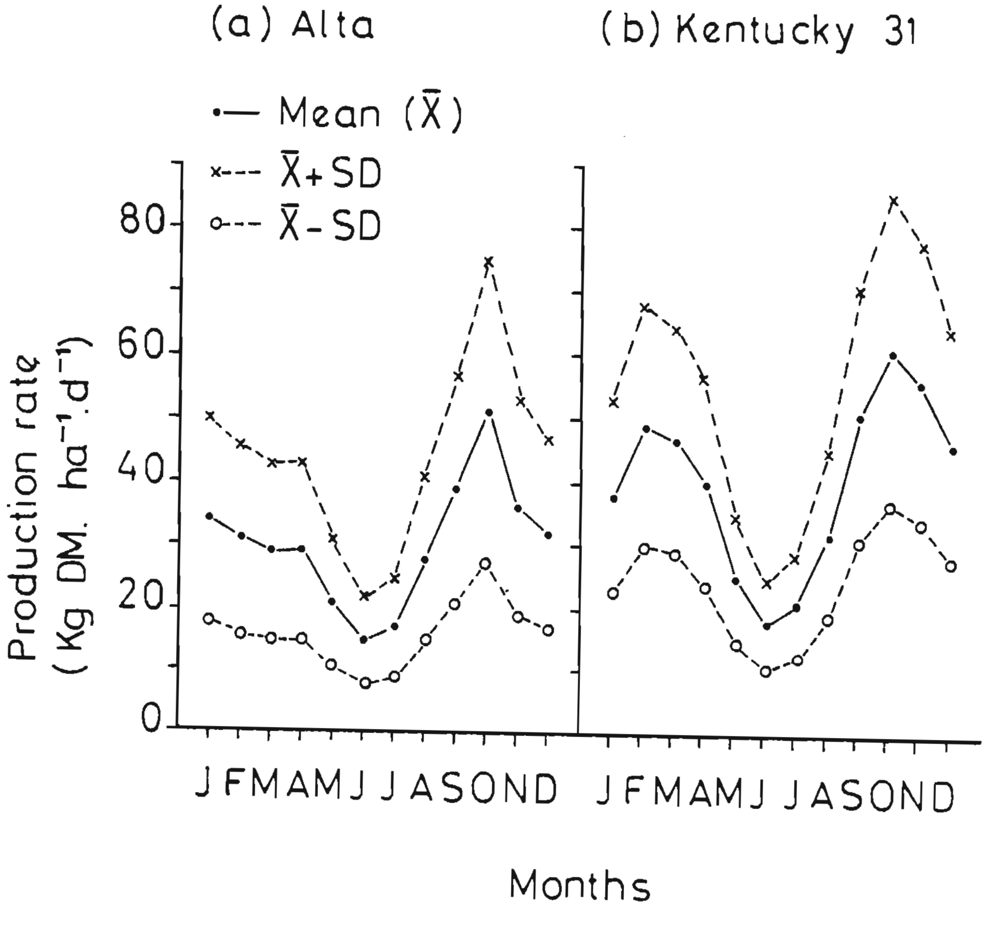


Figure 3.65 The production rate of three fescue cultivars evaluated under irrigation at Outeniqua (1978-83)

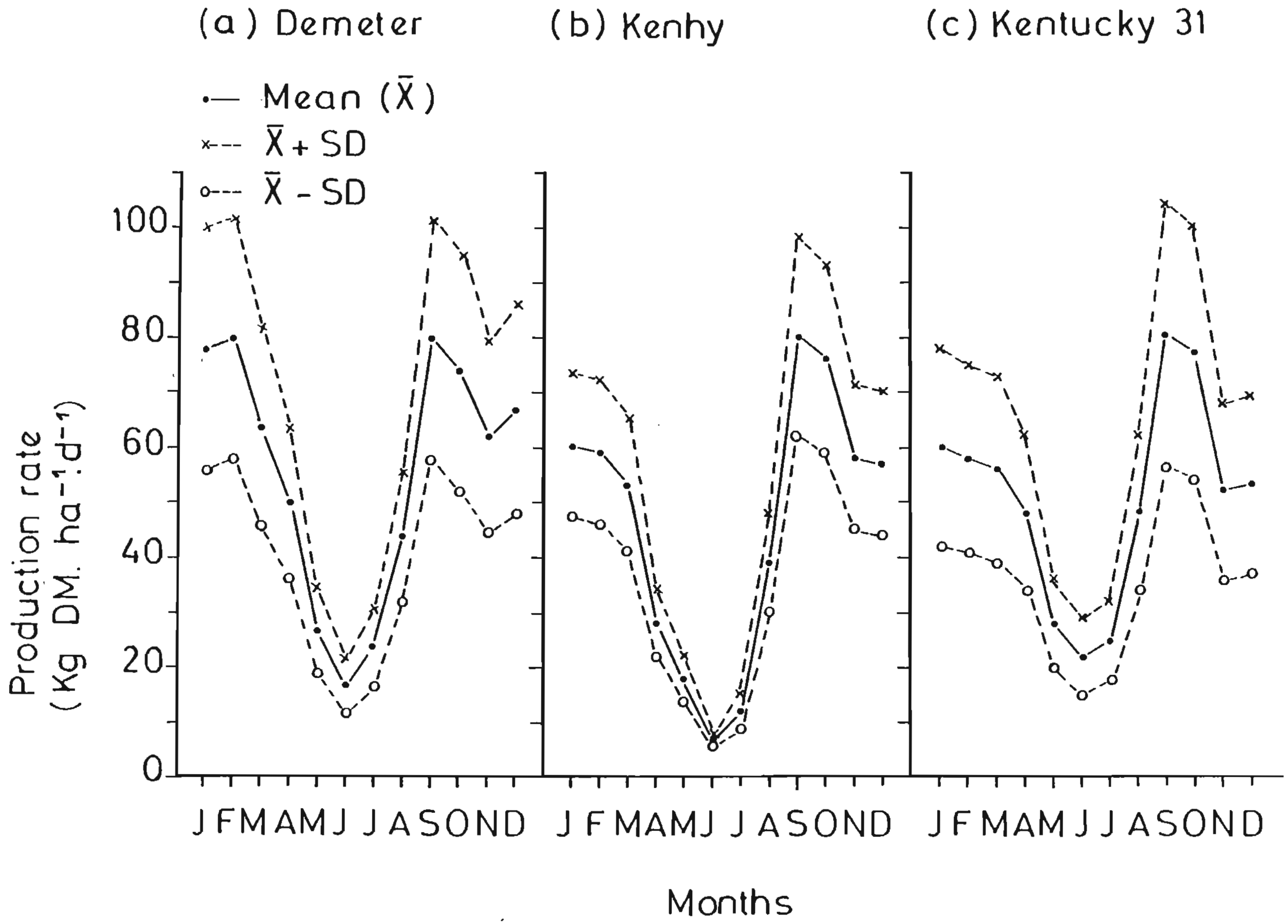


Figure 3.66 The production rate of three fescue cultivars evaluated under irrigation at Oudtshoorn (1978-84)

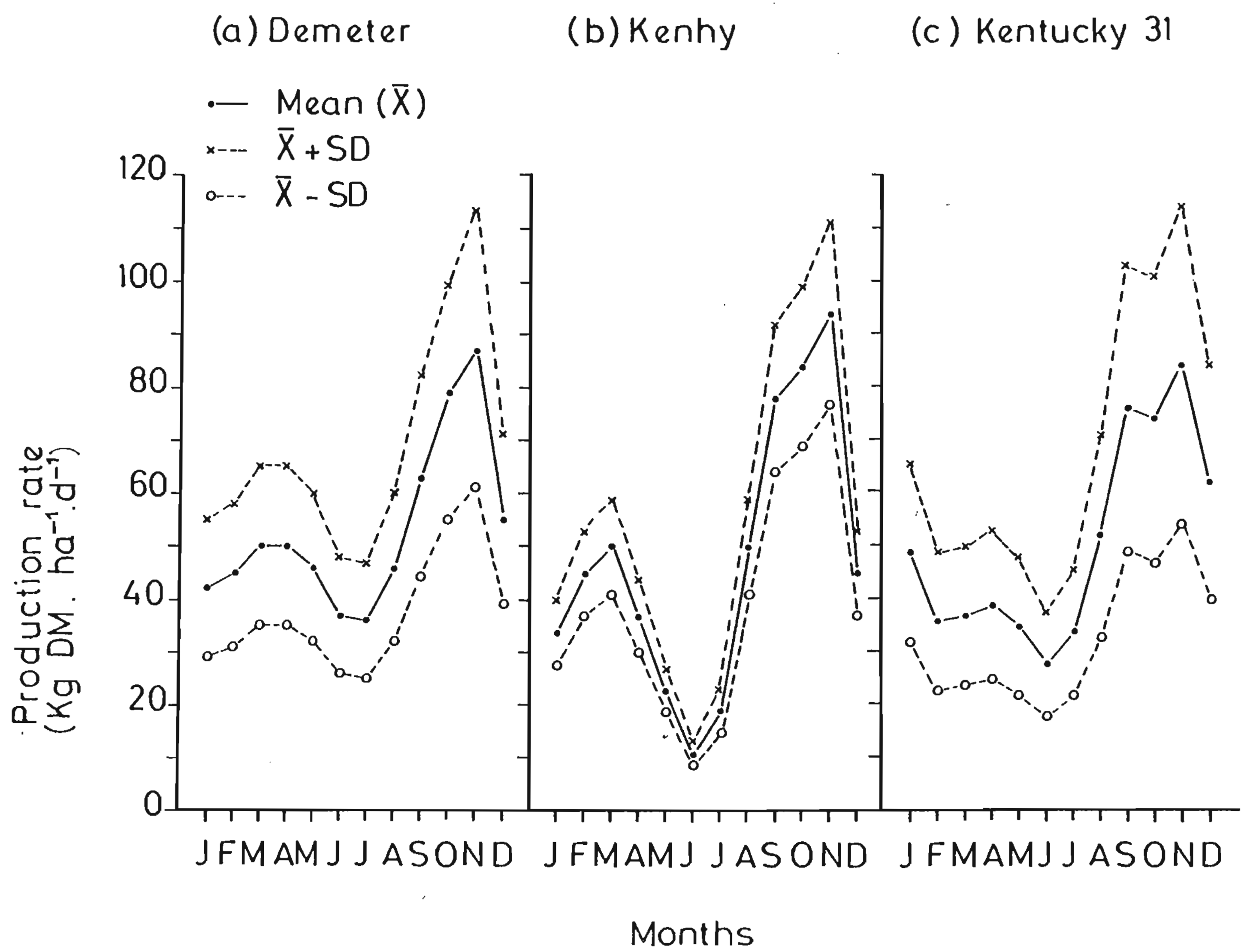


Figure 3.67 The production rate of three fescue cultivars evaluated under dryland at Elsenburg (1981-84)

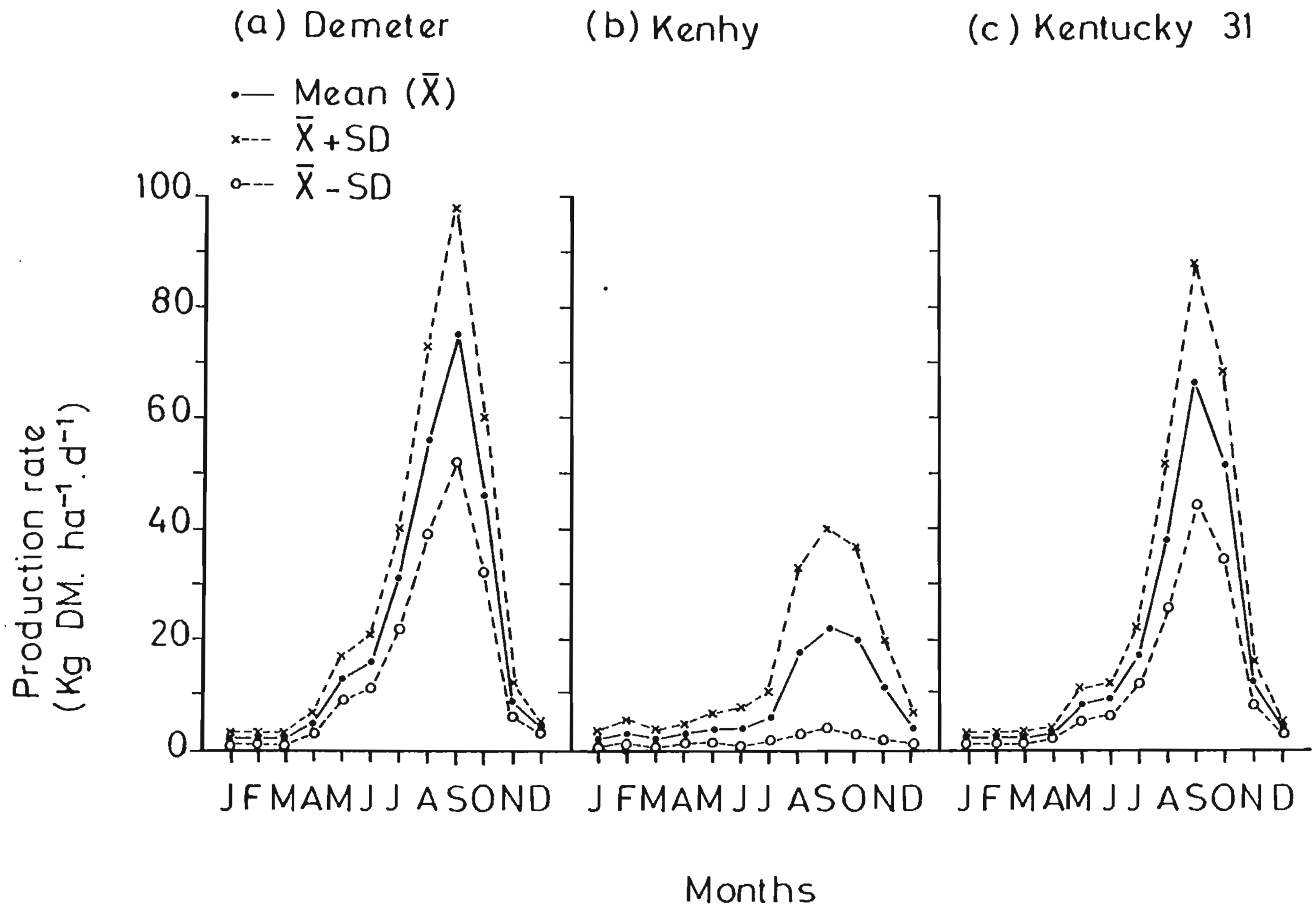


Figure 3.68 The production rate of three fescue cultivars evaluated under dryland at Tygerhoek (1981-84)

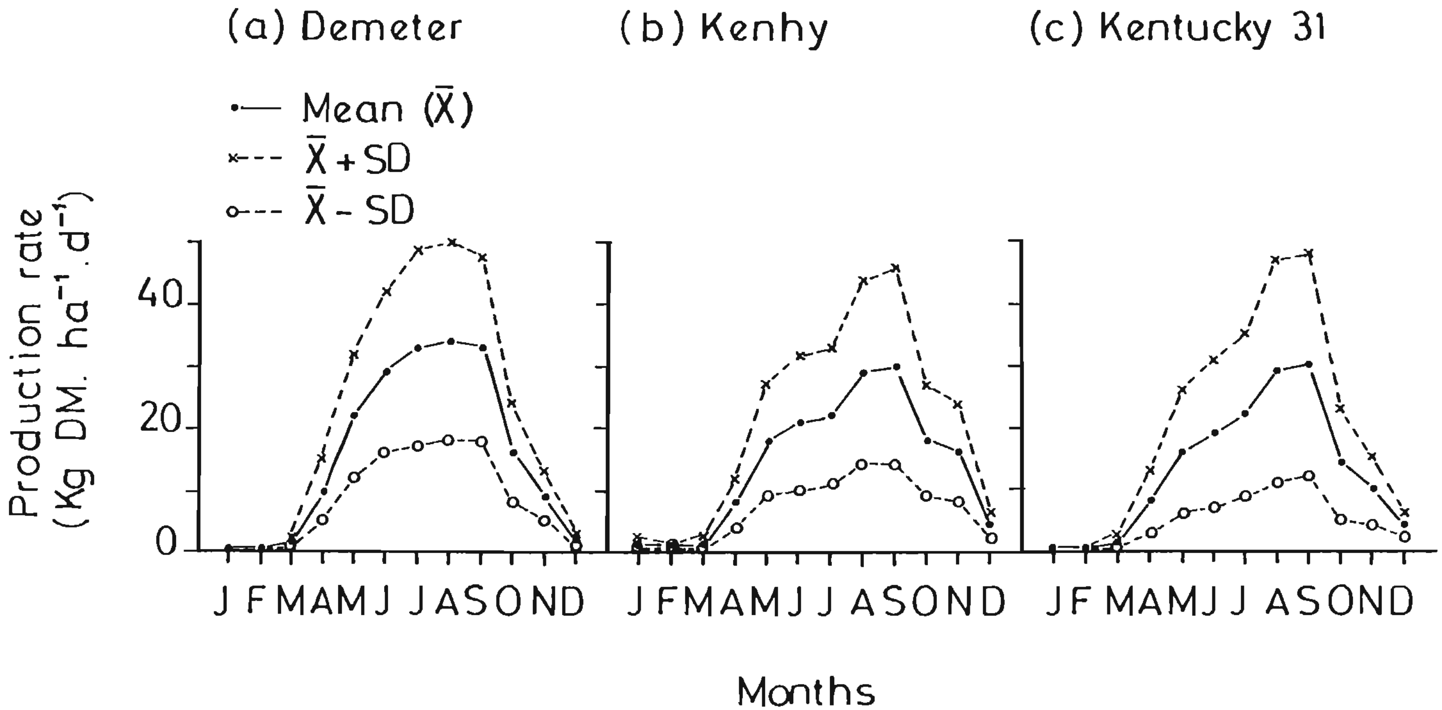
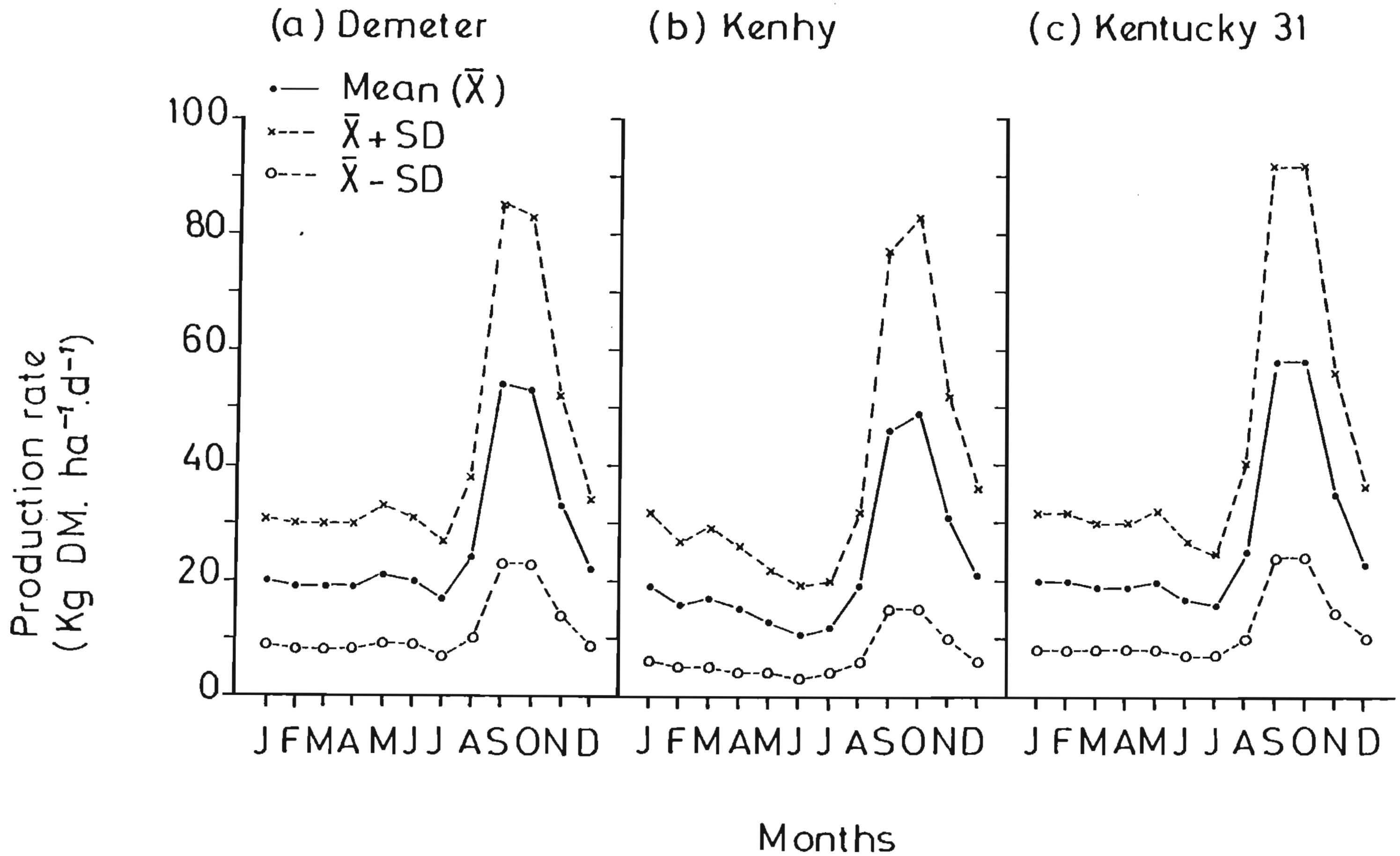


Figure 3.69 The production rate of three fescue cultivars evaluated under dryland at Outeniqua (1978-83)



during the spring flush period (September to November). During December and January Kentucky 31, however, tended to have the highest production rate.

Under dryland conditions at Elsenburg (figure 3.67) the production patterns of Kentucky 31 and Demeter tended to be very similar, although the latter mentioned cultivar tended to have a higher production rate during the period May to September. Kenhy, however, produced very poorly and did not compare very favourably with the other two cultivars.

At Tygerhoek (figure 3.68) the three cultivars, Kentucky 31, Demeter and Kenhy, had very similar production patterns and rates, but Demeter tended to have the highest production rate during May to September. At Outeniqua (dryland) (figure 3.69), Kentucky 31 and Demeter tended to have identical production rates and patterns through the year, while the production rates of Kenhy tended to be lowest, especially during winter.

3.3.7.3 Extrapolation of production rate data

Seasonal production rate data derived at the three irrigated (Welgevallen, Outeniqua and Oudtshoorn) and three dryland sites (Elsenburg, Tygerhoek and Outeniqua), were used for the development of functions for the extrapolation of the seasonal production rates to different seasons. The following functions were derived:

$MI = R.(0,5E)^{-1}$ (two-monthly means),
where R = total monthly rainfall (mm) and E = total monthly class A pan evaporation (mm);

$TI = \exp(-(T-15)^2.86^{-1})$,
where T = mean monthly air temperature (°C);

$RI = Q_{TOT}.17^{-1}$,
when $Q_{TOT} \leq 17$ and

$RI = 1$,

when $Q_{TOT} > 17$, where Q_{TOT} = mean monthly total daily radiation ($MJ.M^{-2}.d^{-1}$);

$GI = MI \times RI \times TI$.

Three relationships were developed between GI and the actual production rate (APR) and used for the calculation of the potential production rate (PPR). The three relationships are depicted in figure 3.70. Under dryland, a single relationship sufficed, as soil did not have much of an influence on the production rate at the different sites. GI was, therefore, the main determinant of seasonal production rate. The following function was derived for use under dryland conditions:

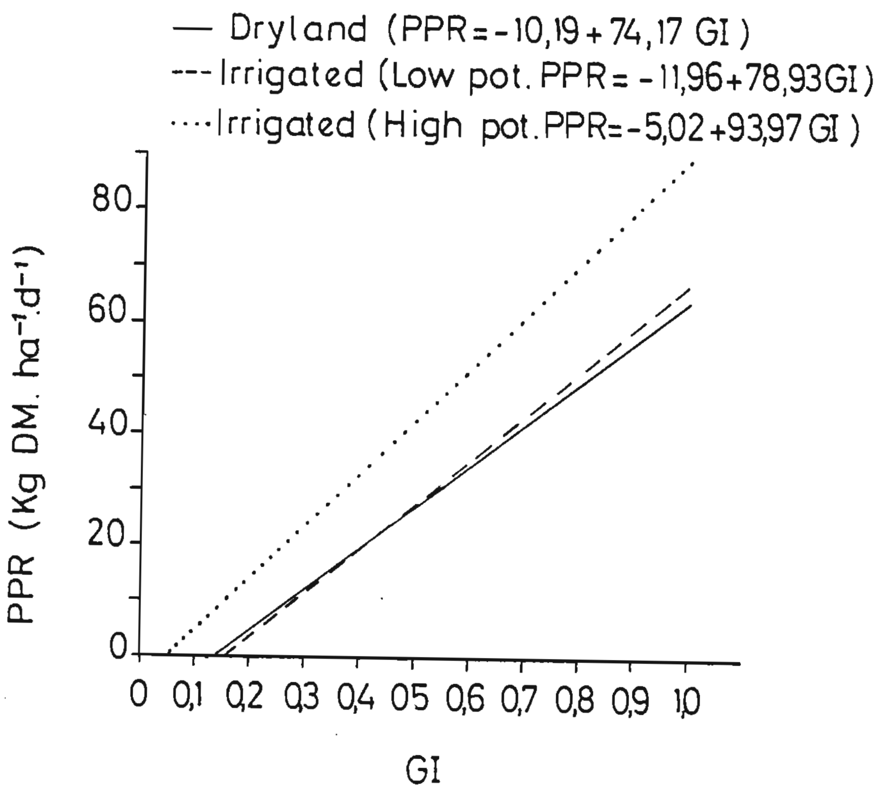
$$PPR = -10,19 + 74,17GI.$$

Under irrigation, however, two functions had to be developed due to the influence of soil potential on seasonal production. A function was, therefore, developed for a high potential soil, represented by the Oakleaf soil form of the Oudtshoorn trial site, as well as one for a low potential soil, represented by the Estcourt and Katspruit soil forms, respectively, of the Outeniqua and Welgevallen trial sites. The functions were as follows:

$$PPR\ (\text{high potential soil}) = -5,02 + 93,97GI$$
$$PPR\ (\text{low potential soil}) = -11,96 + 78,93GI.$$

For the validation of the three above-mentioned functions, data acquired during the last season at most sites, were

Figure 3.70 Relationships between the growth index (GI) and the potential production rate (PPR) for fescue under dryland and irrigation



reserved for the validation of the models. The only site at which all the data were used, was Welgevallen.

As a first step, however, the mean monthly PPR and APR values were compared over the whole trial period at each trial site. These results are presented graphically in figures 3.71 and 3.72. The PPR curves follow that of the APR very well under dryland, as well as under irrigation and R^2 was highly significant at all sites. At Outeniqua (dryland), however, the PPR values deviated slightly more from that of the APR during summer than under irrigation and tended, if anything, to overestimate the actual values.

The results are very promising, especially if the limited amount of data that was available at some of the sites, is considered. Further validation of the model was, however, necessary, using part of the data not used for the development of the models. These results are depicted in figures 3.73 and 3.74.

The results found under irrigation (figure 3.73), were very satisfactory and for both the sites used, i.e. Outeniqua and Oudtshoorn, the R^2 values were highly significant. Under dryland (figure 3.74), the results were equally promising. The values of R^2 were, however, slightly lower than was the case for the long-term values (figure 3.71), as the PPR deviated more from the APR values. It must, however, be borne in mind that the relatively simple models used were never intended to be used for the calculation of PPR values on a monthly basis, but rather for the calculation of long-term potential values, using long-term climatic mean values as inputs.

Using the derived functions, the long-term seasonal PPR was calculated at each site, with long-term mean climatic data as input. The derived curves are depicted in figure 3.75.

Figure 3.71 Comparison of the actual (APR) and predicted potential (PPR) production rate at three irrigated sites over the whole trial period

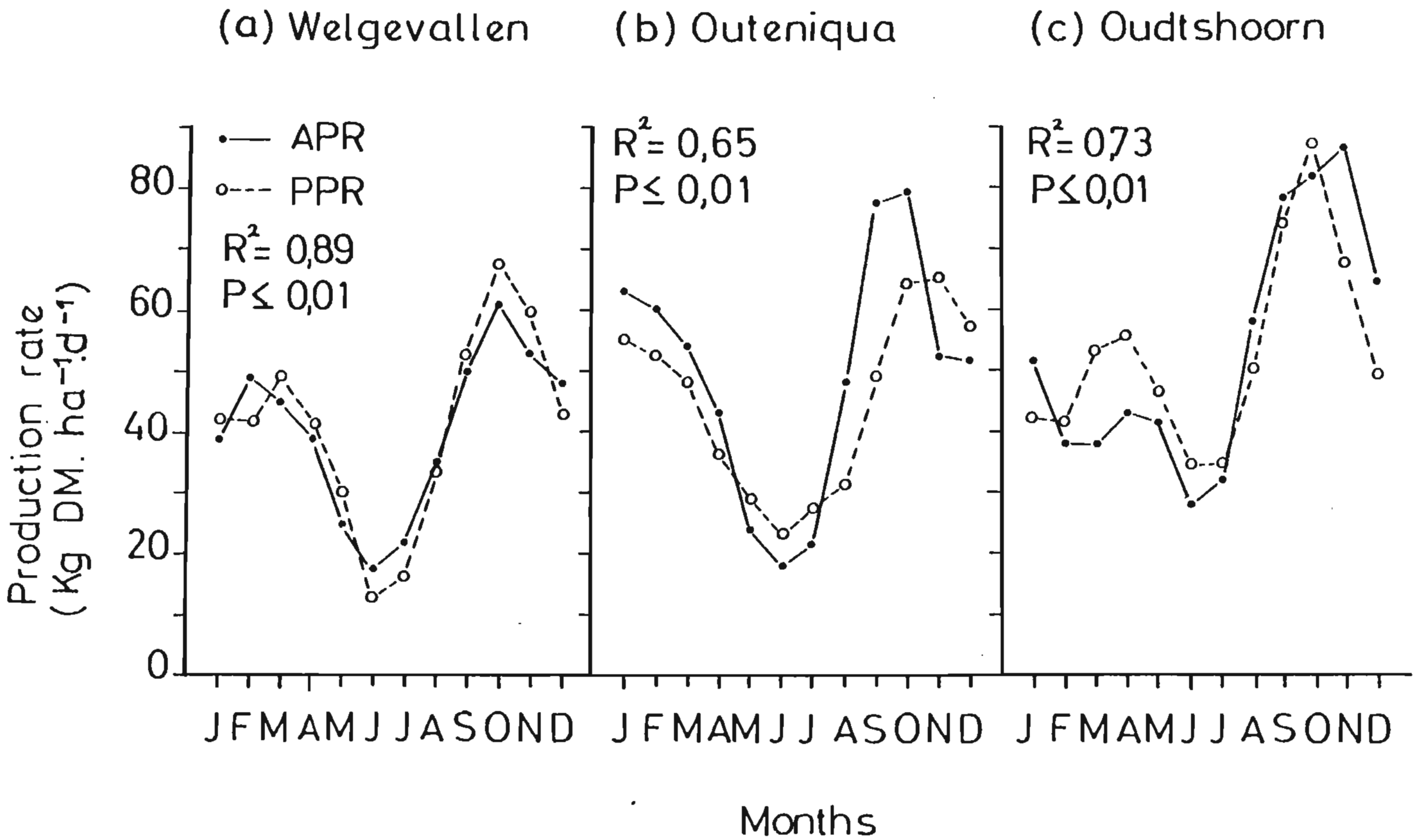


Figure 3.72 Comparison of the actual (APR) and the predicted potential (PPR) production rate at three dryland sites over the whole trial period

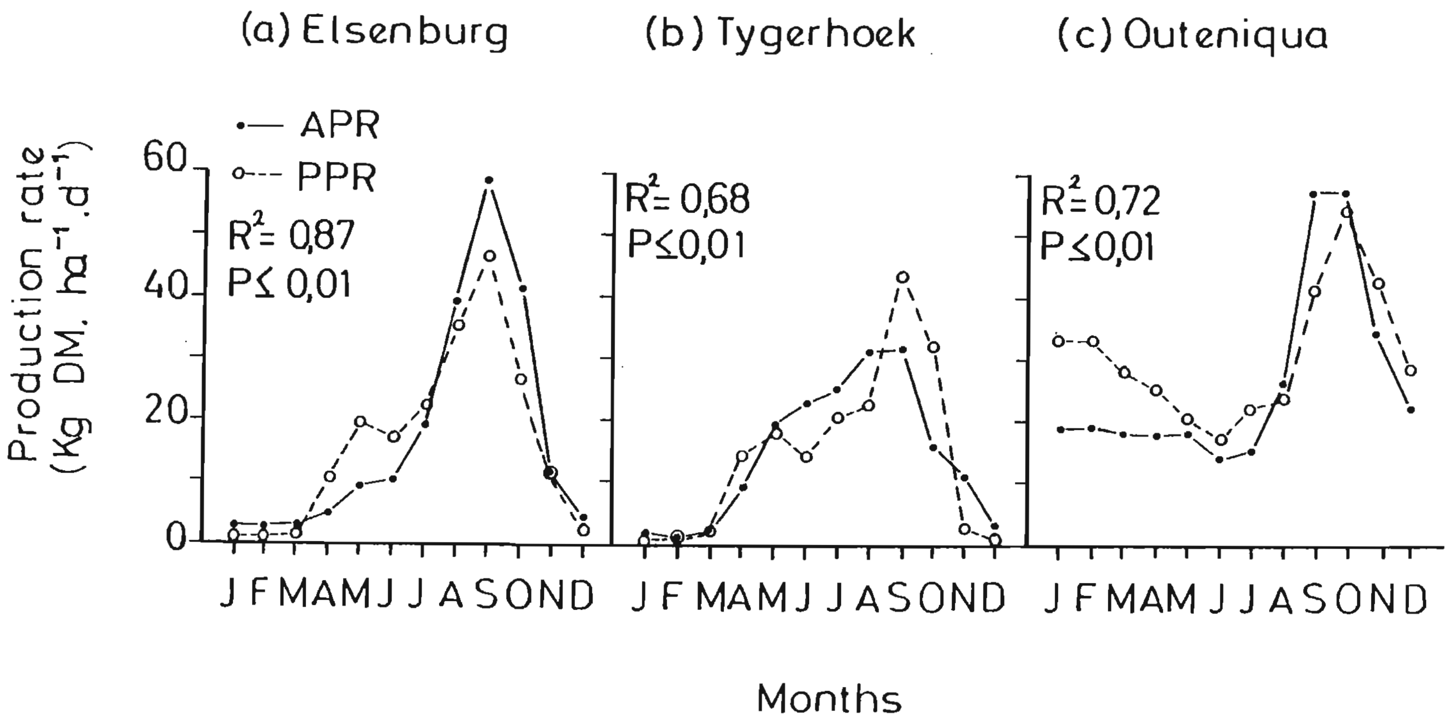


Figure 3.73 Comparison of actual (APR) and predicted potential (PPR) production rates at two irrigated sites, using data which had not been utilised during the development phase

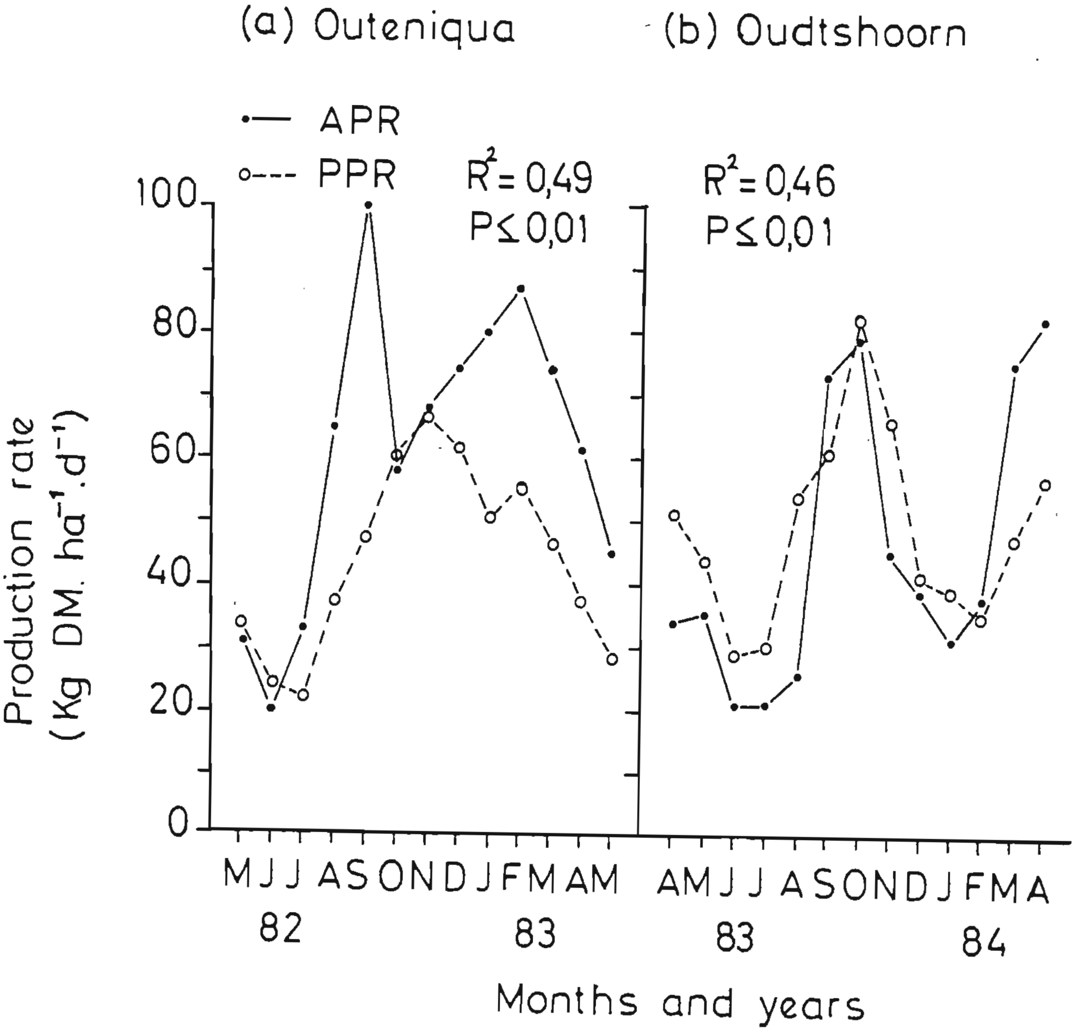


Figure 3.74 Comparison of actual (APR) and predicted potential (PPR) production rates under dryland at three sites, using data which had not been utilised during the development phase

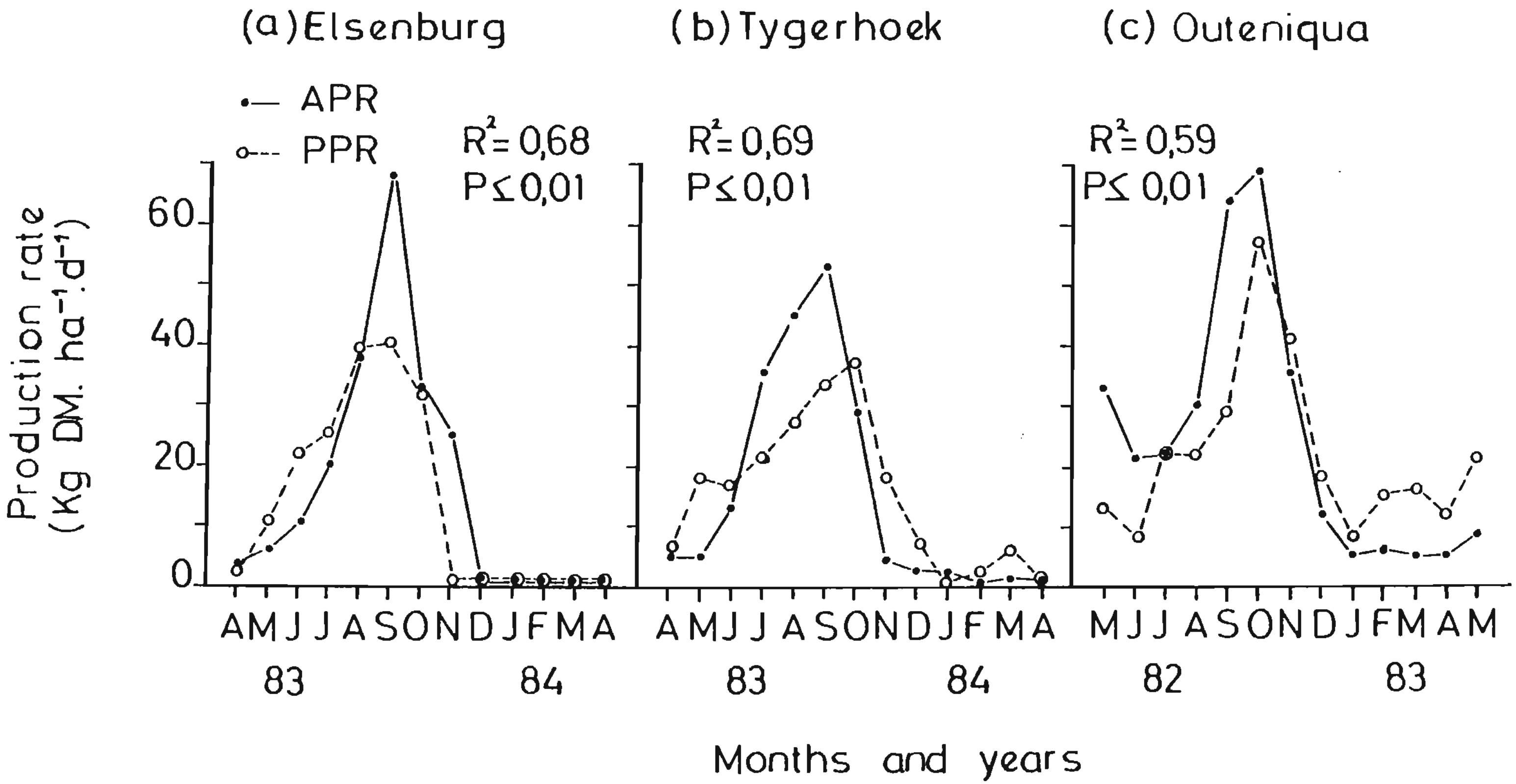
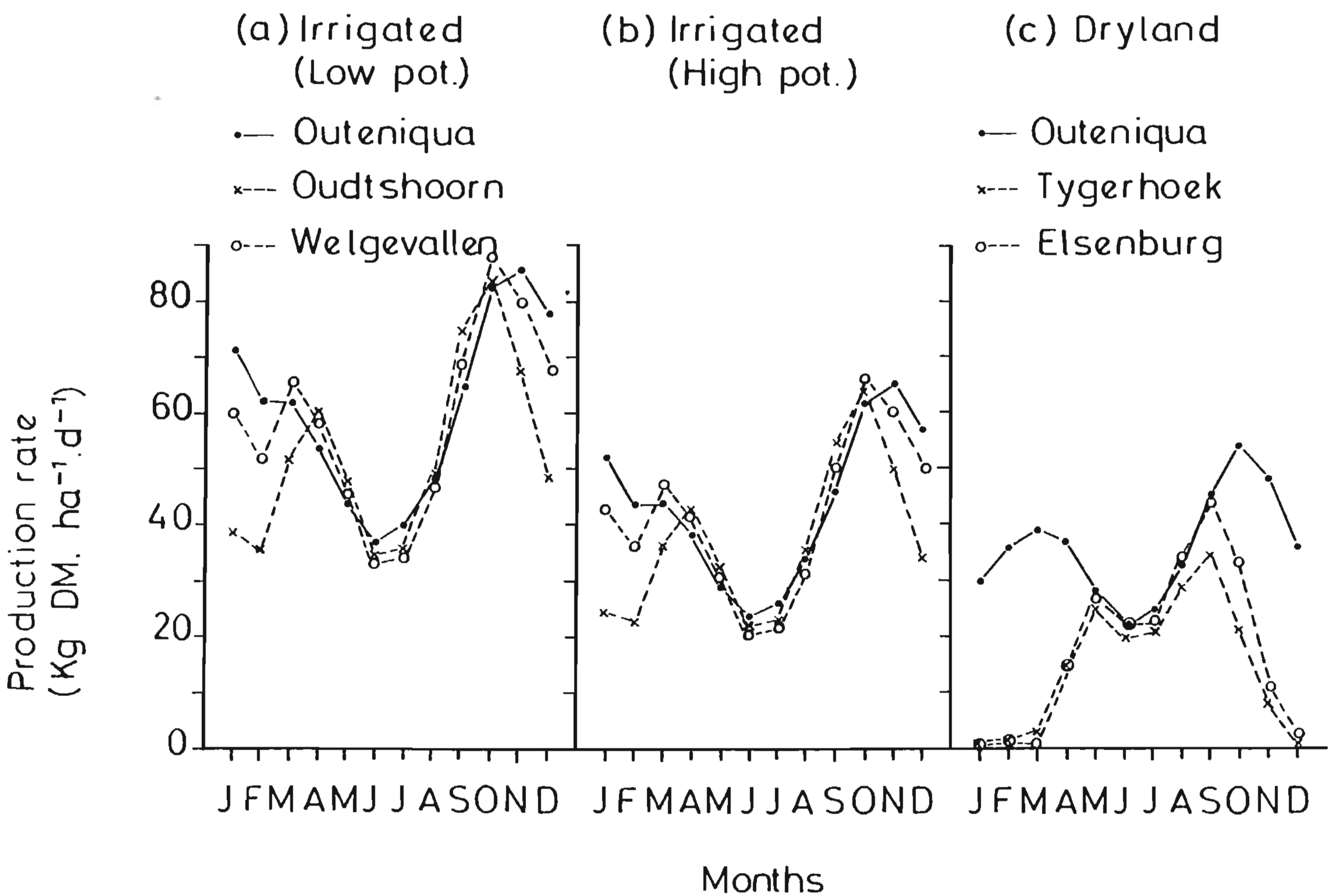


Figure 3.75 The long-term potential production rates (PPR) predicted, using the derived functions and long-term mean climatic data



Under irrigation, the large differences in PPR between the high and low potential soils are very clear at all three the sites. There were, however, also large seasonal variations in the PPR at each site, as well as differences in the seasonal PPR pattern at the different irrigated sites. At Welgevallen and Oudtshoorn, two periods of peak production occurred, i.e. during spring (October) and late summer/autumn (March). At Outeniqua (irrigated), however, only one peak occurred during October. The PPR values, therefore, tended to be highest at Outeniqua during the period November to March and lowest at Oudtshoorn. During the remainder of the year (April to October), the PPR values did not differ much at the different sites and the lowest values occurred during June and July at all sites.

Under dryland conditions the long-term seasonal PPR values do not differ much between Elsenburg and Tygerhoek. At these two sites growth starts during March/April and stops during November/December, with two periods of peak production occurring during May and September. At Outeniqua (dryland) the PPR values are similar to those of the other two dryland sites during the period May to September. At all three dryland sites, the lowest PPR, therefore, tends to occur during June and July. However, at Outeniqua (dryland), the PPR values tend to be much higher during summer than at the other two sites, with two periods of peak PPR occurring during March and October, with the highest during October.

3.3.7.4 Discussion and conclusions

The degree of response of fescue to cutting frequency was generally very small and tended to vary between sites. However, only at Welgevallen, was there an inconsistent response and it can be concluded that this species would generally maintain the highest production rates when cut every eight weeks.

The seasonal production pattern of fescue tended to vary slightly between different sites. Under irrigation two production peaks generally occurred, with the highest occurring during spring and the lowest during late summer. Between the peak production periods, one or two periods of very low production occurred of which the lower was during winter and the higher during early summer. This, therefore, indicates that the seasonal production of irrigated fescue would be most limiting during winter.

Under dryland conditions, a greater variation in seasonal production pattern occurred between the different sites. Generally, however, the highest production rates were attained during spring and the lowest during summer. Soil moisture, therefore, had a very important limiting influence on the seasonal production rates during summer. This is substantiated by the fact that the highest summer production rates was attained at Outeniqua (dryland), the site at which the summer soil moisture regime was most favourable.

Four fescue cultivars, Kentucky 31, Demeter, Alta and Kenhy, were evaluated under irrigation. It was generally found that the production patterns of Kentucky 31 and Demeter did not differ very much and that they were the highest producing. Demeter, however, tended to have the highest winter production rates and would therefore seem to be the most logical choice.

Three cultivars, Demeter, Kentucky 31 and Kenhy, were evaluated under dryland conditions. Kentucky 31 and Demeter were the highest producing during the greater part of the year at all three dryland sites. The greatest difference between the three cultivars occurred during winter, when Demeter was the highest and Kenhy the lowest producing.

Demeter should, therefore, be an even better choice under dryland than under irrigation.

The extrapolation of the actual measured seasonal production rates was very successful. However, the relationship between the APR and the GI, used to calculate the PPR, differed at irrigated sites, according to soil potential. This necessitated the development of two separate functions under irrigation. Under dryland, however, one function was sufficient, as the soil factor had a negligible influence. The effectivity of the different functions to extrapolate APR values was subsequently evaluated and found to be satisfactory under dryland, as well as under irrigation. This, therefore, indicated that the models could safely be used for extrapolation to different seasons at the same site.

The functions were subsequently used to calculate long-term PPR values for each site, using long-term mean monthly climatic data as input. Under irrigation, the calculated PPR values differ between soils of different potential, as well as seasonally at and between sites. Under dryland, equally large seasonal differences and differences between sites occur. During summer, the low MI values depress the PPR values at Elsenburg and Tygerhoek, but under dryland at Outeniqua and at the irrigated sites the PPR values are lowest during winter (June/July), resulting in the PPR values being most limiting during winter at the last mentioned sites. Higher MI values during summer at Outeniqua (dryland), however, result in higher PPR values being calculated at this site at this time of the year. Under dryland, as well as under irrigation, the highest PPR values occur during spring (September/October).

3.3.8 Cocksfoot

3.3.8.1 Influence of cutting frequency

The mean production rate (kg $DM.ha^{-1}.d^{-1}$) of all cocksfoot cultivars in three irrigated (Welgevallen, Outeniqua and Oudtshoorn) and three dryland trials (Elsenburg, Tygerhoek and Outeniqua), cut at three frequencies (four-, six- and eight-weekly), are depicted in figure 3.76.

The response of cocksfoot to the three cutting treatments was very small. At only one locality, Outeniqua (dryland and irrigated), was there any significant response between the four- and eight-weekly cutting frequencies. With the exception of Welgevallen, the tendency was, however, for the production rates to be highest at the eight-weekly cutting frequency.

3.3.8.2 Seasonal production

The mean seasonal production rates (kg $DM.ha^{-1}.d^{-1}$) of all cocksfoot cultivars evaluated in cutting trials at three irrigated (Welgevallen, Outeniqua and Oudtshoorn) and three dryland sites (Elsenburg, Tygerhoek and Outeniqua), are depicted in figures 3.77 and 3.78, respectively.

The standard deviations calculated for each site, which indicates the range of seasonal variation in the production rates, are also depicted. The seasonal production pattern did not differ much at the different irrigated sites (figure 3.77). At Oudtshoorn and Welgevallen the production rates, however, tended to be much lower during summer than at Outeniqua (irrigated). At all three sites the lowest production rates occurred during winter (May to July) and the highest during October/November.

Figure 3.76 Influence of cutting frequency on the mean production rate of cocksfoot under irrigation and dryland at Elsenburg (1981-84), Tygerhoek (1981-84), Outeniqua (1981-83), Welgevallen (1979-81) and Oudtshoorn (1981-84) (* LSD's for dryland and irrigated trials)

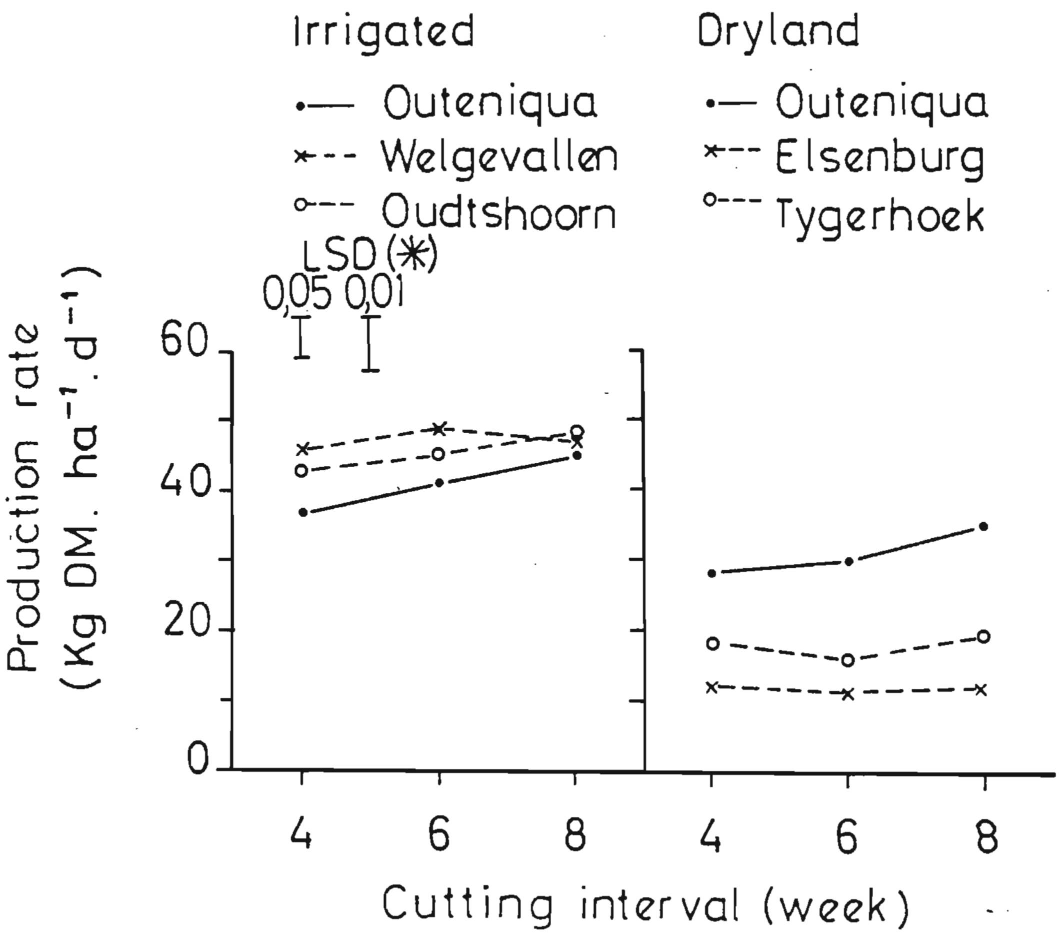


Figure 3.77 The production rate over all cocksfoot cultivars under irrigation at Welgevallen (1978-84), Outeniqua (1978-83) and Oudtshoorn (1978-84)

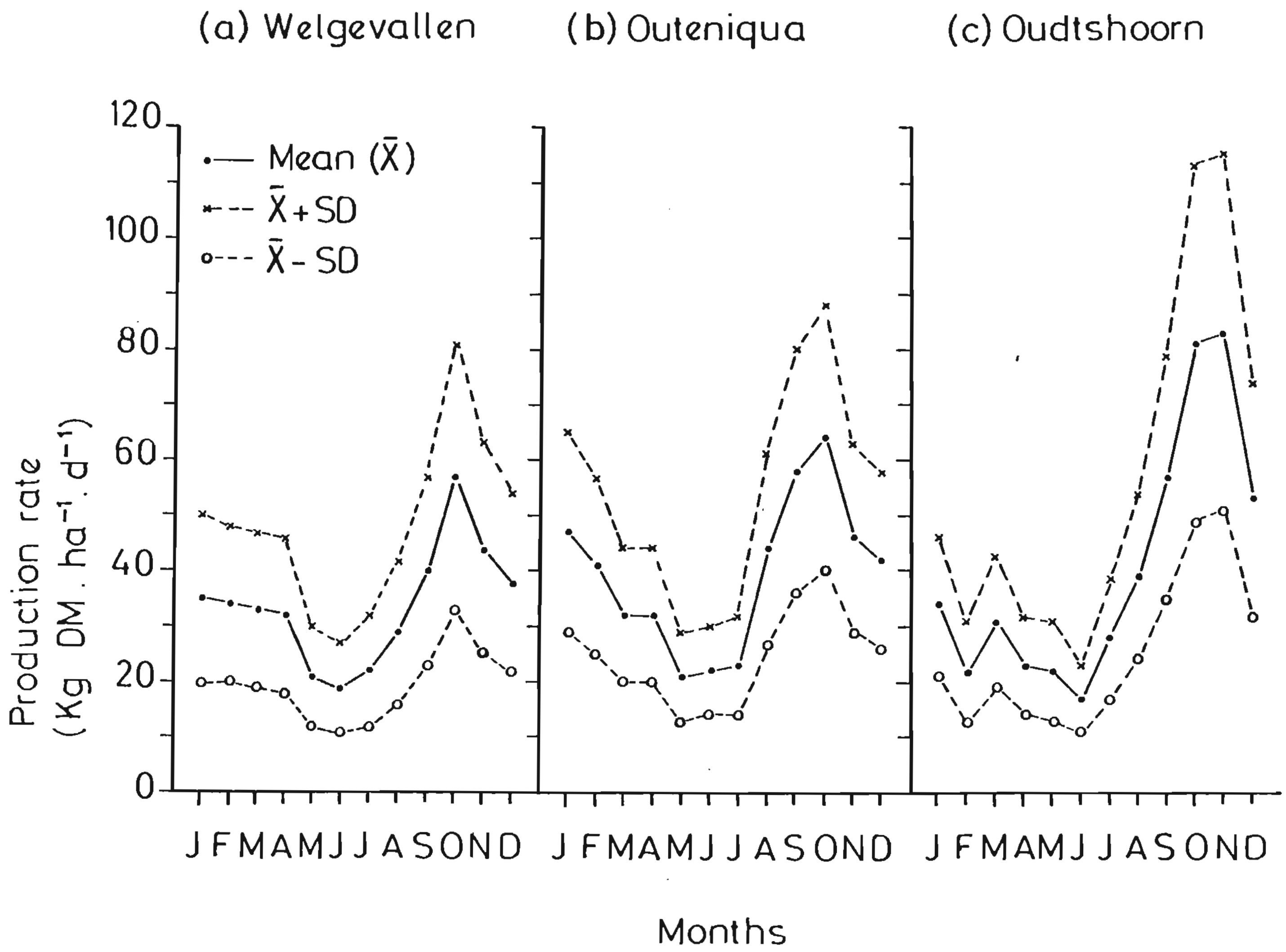
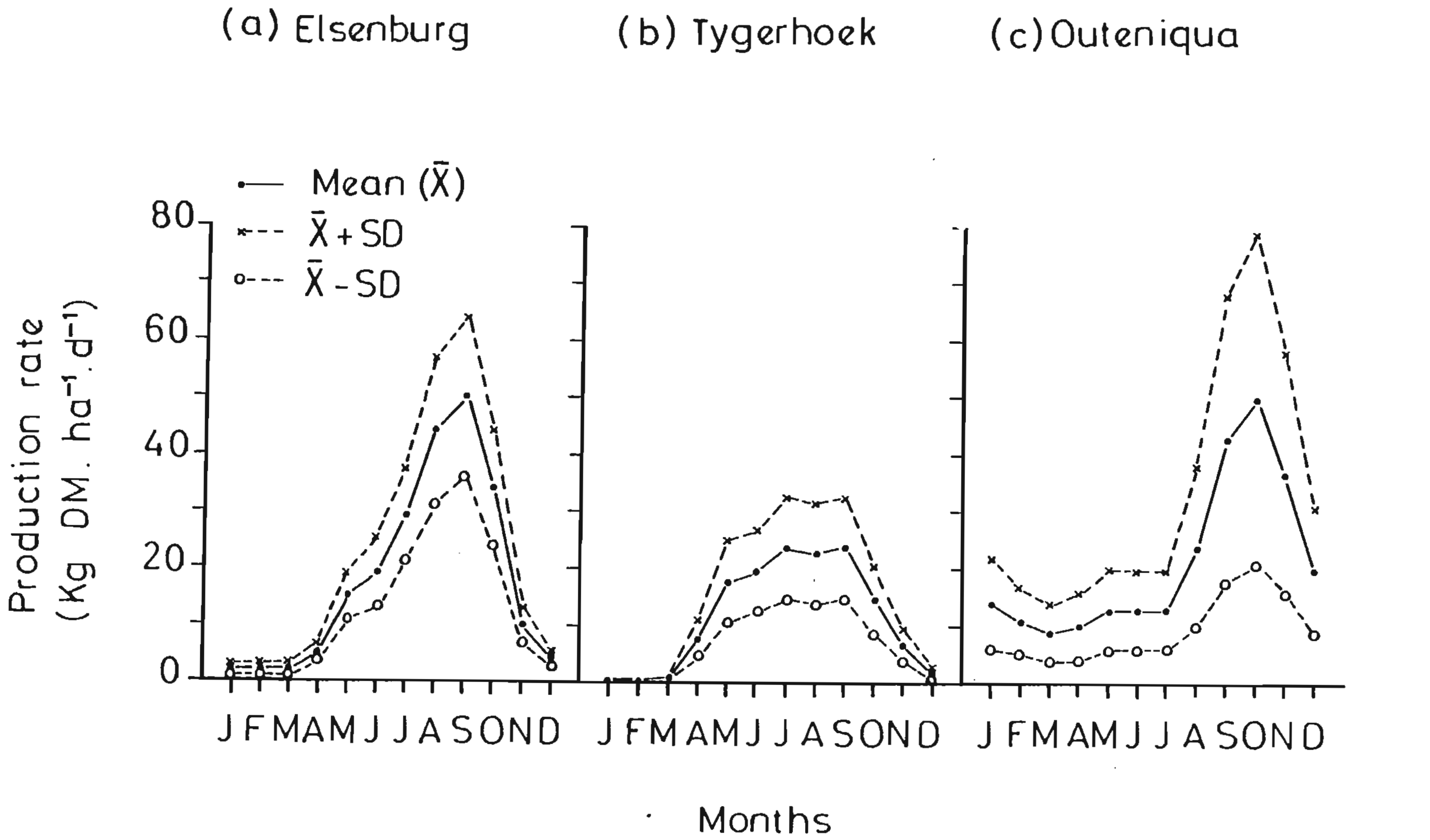


Figure 3.78 The production rate over all cocksfoot cultivars under dryland conditions at Elsenburg (1981-84), Tygerhoek (1981-84) and Outeniqua (1978-83)



Under dryland (figure 3.78) the seasonal production pattern and rates of cocksfoot varied greatly between the different sites. At Elsenburg and Tygerhoek very little or no growth occurred during the period December to March. Growth, however, resumed during April at these two sites and much higher production rates occurred during subsequent months until September, before a decrease occurred. The production rates, however, tended to reach a much higher peak at Elsenburg than at Tygerhoek during spring.

At Outeniqua (dryland) the production rates tended to be higher during summer than at the other two dryland sites and varied little during the period January to July. The production rates at this site, however, tended to be much lower during winter. During the period August to December the production rates at Outeniqua (dryland) increased to a distinctive peak during October.

A number of cultivars were evaluated at each locality. Unfortunately only two cultivars, Currie and Danish, were evaluated at Welgevallen. At all the other sites, however, three cultivars, Currie, Hera and Karkloof were evaluated. These results are depicted in figures 3.79 to 3.84.

Under irrigation at Welgevallen (figure 3.79), Currie and Danish had very much the same production patterns, although the production rates of Currie tended to be the highest. At Outeniqua (irrigated) (figure 3.80) and Oudtshoorn the three cultivars Currie, Hera and Karkloof also tended to have similar production patterns and rates.

Under dryland conditions at Elsenburg (figure 3.82), Tygerhoek (figure 3.83) and Outeniqua (figure 3.84) the seasonal production patterns of the three cultivars Currie, Hera and Karkloof were very similar. At Tygerhoek and Elsenburg, Currie seemed to have had the highest production

Figure 3.79 Production rate of two cocksfoot cultivars under irrigation at Welgevallen (1978-81)

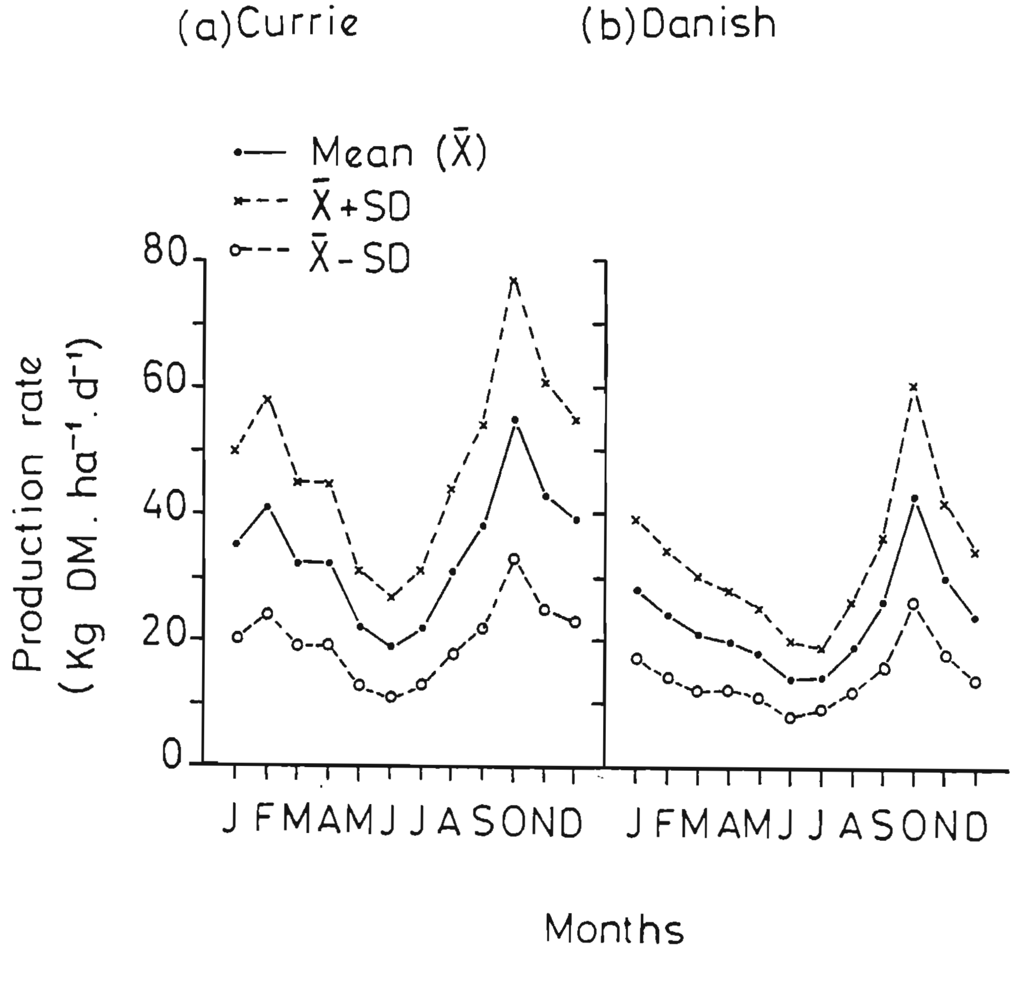


Figure 3.80 Production rate of three cocksfoot cultivars under irrigation at Outeniqua (1978-83)

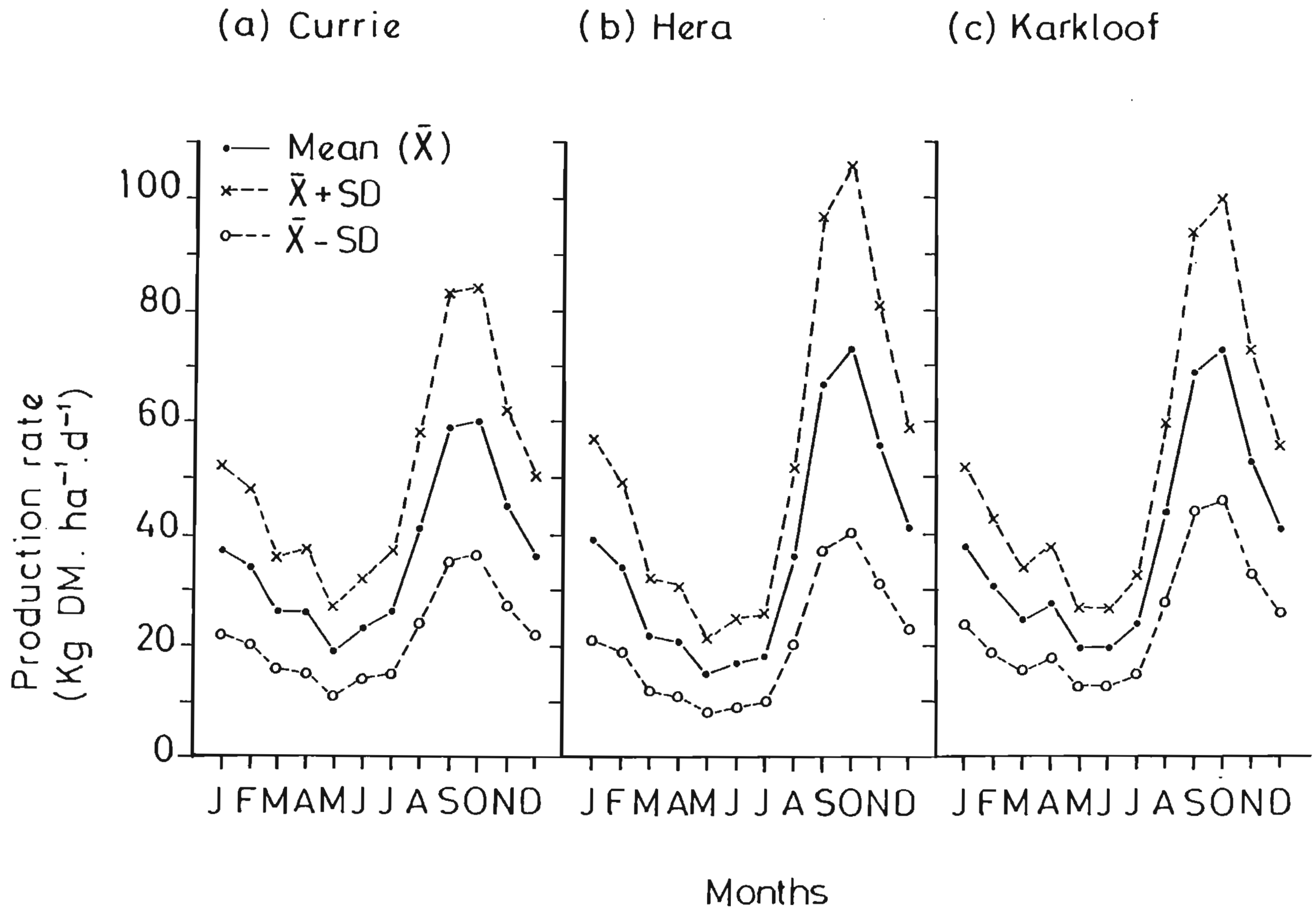


Figure 3.81 Production rate of three cocksfoot cultivars under irrigation at Oudtshoorn (1978-84)

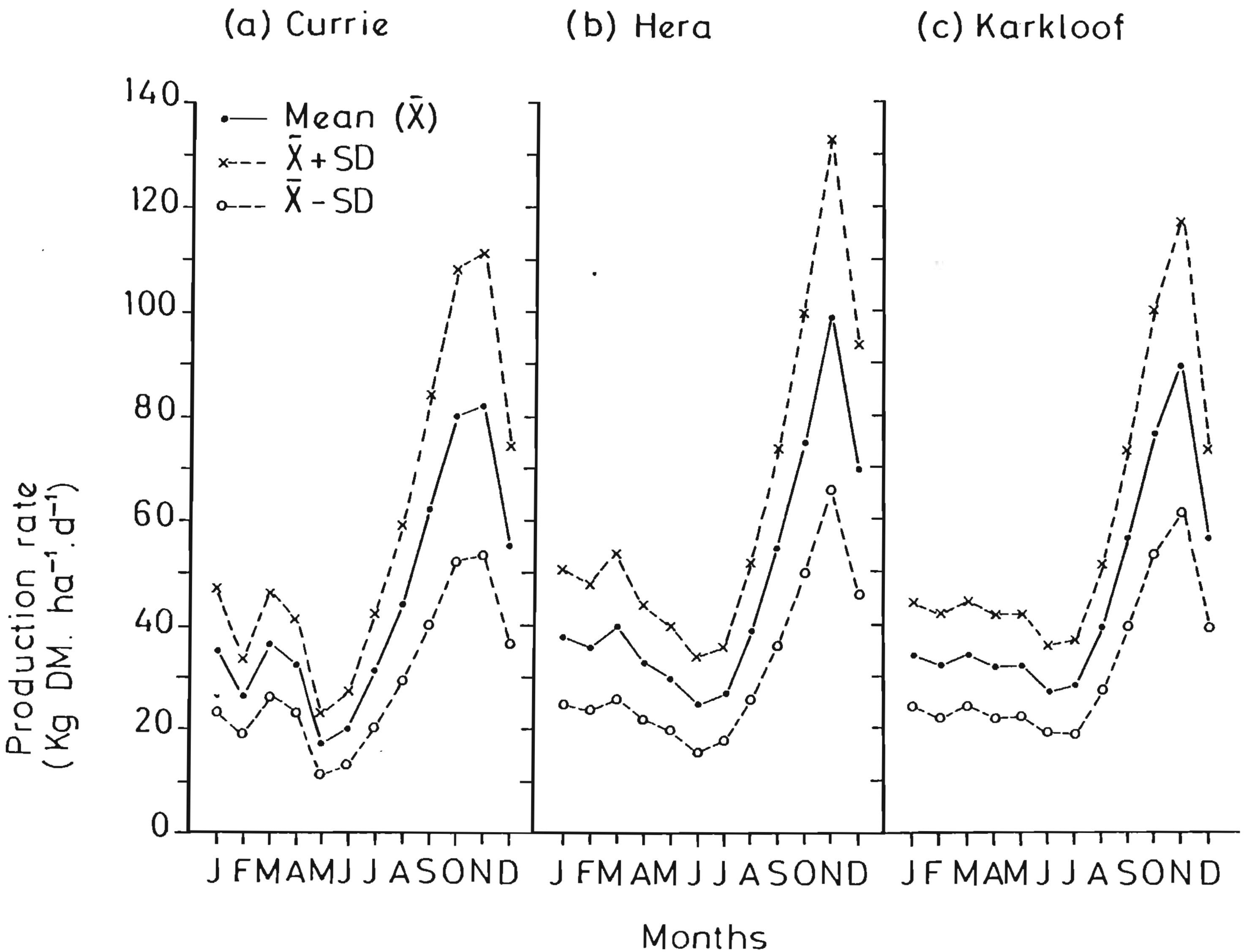


Figure 3.82 Production rate of three cocksfoot cultivars under dryland at Elsenburg (1981-84)

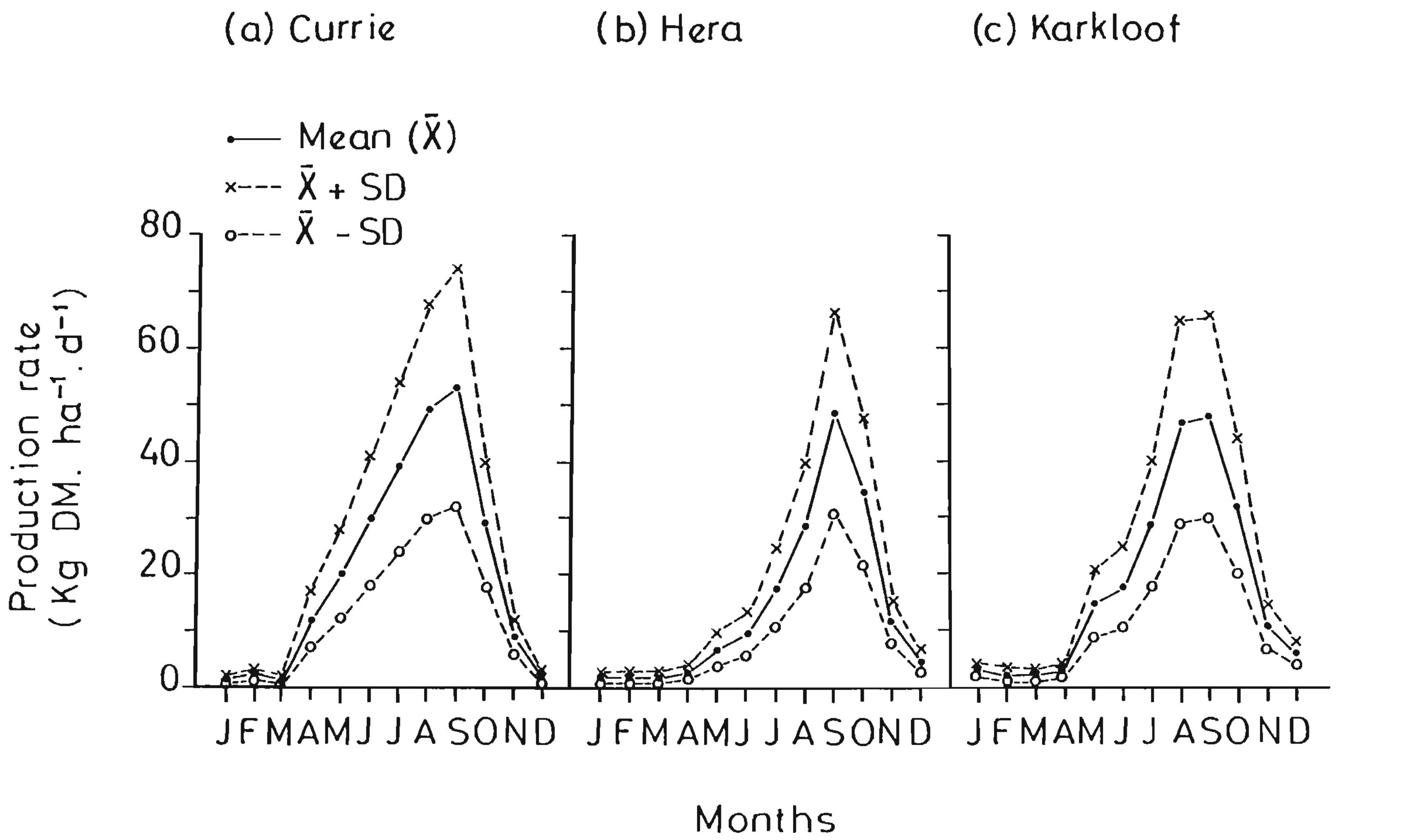


Figure 3.83   Production rate of three cocksfoot cultivars under dryland at Tygerhoek (1981-84)

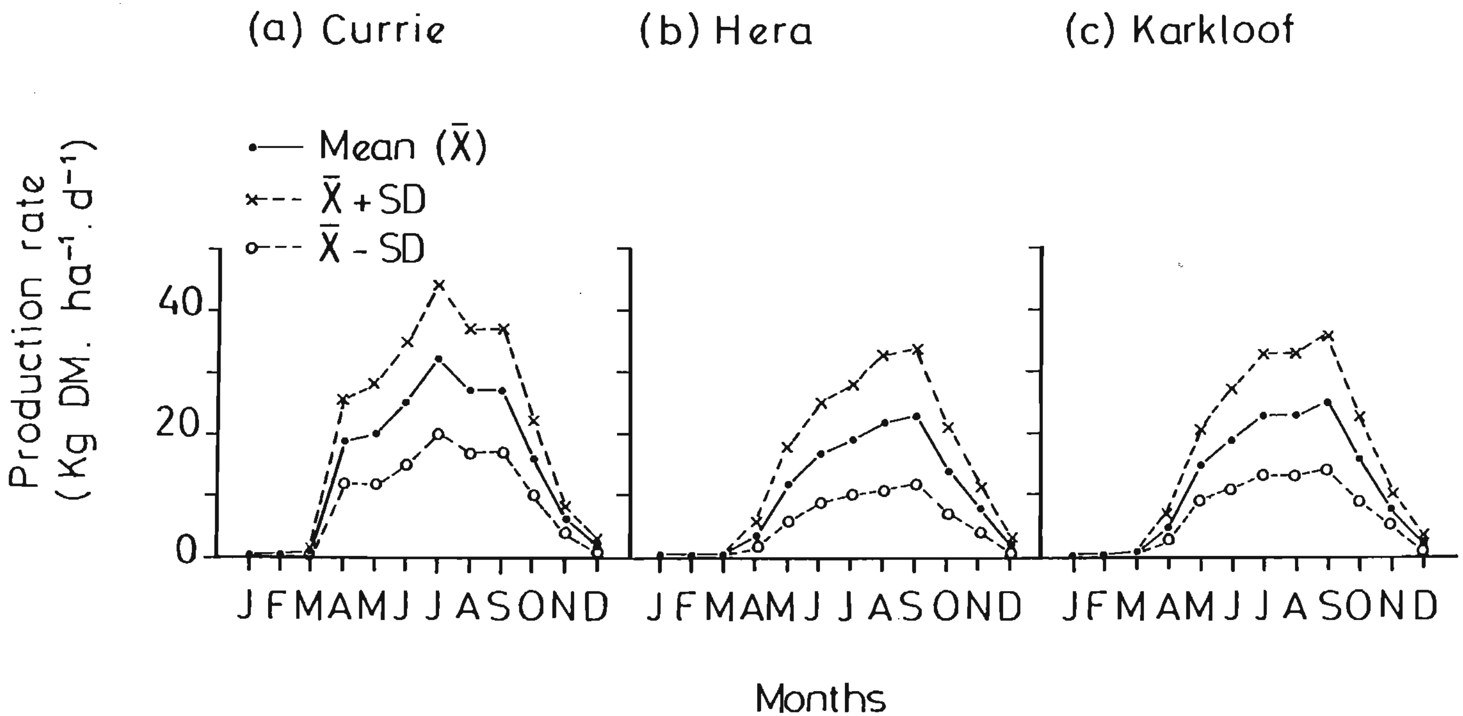
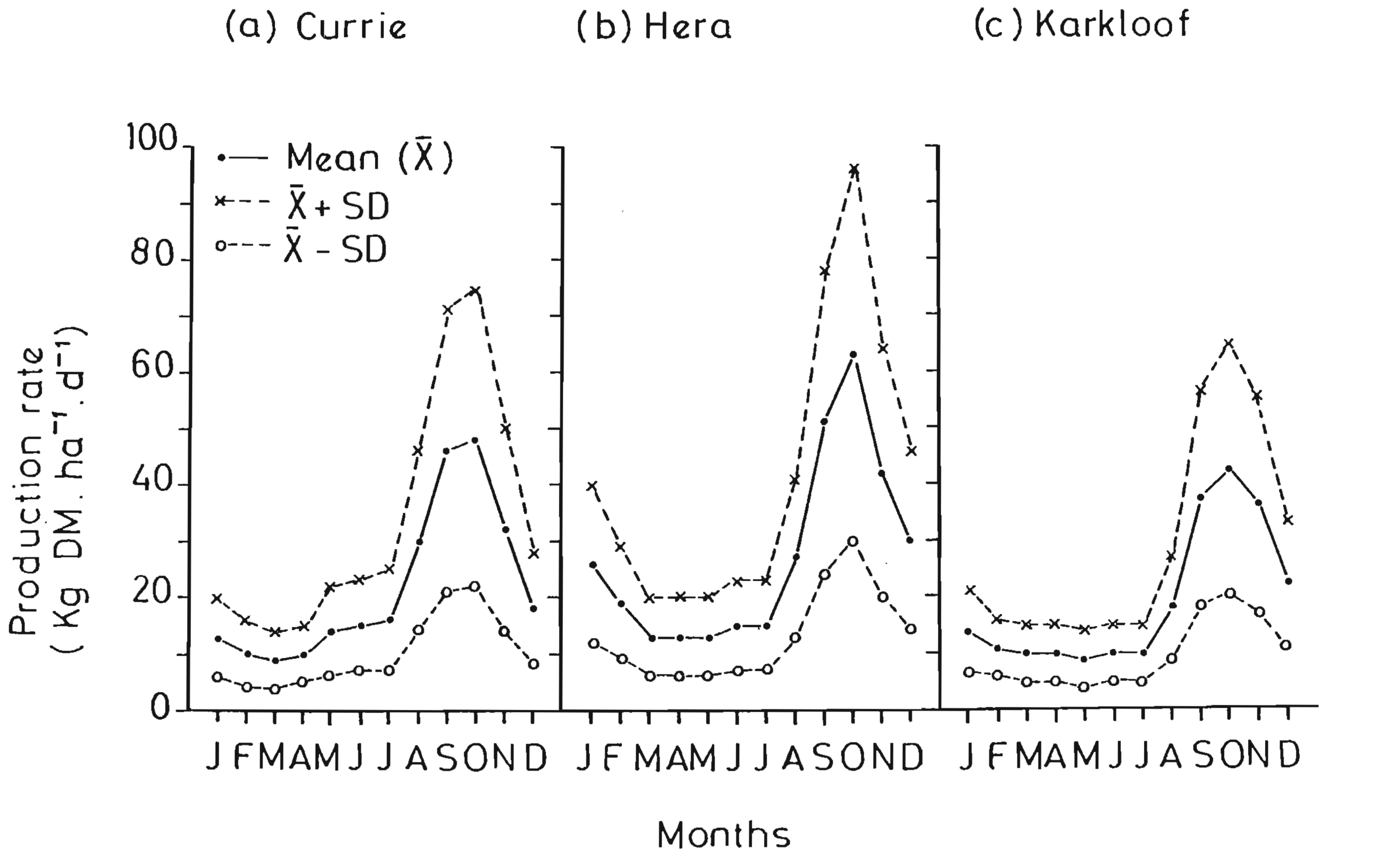


Figure 3.84 Production rate of three cocksfoot cultivars under dryland at Outeniqua (1978-83)



rates during the greater part of the year, but at Outeniqua very few differences were apparent.

3.3.8.3 Extrapolation of production rate data

Seasonal production rate data, derived at three irrigated (Welgevallen, Outeniqua and Oudtshoorn) and three dryland sites (Elsenburg, Tygerhoek and Outeniqua), were used for the development of functions for the extrapolation of the seasonal production rates to different seasons. The following functions were derived:

$MI = R.(0,5E)^{-1}$ (two-monthly means),
where R = total monthly rainfall (mm) and E = total monthly class A pan evaporation (mm);

$TI = \exp(-(T-15)^2.86^{-1})$,
where T = mean monthly air temperature (°C);

$RI = Q_{TOT}.17^{-1}$,
when $Q_{TOT} \leq 17$ and

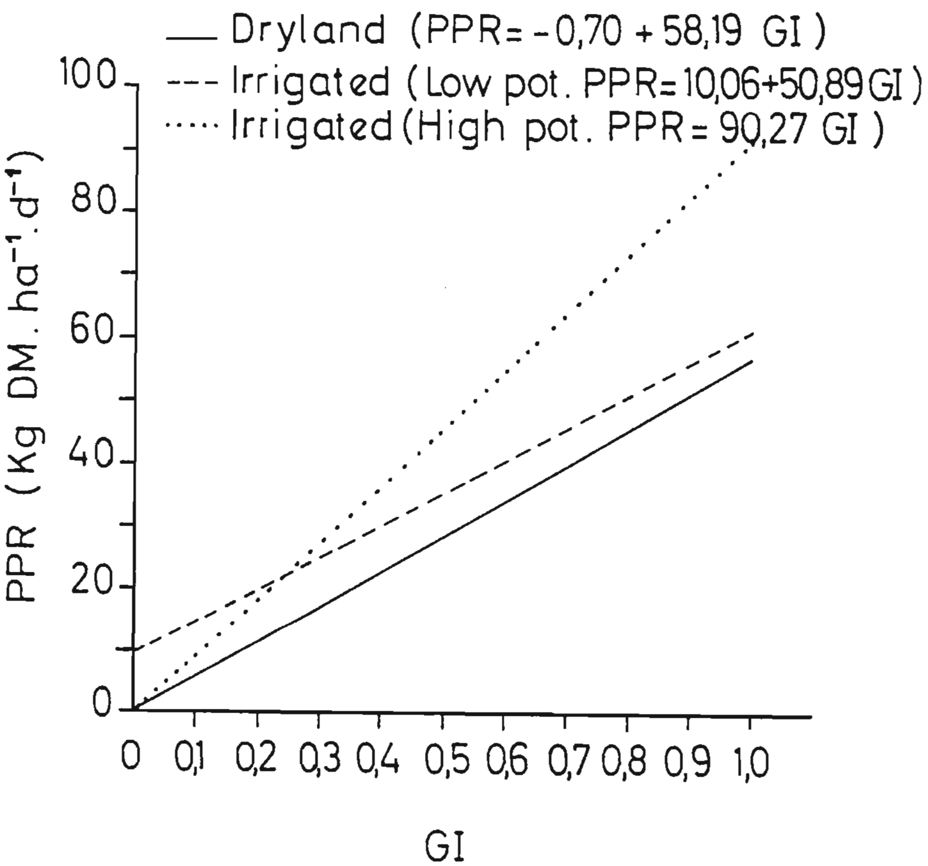
$RI = 17.Q_{TOT}$,
when $Q_{TOT} > 17$ and where Q_{TOT} = mean monthly total daily solar radiation ($MJ.M^{-2}.d^{-1}$);

$RTI = RT.RT_{MAX}^{-1}$,
where $RT = Q_{TOT}.T^{-1}$ and RT_{MAX} = maximum RT value;

$GI = MI \times RI \times TI \times RTI$.

Three relationships were developed between GI and the actual production rate (APR) and used for the calculation of the potential production rate (PPR). The three relationships are depicted graphically in figure 3.85. Under dryland a

Figure 3.85 Relationships between the growth index (GI) and the potential production rate (PPR) for cocksfoot under dryland and irrigation



single relationship sufficed, as soil did not have a very large influence on the production rates at the different sites. GI was, therefore, the main determinant of seasonal production rate. The following function was derived for use under dryland:

$$PPR = -0,70 + 58,19GI.$$

Under irrigation two functions had to be developed due to the influence of soil potential on seasonal production. A function was, therefore, developed for a high potential soil, represented by the Oakleaf soil form of the Oudtshoorn trial site, as well as one for a low potential soil, represented by the Estcourt and Katspruit soil forms, respectively of the Outeniqua and Welgevallen trial sites. The functions were as follows:

$$PPR \text{ (high potential soil)} = 90,27GI$$

$$PPR \text{ (low potential soil)} = 10,06 + 50,89GI.$$

For the validation of the three above-mentioned functions, data acquired during the last season, were excluded so that they could be used for this purpose. The only site at which all the data were used for model development was Welgevallen. As a first step, the PPR and APR values were compared over the whole trial period at each trial site. These results are depicted in figures 3.86 and 3.87.

The PPR curves followed that of the APR very well under irrigation (figure 3.86), as well as under dryland (figure 3.87) and at all sites the R^2 values were highly significant. Under dryland conditions (figure 3.87), however, the PPR values deviated more from the APR curves than under irrigation. The largest deviations occurred during the period December to April at Outeniqua (dryland) and during May to October at Elsenburg.

Figure 3.86 Comparison of actual (APR) and predicted potential (PPR) production rates at three irrigated sites over the whole experimental period

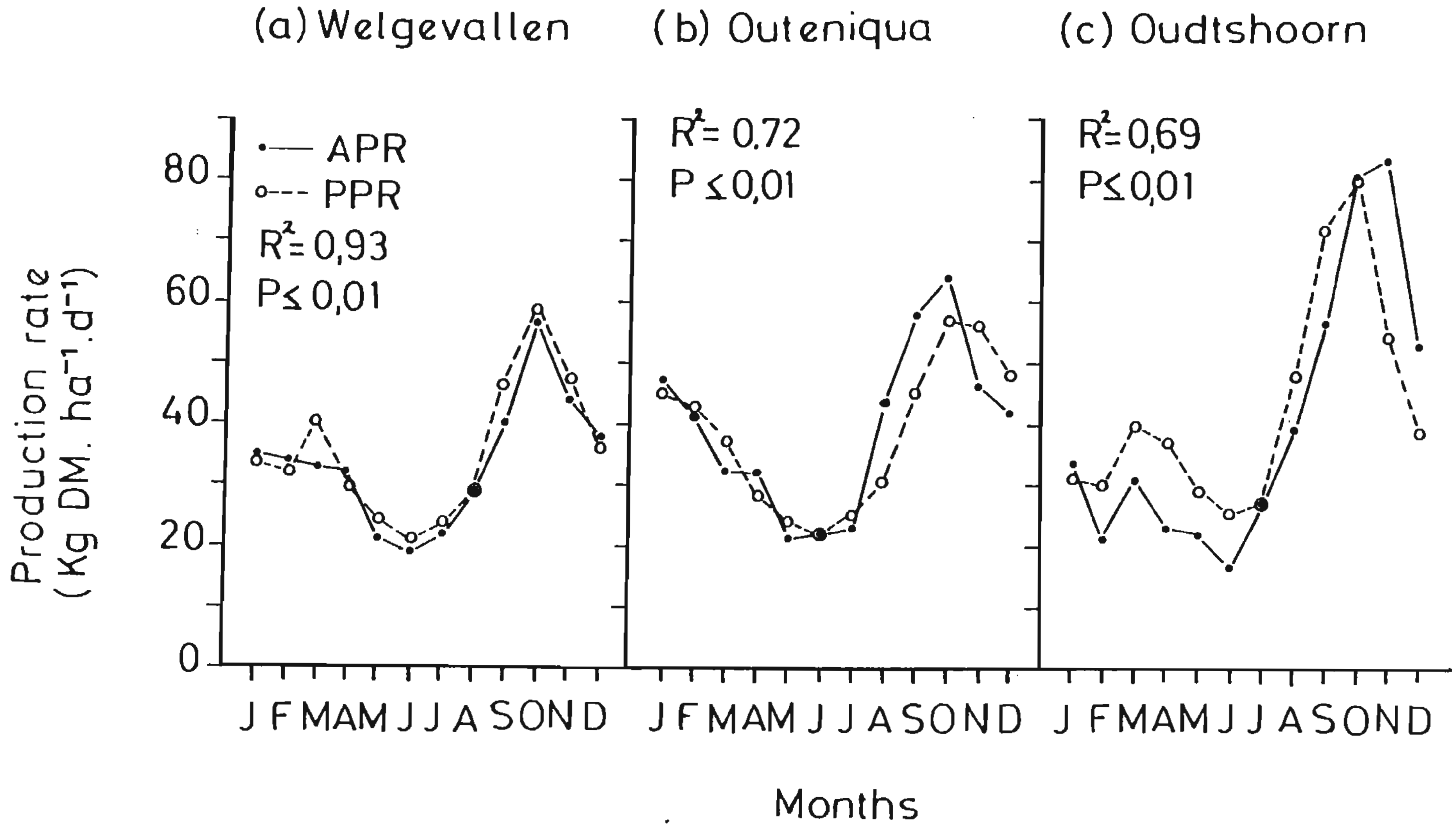
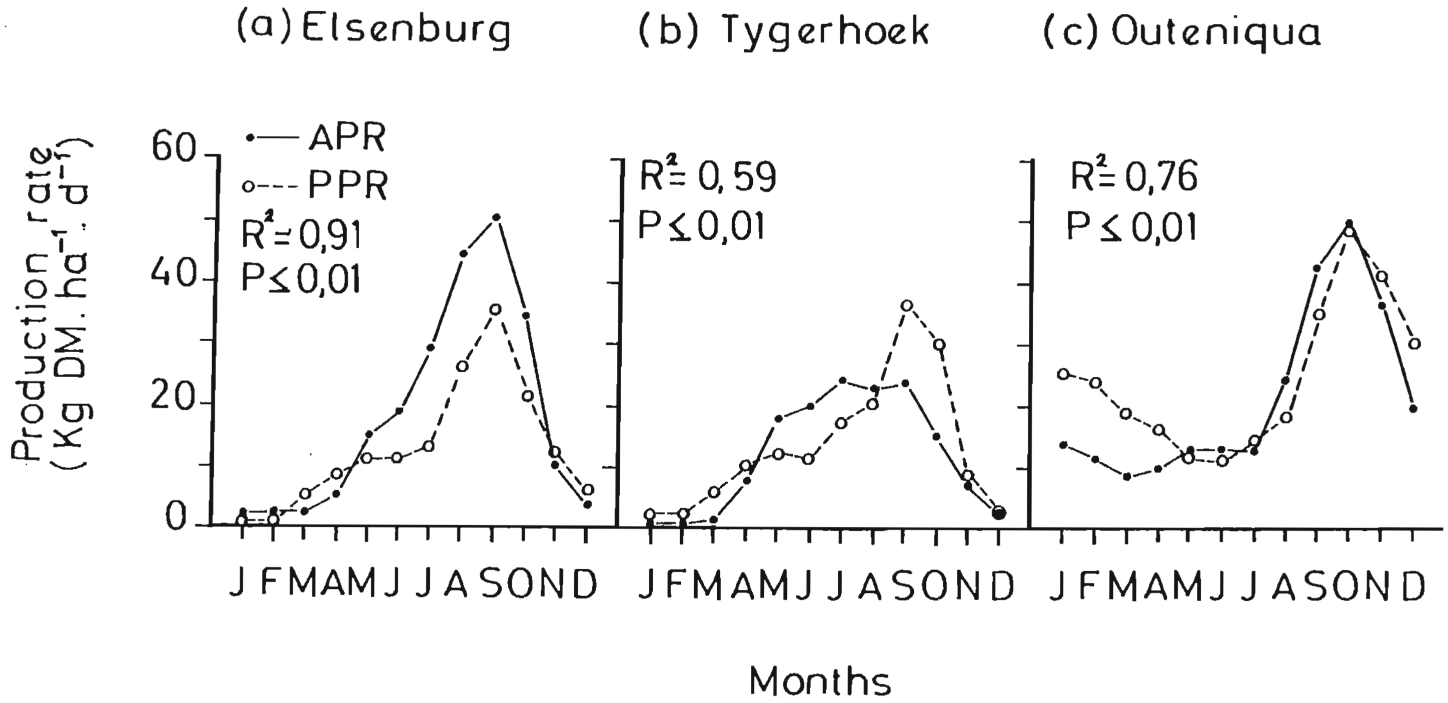


Figure 3.87 Comparison of actual (APR) and predicted potential (PPR) production rates at three dryland sites over the whole experimental period



The results were promising, but a further validation of the models was necessary. As has been indicated, part of the data not used for the development of the models was used for this purpose. These results are presented in figures 3.88 and 3.89 respectively. The results found under irrigation at Outeniqua and Oudtshoorn (figure 3.88) were very satisfactory and for both the sites the R^2 values were highly significant. Under dryland the results were equally promising and although the PPR values deviated more from the APR curves than under irrigation, the R^2 values were significant in all cases. These values were, however, lower than was found for the longer term values (figure 3.86). It must, however, be borne in mind that the models used were very simple and therefore not entirely suitable for the prediction of actual monthly PPR values. For the calculation of long-term PPR values using long-term mean monthly climatic data, these models should, however, be satisfactory.

Using the derived functions, the long-term PPR values were calculated for each site, with long-term mean monthly climatic data as input. The derived curves are depicted in figure 3.90. Under irrigation there seems to be no difference between the PPR calculated for low and high potential soils during the period May to July. During the rest of the year, the PPR values for the high potential soils, however, seem to be much higher. The PPR values for the different sites also do not seem to differ during the period April to September. During the period October to March, however, the PPR values are lowest at Oudtshoorn and during the period November to February they are highest at Outeniqua. During March and October they are highest at Welgevallen.

Figure 3.88 Comparison of actual (APR) and predicted potential (PPR) production rates at two irrigated sites, using data which had not been utilised during the development phase

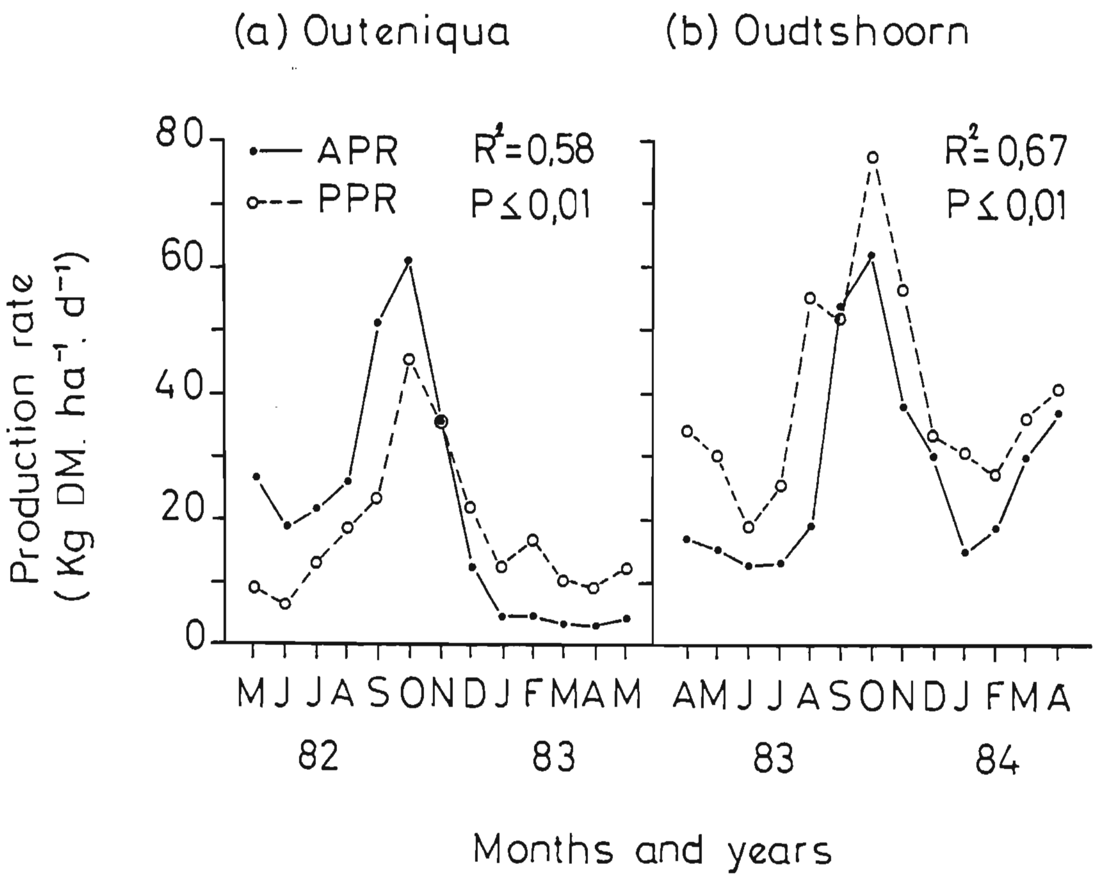


Figure 3.89 Comparison of actual (APR) and predicted potential (PPR) production rates at three dryland sites, using data which had not been utilised during the development phase

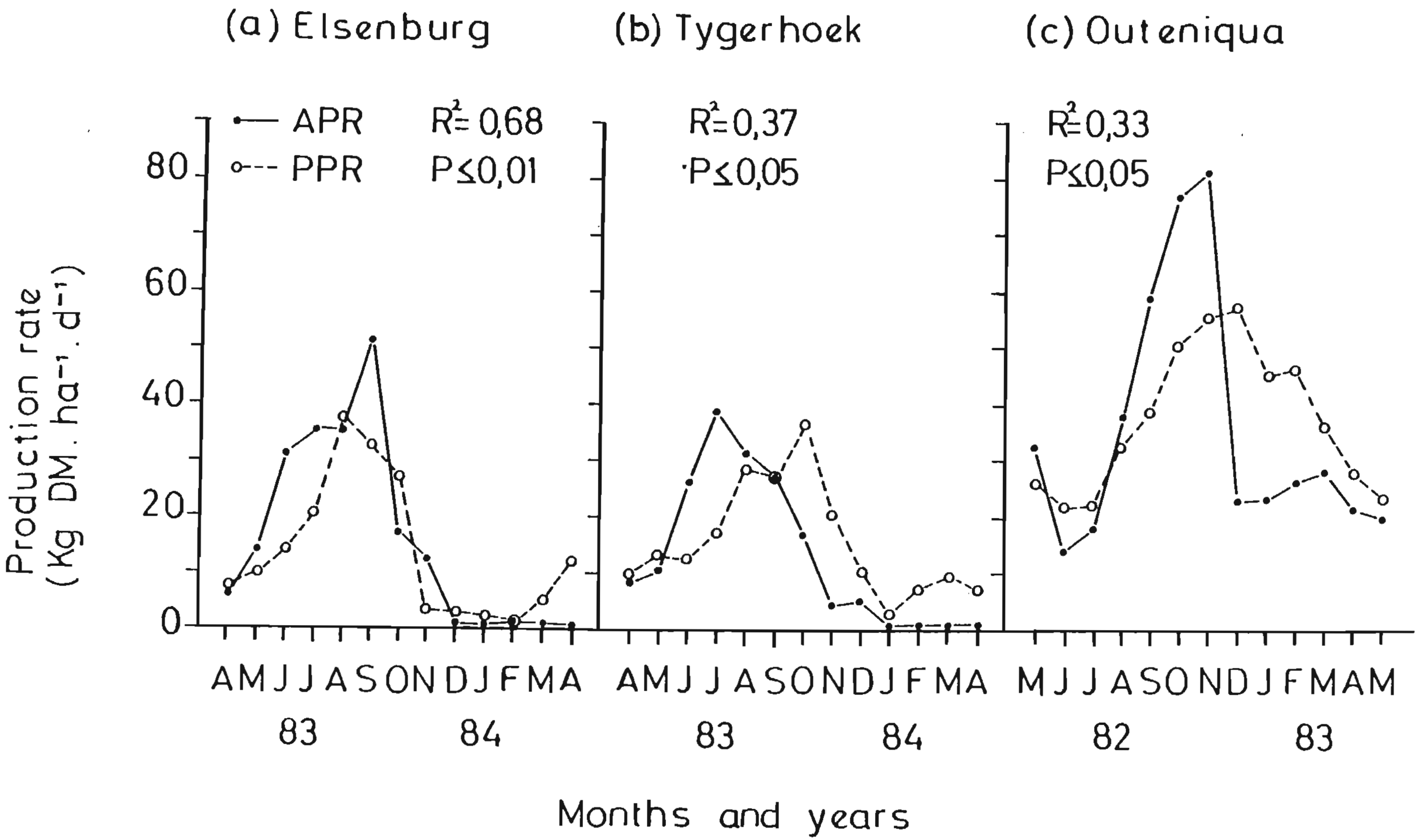
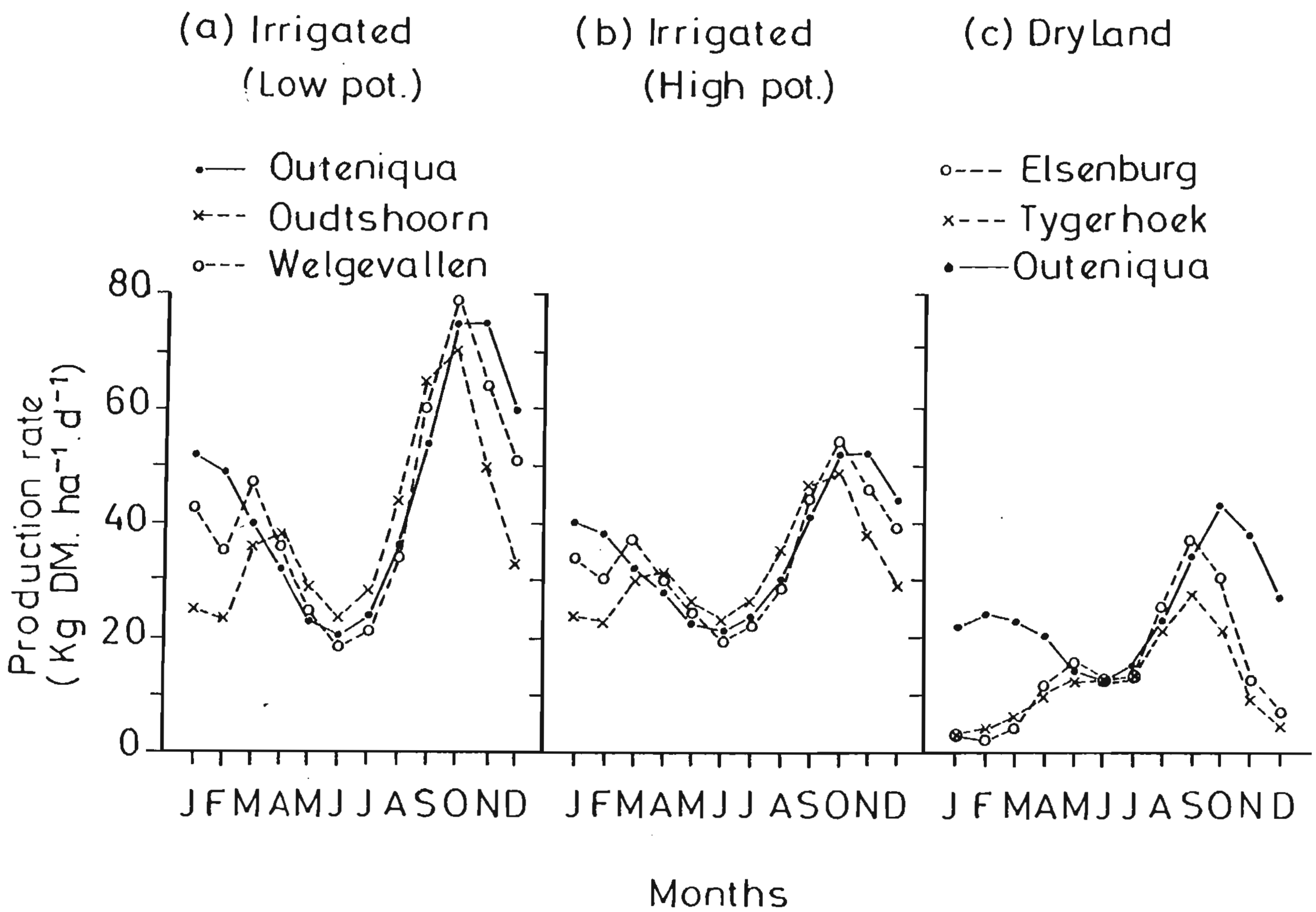


Figure 3.90 Long-term potential production rate (PPR) of cocksfoot, predicted using the derived functions and long-term mean climatic data



The PPR values of the three dryland sites do not differ much between sites during the period May to August. During September the values for Elsenburg and Outeniqua (dryland) are very similar, but tend to be higher than those calculated for Tygerhoek. During the period October to April the PPR values of Outeniqua (dryland), however, are much higher than those calculated for Elsenburg and Tygerhoek, while those of the latter two sites do not differ much.

3.3.8.4 Discussion and conclusions

The response of cocksfoot to cutting treatments was very small, but the general tendency was for the production rates to be highest at the eight-weekly cutting frequency. It therefore seems as if cocksfoot is not very sensitive to cutting frequency and would have very much the same production rate over a wide range of cutting frequencies.

The production pattern of cocksfoot did not differ very much at the different irrigated sites. Generally, the lowest production rates under irrigation occurred during winter and the highest during spring. The production rates were also greatly depressed during summer at Oudtshoorn and Welgevallen and cocksfoot, therefore, generally seems to produce very seasonally under irrigation.

Under dryland the seasonal production pattern of cocksfoot varied quite substantially between the different sites. At Elsenburg and Tygerhoek the highest production rates tended to occur during winter and spring, while the production rates at Outeniqua (dryland) seemed highest during spring. The summer production rates at Outeniqua (dryland) were, however, much higher than at the other two sites, but during winter the production rates tended to be lower at Outeniqua. The most limiting period at Elsenburg and Tygerhoek, therefore, seems to be summer, while this seems to occur during winter, as well as in summer, at Outeniqua.

Evaluating the four cultivars Currie, Hera, Karkloof and Danish under irrigation, it was found that the difference between the cultivars was very small and it is doubtful whether there would be any practical advantage in any specific cultivar. Under dryland conditions at Elsenburg and Tygerhoek the production rates of Currie, however, tended to be much higher than that of Hera and Karkloof. At Outeniqua (dryland) there again seemed very little difference between the three cultivars.

Under dryland, in an area with a Mediterranean type rainfall distribution, i.e. having relatively dry summers and very wet winters such as Tygerhoek and Elsenburg, Currie would, therefore, be the most logical choice. Under irrigation, and under dryland in an area receiving a reasonable amount of summer rainfall there seems to be very little difference between the cultivars.

The production rates, determined in the cutting trials, were used to develop functions depicting the relationship between mean monthly climatic data and production rates. Under dryland conditions, only one function was sufficient to describe the relationship between GI and the actual production rate (APR), used to predict the potential production rate (PPR). Under irrigation, two separate functions, one for a high potential and one for a low potential soil situation were, however, necessary.

The functions were validated by comparing PPR values with APR values over the whole experimental period at all sites, as well as with new APR data for one season only. It was subsequently found that the PPR values followed the APR curves very well and that R^2 was significant in all cases.

The functions were subsequently used to extrapolate the production rates to different seasons at the different sites, using long-term mean monthly climatic values as input. Under irrigation, the calculated PPR seems to vary over seasons, as well as between soils of different potential at the same site. The greatest difference between different soils, as well as between different sites, seems to occur during the period November to March and during this period the highest PPR is generally calculated for Outeniqua (irrigated). Under dryland conditions the largest differences between sites seem to occur during the period September to April, during which the PPR values also seem to be highest at Outeniqua (dryland).

The seasonal pattern of the long-term PPR values also differ at the different sites. Under irrigation two peaks occur at Oudtshoorn and Welgevallen, the highest during October and the lowest during March/April. At Outeniqua (irrigated), however, only one peak occurs during October/November. Under dryland at Outeniqua the lowest PPR rates occur during winter (May to July), but at both Elsenburg and Tygerhoek the PPR values are lowest during summer (December to March).

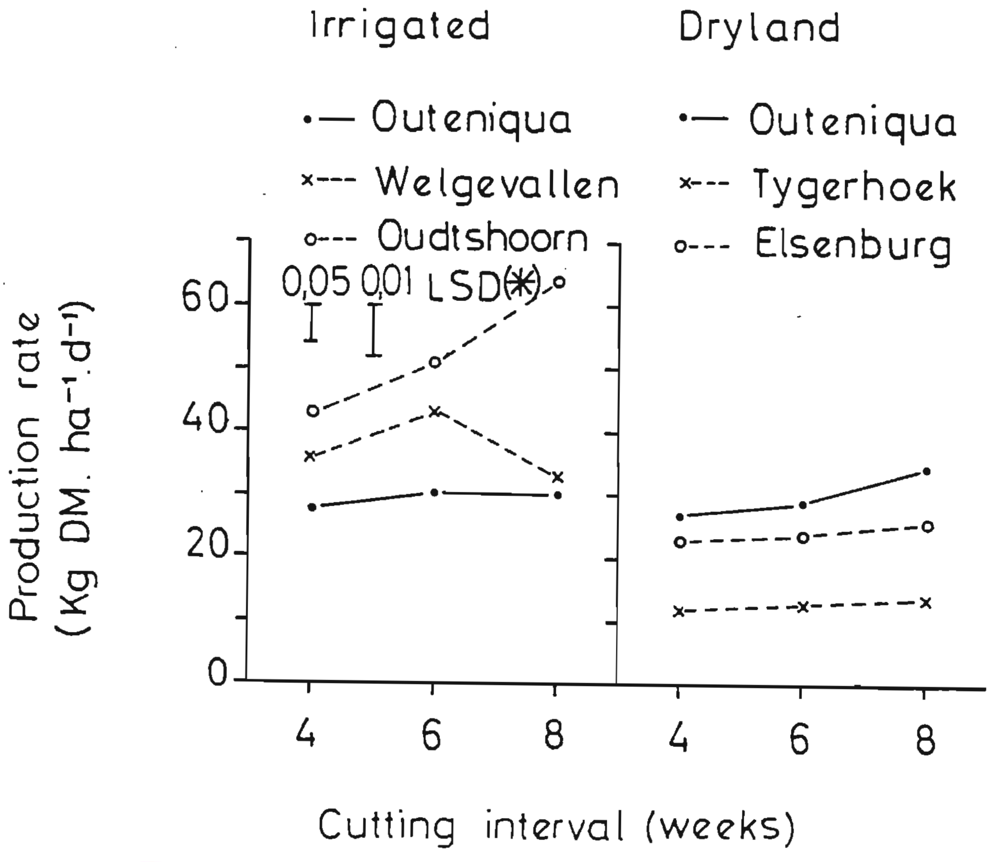
3.3.9 Phalaris

3.3.9.1 Influence of cutting frequency

The mean production rate (Kg $DM.ha^{-1}.d^{-1}$) of Phalaris (cv Seedmaster) in three irrigated (Welgevallen, Outeniqua and Oudtshoorn) and three dryland trials (Elsenburg, Tygerhoek and Outeniqua), cut at three frequencies (four-, six- and eight-weekly), are depicted in figure 3.91.

The degree of response to cutting frequency differed at the different sites. Welgevallen, Oudtshoorn and Outeniqua

Figure 3.91 Influence of cutting frequency on the mean production rate of Phalaris under irrigation and dryland at Elsenburg (1981-84), Tygerhoek (1981-84), Outeniqua (1981-83), Welgevallen (1979-81) and Oudtshoorn (1981-84) (* LSD's for dryland and irrigated trials)



(dryland) were the only sites at which a significant response was noted. At Oudtshoorn and Welgevallen the response was significant between the four- and six-, as well as between the six- and eight-weekly frequencies, but at Outeniqua (dryland) only between the four- and eight-weekly frequencies.

The form of the response also differed at the different sites. At Oudtshoorn and Outeniqua (dryland), the highest production rates were attained at the eight-weekly frequency, but at Welgevallen a peak occurred at the six-weekly frequency. In spite of the significant response at Outeniqua (dryland), the response was generally very small at the dryland sites.

3.3.9.2 Seasonal production

Only one cultivar was evaluated at all the sites, i.e. cv Seedmaster, and the results of this cultivar will be used in all the subsequent discussions. The mean seasonal production rates (Kg $DM.ha^{-1}.d^{-1}$) of Seedmaster in cutting trials at three irrigated (Welgevallen, Outeniqua and Oudtshoorn) and three dryland sites (Elsenburg, Tygerhoek and Outeniqua), are depicted in figures 3.92 and 3.93, respectively. Also depicted, are the standard deviations calculated for each site, which indicate the seasonal variation in mean monthly production rates.

The seasonal production pattern of Phalaris seems to differ at the three irrigated sites (figure 3.92). At Welgevallen, the lowest production rates were measured during January/December. Two peaks occurred at this site, i.e. during October (the highest) and February/March. At Outeniqua (irrigated) the production rates tended to be very low and reasonably constant during the whole period December to July. During the period August to October, a sharp

Figure 3.92 The production rate of <u>Phalaris</u> (cv. Seedmaster) under irrigation at Welgevallen (1978-81), Outeniqua (1978-83) and Oudtshoorn (1978-84)

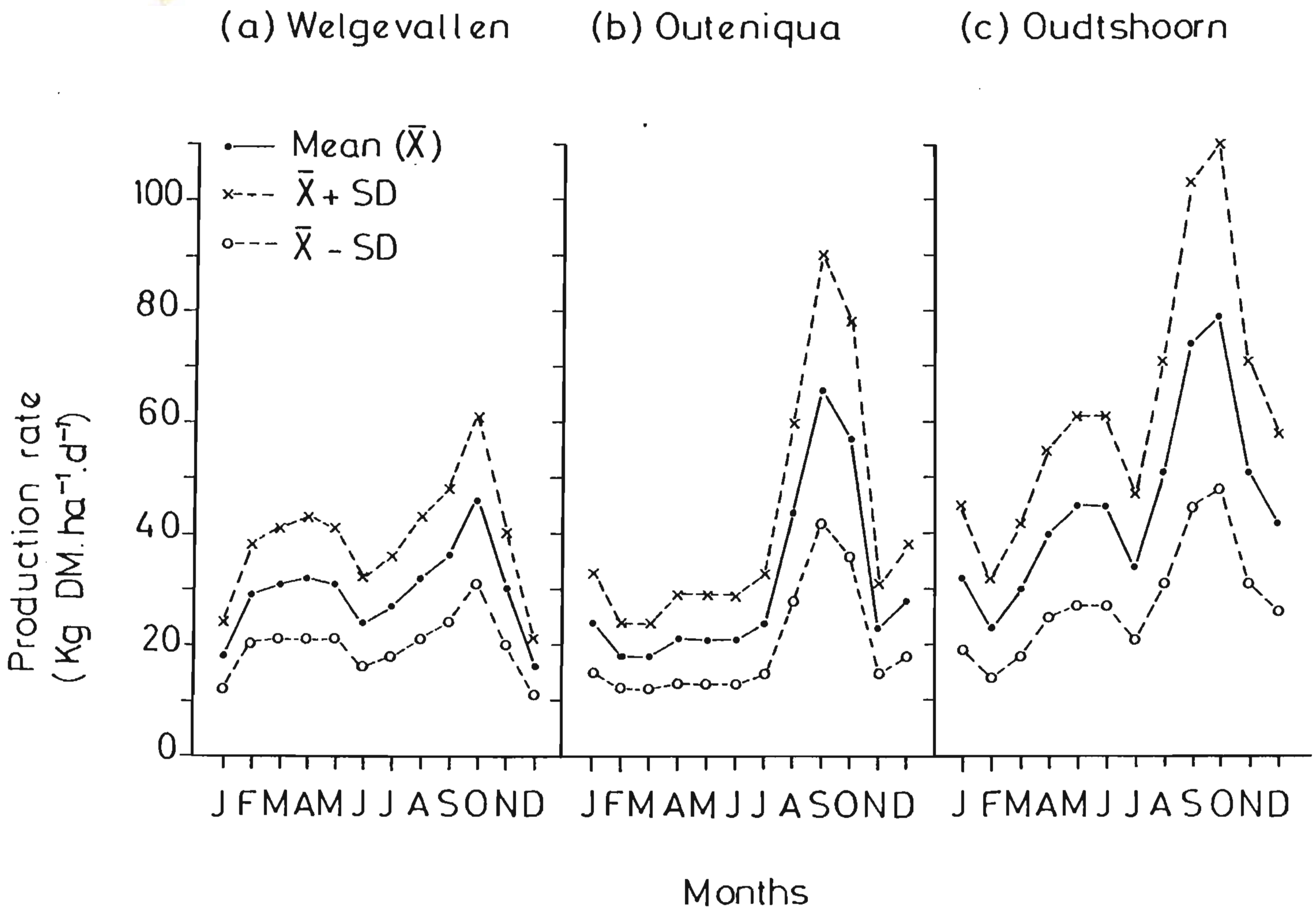
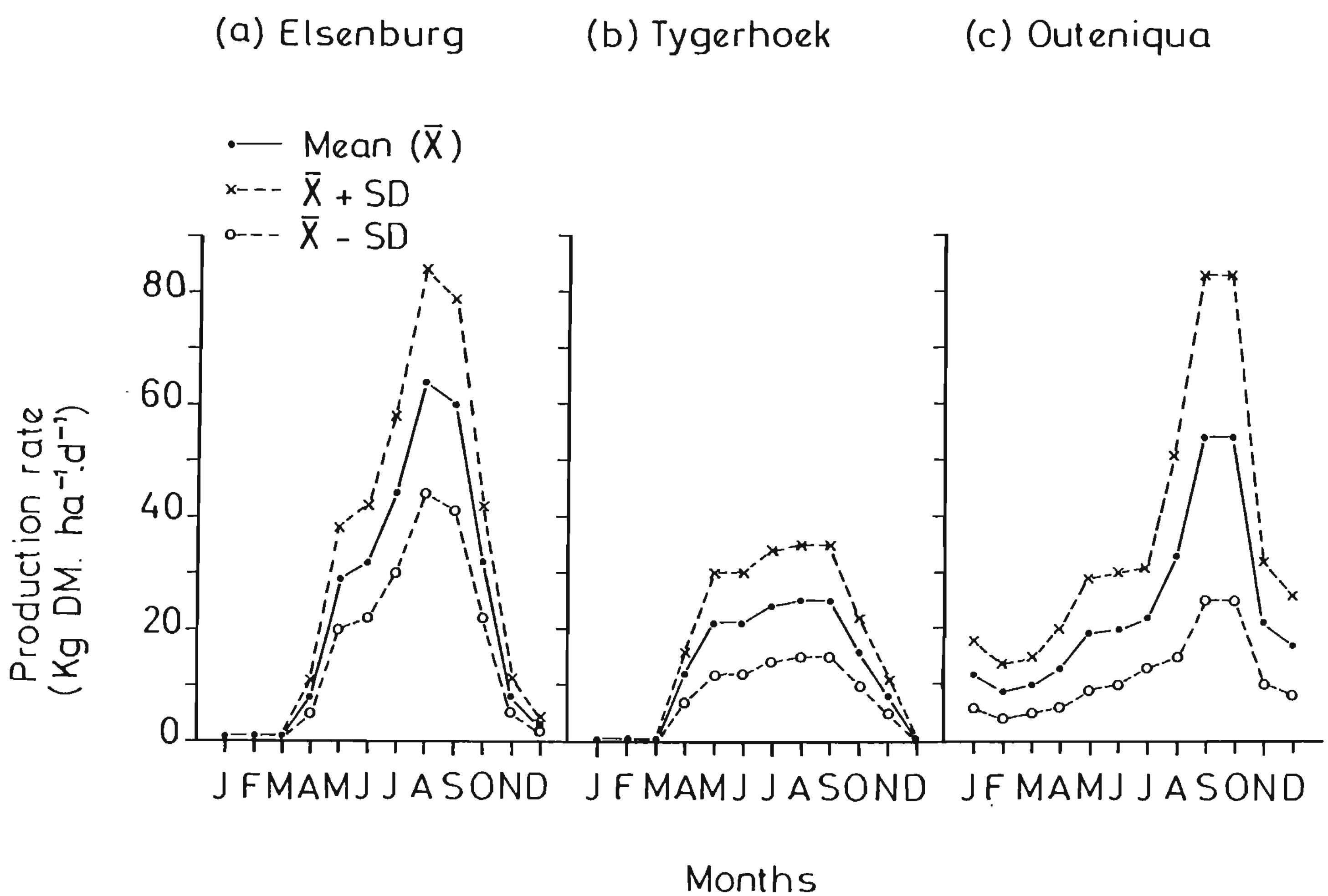


Figure 3.93 The production rate of Phalaris (cv. Seedmaster) under dryland at Elsenburg (1981-84), Tygerhoek (1981-84) and Outeniqua (1978-83)



increase in production rate resulted in a peak during September at this site. At Oudtshoorn, the production rates tended to be lowest during February and July, with peaks occurring during May/June and October (the highest).

Under dryland conditions (figure 3.93) the production pattern of Phalaris was very similar at Elsenburg and Tygerhoek, but the production rates were higher at the first of these sites. At both the latter mentioned sites no material was produced during the period December to March. During April the production rates increased sharply at both sites, resulting in a pronounced peak during August at Elsenburg and a uniformly high production rate during the period May to September at Tygerhoek.

At Outeniqua (dryland), the production rates were higher than at the previous two sites during the period December to March, but were still very low. Production rates at this site also increased much more gradually during subsequent months than was the case at the previously mentioned sites. This resulted in a peak during September and October at Outeniqua (dryland), beyond which the production rates once again declined sharply. The main feature of the production rates of Phalaris was the fact that they were generally relatively high during the winter period at the dryland, as well as the irrigated sites.

3.3.9.3 Extrapolation of production rate data

Seasonal production rate data derived at three irrigated (Welgevallen, Outeniqua and Oudtshoorn) and three dryland sites (Elsenburg, Tygerhoek and Outeniqua), were used for the development of functions for the extrapolation of the seasonal production rates to different seasons. The following functions were derived:

$MI = R.(0,5E)^{-1}$ (two-monthly means),
where R = total monthly rainfall (mm) and E = total monthly class A pan evaporation (mm);

$TI = \exp(-(T-13)^2.86^{-1})$,
where T = mean monthly air temperature(°C);

$RI = Q_{TOT}.13^{-1}$,
when $Q_{TOT} \leq 13$ and

$RI = 13.Q_{TOT}^{-1}$,
when $Q_{TOT} > 13$ and Q_{TOT} = mean monthly daily solar radiation ($MJ.m^{-2}.d^{-1}$);

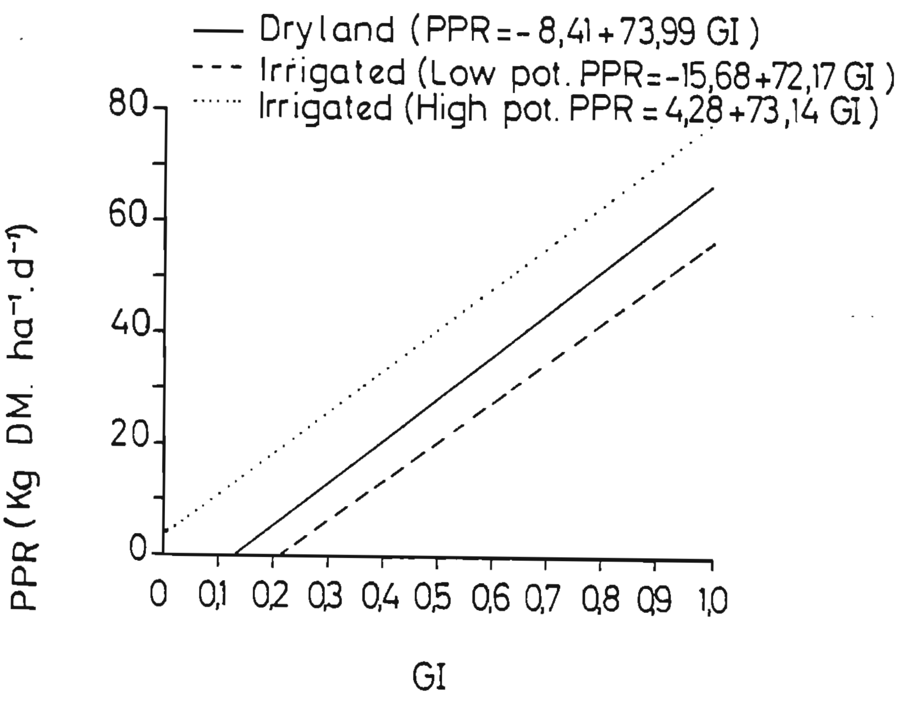
GI = MI x TI x RI.

Relationships were subsequently developed between GI and the actual production rate (APR) and used for the calculation of the potential production rate (PPR). These relationships are depicted in figure 3.94. Under dryland conditions, a single relationship sufficed as soil did not have a large influence on the production rates at the different sites and GI, therefore, seemed to be the main determinant of seasonal production rate. The following function was derived for use under dryland conditions:

$$PPR = -8,41 + 73,99GI.$$

Under irrigation, however, soil did have an influence on the seasonal production rate and two separate functions were developed. The function for a high potential soil was developed from the Oudtshoorn trial site, represented by the Oakleaf soil form, while a second function was developed for a low potential soil and was derived using data acquired at the Outeniqua trial site, on an Estcourt soil, as well as at

Figure 3.94 Relationships between the growth index (GI) and the potential production rate (PPR) for *Phalaris* under dryland and irrigation



the Welgevallen trial site, on a Sterkspruit soil. The two functions were as follows:

$$PPR\ (high\ potential) = 4,28 + 73,14GI$$
$$PPR\ (low\ potential) = -15,68 + 72,17GI$$

For the validation of the above mentioned functions, data acquired during the last season at all trial sites was reserved so that it could be used for this purpose. As a first step, the PPR and APR values were compared over the whole trial period at each trial site. These results are depicted in figures 3.95 and 3.96.

Under irrigation (figure 3.95) the PPR values had the same general trend as those of APR and in all cases the correlations were significant. The APR values were generally overestimated from autumn to early spring at all sites, while the late spring and the summer values were mostly underestimated at Welgevallen and Oudtshoorn.

Under dryland conditions (figure 3.96) the correlation was highest at Elsenburg. The PPR values followed the APR almost perfectly at this site. At the other two dryland sites, Tygerhoek and Outeniqua the correlations were, however, almost as high and the PPR values also followed the APR rather well, although large deviations did occur at times at these two sites.

The results were generally very promising, but as a further step the functions were also validated by using data which had not been utilised during the development phase. These results are depicted in figures 3.97 and 3.98. In the irrigated trials (figure 3.97), the correlations were much lower than had been the case previously when the longer term data was utilised, but they were still significant. In most cases, the PPR curves had basically the same trend as that

Figure 3.95 Comparison of actual (APR) and predicted potential (PPR) production rates at three irrigated sites over the whole experimental period

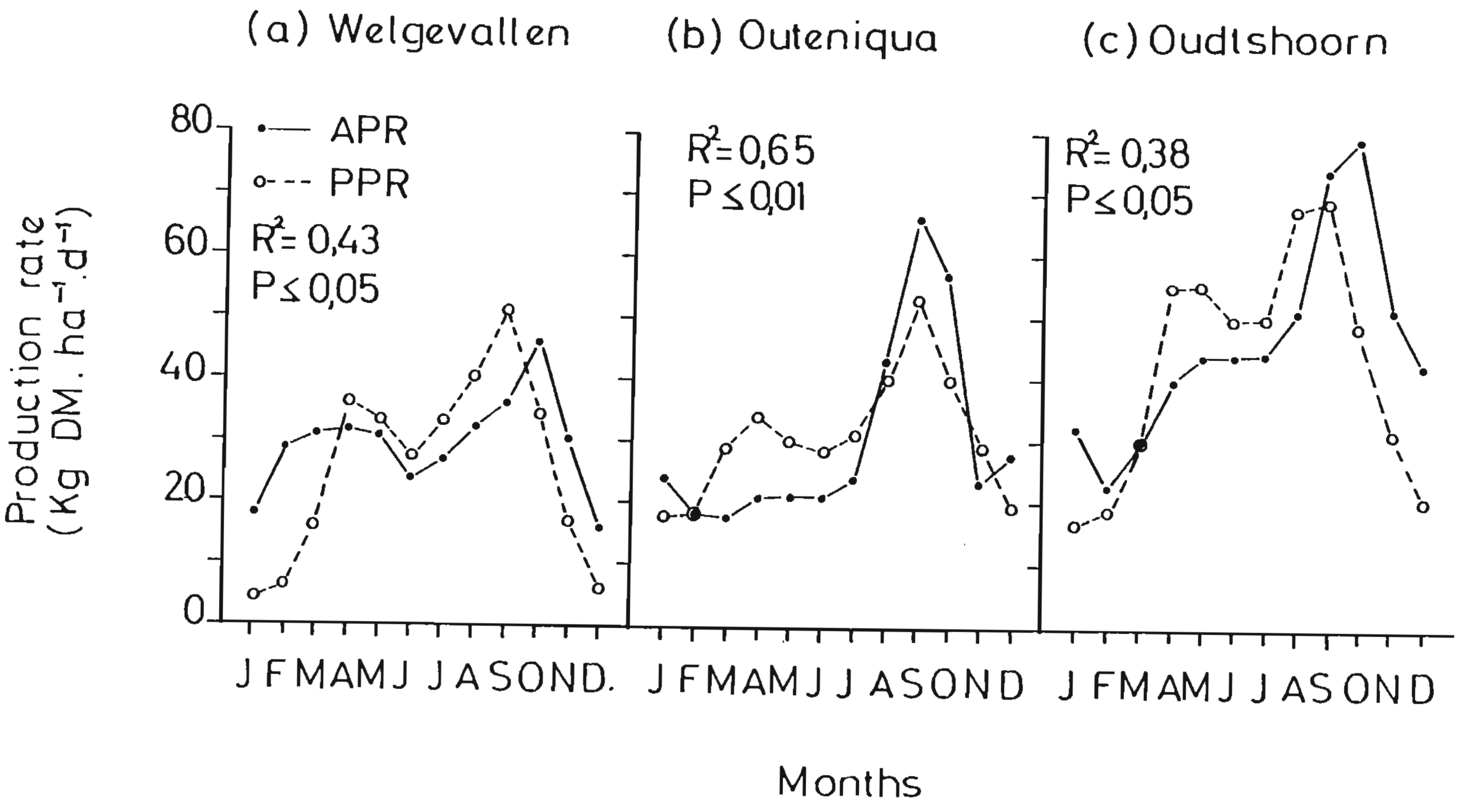


Figure 3.96 Comparison of actual (APR) and predicted potential (PPR) production rates at three dryland sites over the whole experimental period

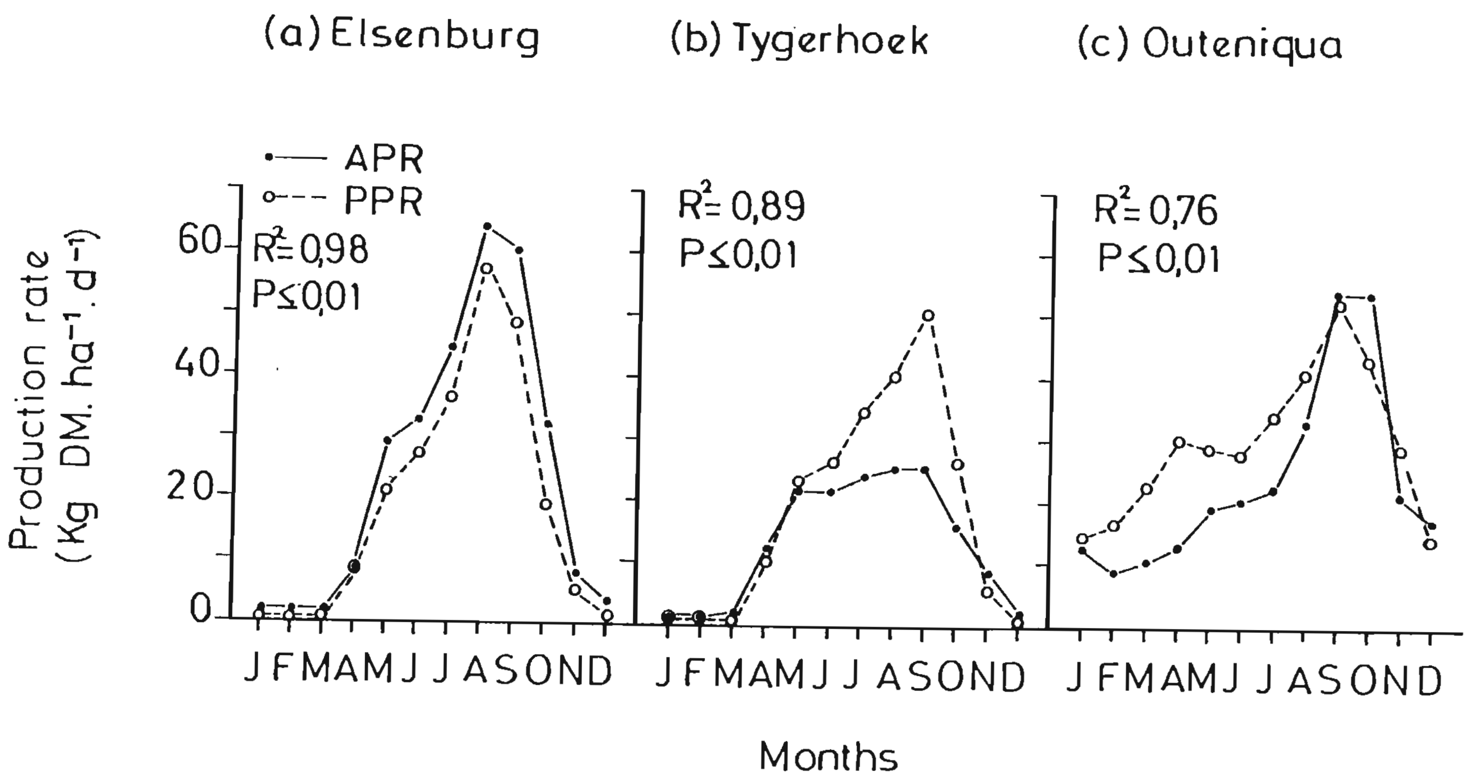


Figure 3.97 Comparison of actual (APR) and predicted potential production (PPR) rates at three irrigated sites, using data which had not been utilised during the development phase

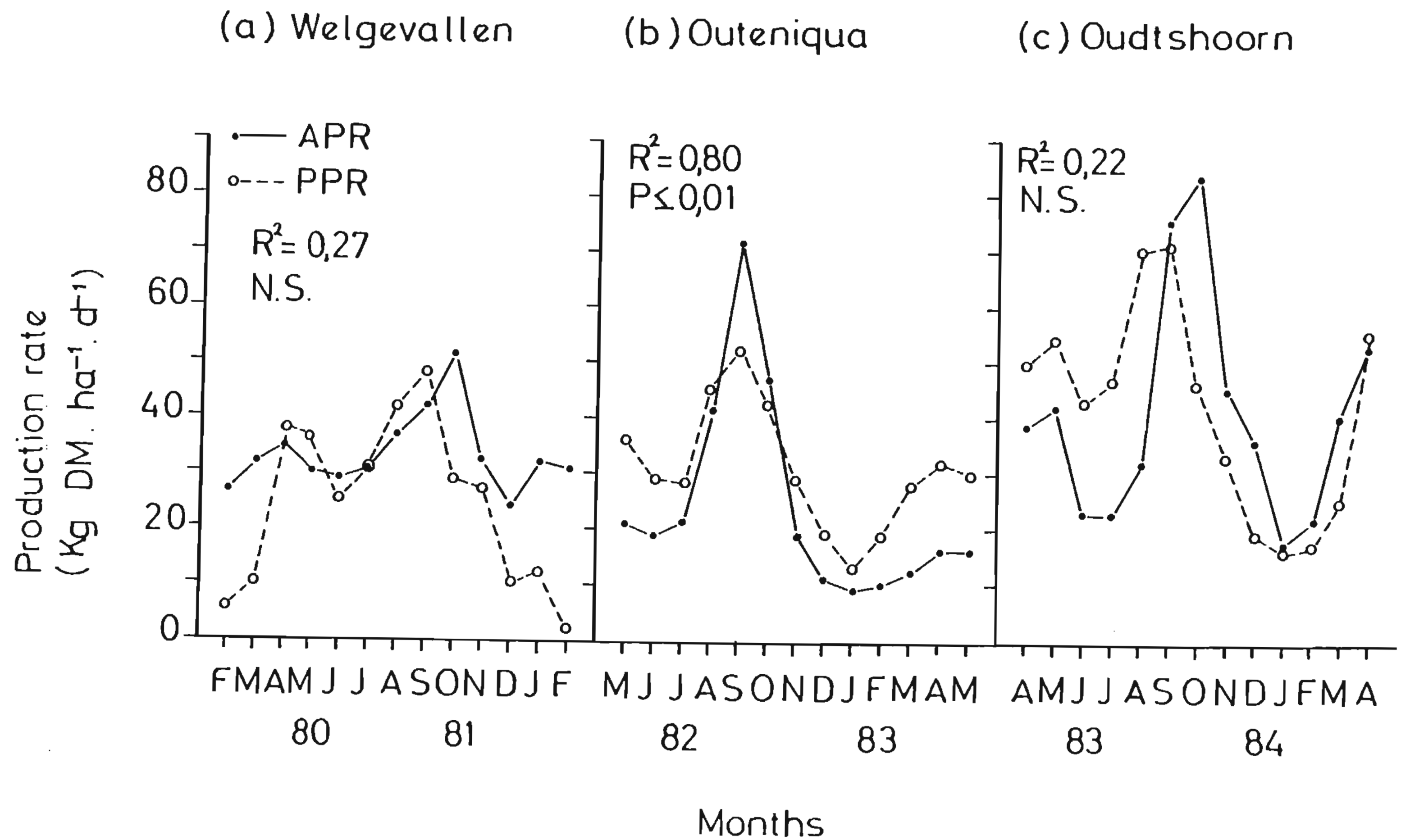
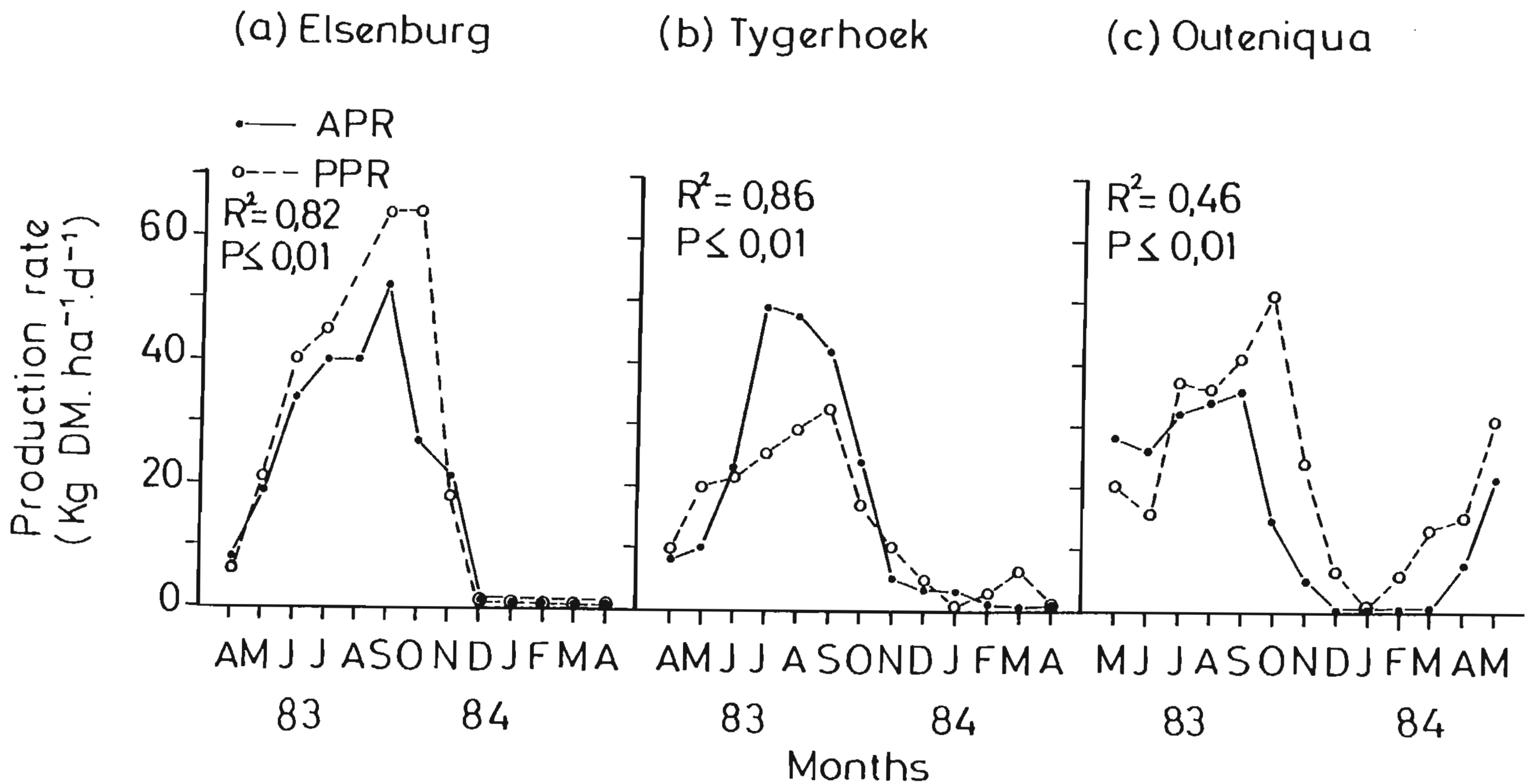


Figure 3.98 Comparison of actual (APR) and predicted potential production (PPR) rates at three dryland sites, using data which had not been utilised during the development phase



of APR, but at Welgevallen the PPR values deviated rather drastically from APR during the period December to March.

Under dryland conditions (figure 3.98), the results were more promising at all three sites than under irrigation and the correlations were all highly significant. In all three cases the PPR and APR curves had very similar trends, although deviations did occur.

It must be borne in mind that the functions which were used are very simple and not entirely suitable for the prediction of actual monthly PPR values. The models should, however, be effective enough when used for the prediction of long-term PPR values, using mean monthly climatic data as input. Using the derived functions, long-term PPR values were, therefore, calculated for each site, using long-term mean monthly climatic data as input. The derived curves are depicted in figures 3.99 and 3.100.

Under irrigation (figure 3.99), two separate funtions were applied to each of the three irrigated localities, using climatic data derived at each site, as input. During the period April to September, there is very little difference between the monthly PPR values predicted at the sites with the same soil potential. During the period October to March differences between the different sites, due to climate are, however, relatively large and the PPR values calculated for Outeniqua are clearly highest, while those calculated for Oudtshoorn are lowest. Differences in PPR value, due to differences in soil potential, are clearly smaller than the differences due to climate.

Under dryland conditions (figure 3.100), the long-term PPR values for Elsenburg and Tygerhoek are very similar and during the period March to August the values derived for Outeniqua are also similar to those of the other two sites.

Figure 3.99 Long-term potential production rate (PPR) of Phalaris under irrigation predicted, using the derived functions and long-term mean climatic data

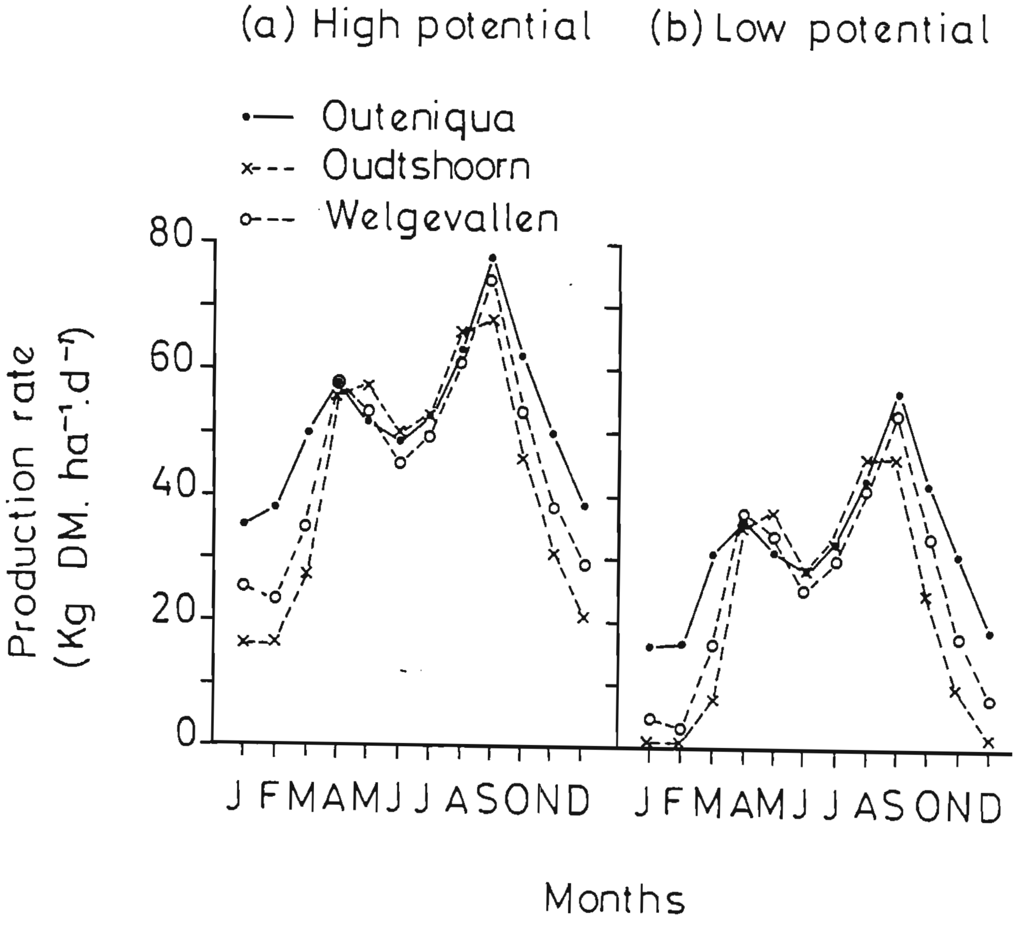
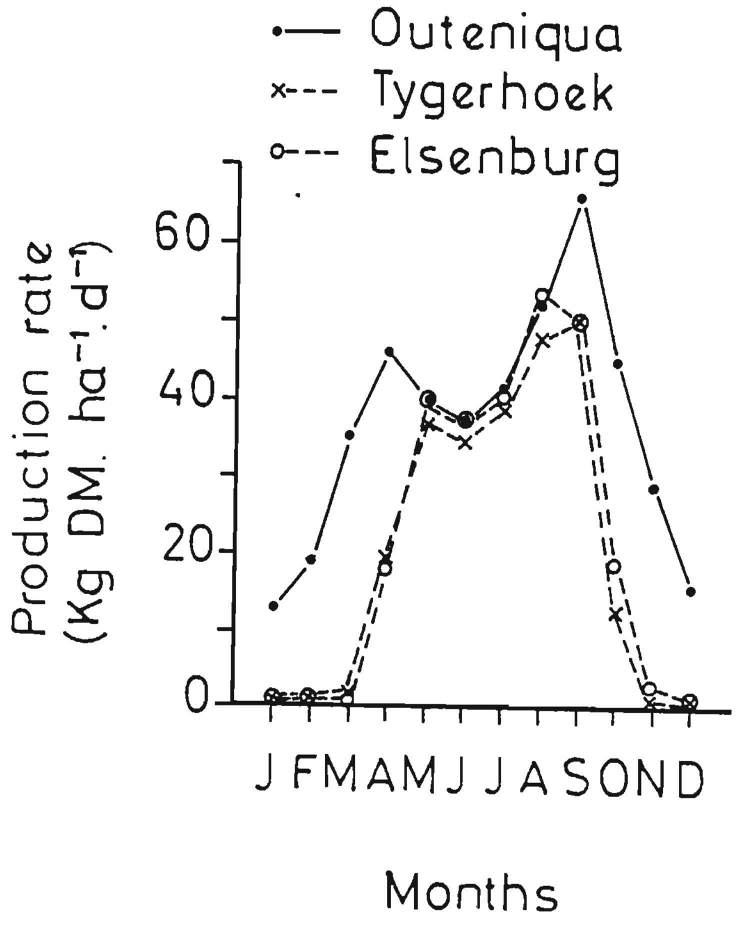


Figure 3.100 Long-term potential production rate (PPR) of Phalaris under dryland predicted, using the derived functions and long-term mean climatic data



During the period September to April the values derived at Outeniqua are, however, much higher.

3.3.9.4 Discussion and conclusions

In the cutting frequency trials, it was found that the form as well as the degree of response of Phalaris to cutting frequency, differed at the different sites. This made it impossible to define a general response to cutting frequency. Generally, however, it seems as if Phalaris would maintain the highest production rate when cut no more frequently than eight-weekly.

The seasonal production pattern of Phalaris differed substantially at the different irrigated and dryland sites. Generally, however, the highest production rates occurred during spring and the lowest during summer. In some cases, however, a second peak occurred during autumn and a second trough during mid-winter. The main feature of the production rates of Phalaris was the fact that the rates were generally relatively high during winter.

The production rate data, determined from the cutting trials, were further utilised for the development of functions depicting the relationship between mean monthly climatic data and the mean monthly production rates. Under dryland conditions, only one function was necessary, but under irrigation differences in soil potential necessitated the development of two separate functions representing the relationship between GI and APR on a high and a low potential soil, respectively.

The functions were validated by comparing PPR values with mean monthly APR values over the whole experimental period at all sites, as well as with new APR values not used during the development phase. In most cases the PPR values followed those of APR very well and resulted in very high and significant correlations. It was therefore concluded that the functions could safely be used for the extrapolation of the mean monthly production rate data, using long-term mean monthly climatic data as input.

This was subsequently done by extrapolating the production rates to different seasons on the different sites. Under irrigation, the greatest difference between sites with the same soil potential, occur during the period October to March. During this period the production rates seem highest at Outeniqua (irrigated) and lowest at Oudtshoorn. The low production rates at Oudtshoorn during this period can be attributed to the much higher summer temperatures at this trial site. Differences due to soil potential are, however, much smaller than those attributable to climate.

Under dryland conditions the values derived at the three different sites do not differ during the winter period, but during spring and autumn (September to April) the values derived at Outeniqua (dryland) are much higher than those derived at the other two sites. This can be attributed to the more favourable moisture conditions at the Outeniqua trial site.

The high winter production potential of this grass indicates its potential as an important component of temperate pasture mixtures under dryland, as well as under irrigation.

3.3.10 Perennial ryegrass

3.3.10.1 Influence of cutting frequency

The mean production rate (Kg $DM.ha^{-1}.d^{-1}$) of all perennial ryegrass cultivars evaluated in three irrigated (Welgevallen, Outeniqua and Oudtshoorn) and one dryland trial (Outeniqua) and cut at three frequencies (four-, six- and eight-weekly), are depicted in figure 3.101.

At only one site, Welgevallen, was there a significant difference between cutting treatments. At this site the highest production rate was attained at the six-weekly cutting frequency.

3.3.10.2 Seasonal production

Three cultivars were evaluated at four sites. The production rates (Kg $DM.ha^{-1}.d^{-1}$) derived at the three irrigated (Welgevallen, Outeniqua and Oudtshoorn) and one dryland (Outeniqua) site, are depicted in figures 3.102 and 3.103. Also depicted are the mean standard deviations, indicating the range of seasonal variation in the production rates.

The seasonal production pattern did not differ at the three irrigated sites (figure 3.102). During the period January to June the production rates were very low at all sites, while they increased sharply during July to reach a peak during October after which an equally sharp decline occurred. The actual production rates, however, differed slightly at the sites and during the period July to January they were highest at Oudtshoorn and lowest at Welgevallen.

Under dryland conditions at Outeniqua (figure 3.103), the production rates were very low during summer. The lowest production rates were recorded during the period January to April at this site, but during May they increased sharply, resulting in a peak during September/October. During November and December production rates, however, once again declined very sharply.

Figure 3.101 Influence of cutting frequency on the mean production rate of perennial ryegrass under irrigation and dryland at Outeniqua (1981-83), Welgevallen (1979-31) and Oudtshoorn (1981-84) (* LSD's for dryland and irrigated trials)

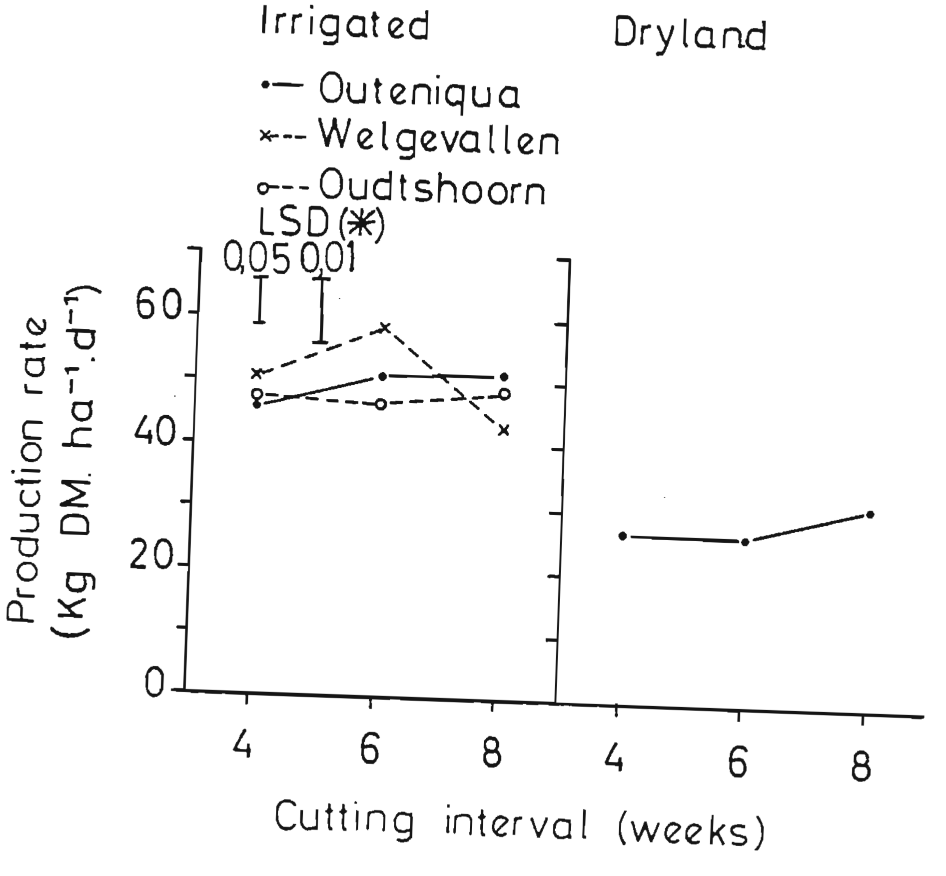


Figure 3.102 The production rate of perennial ryegrass under irrigation at Welgevallen (1978-81), Outeniqua (1978-83) and Oudtshoorn (1978-84)

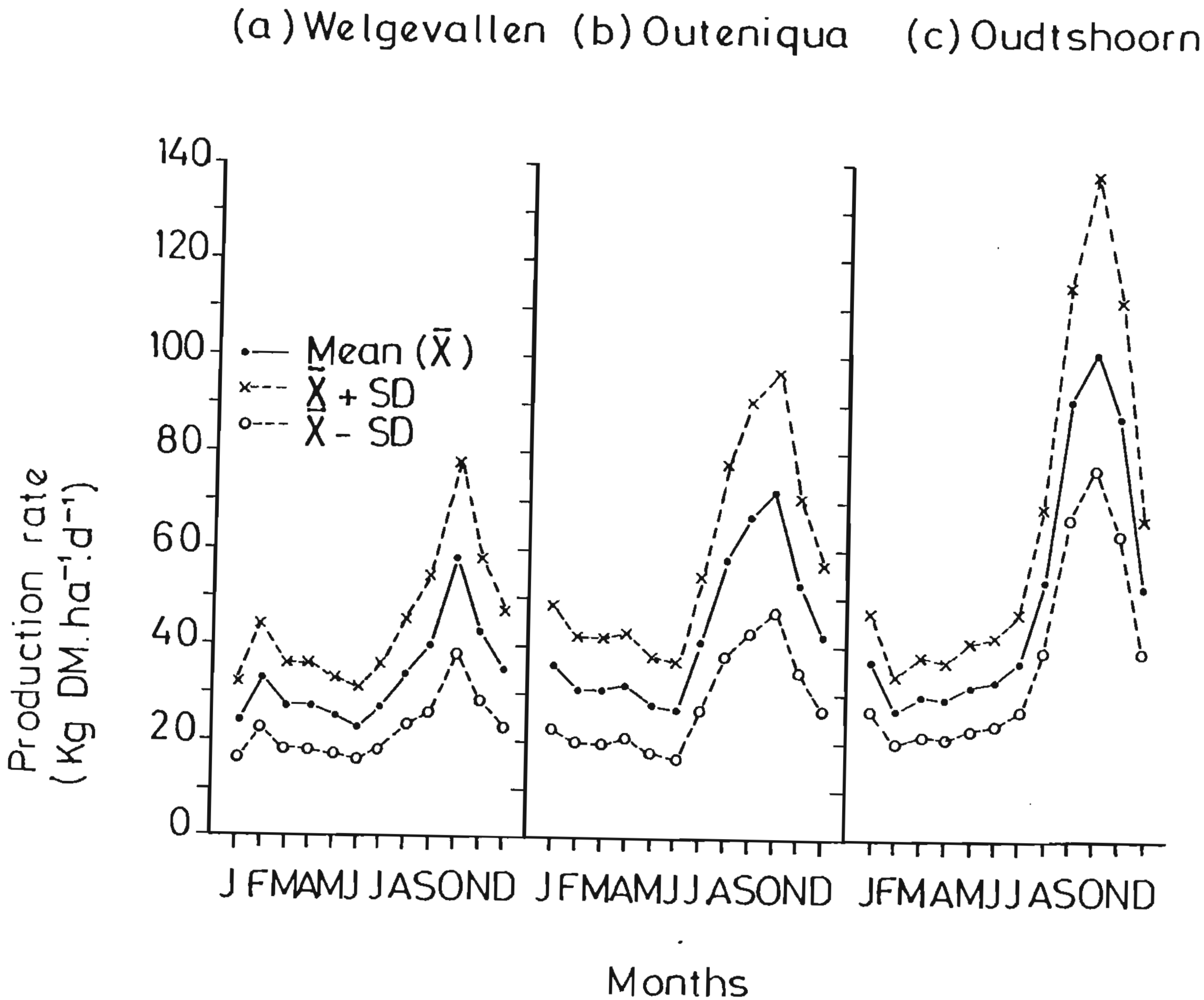
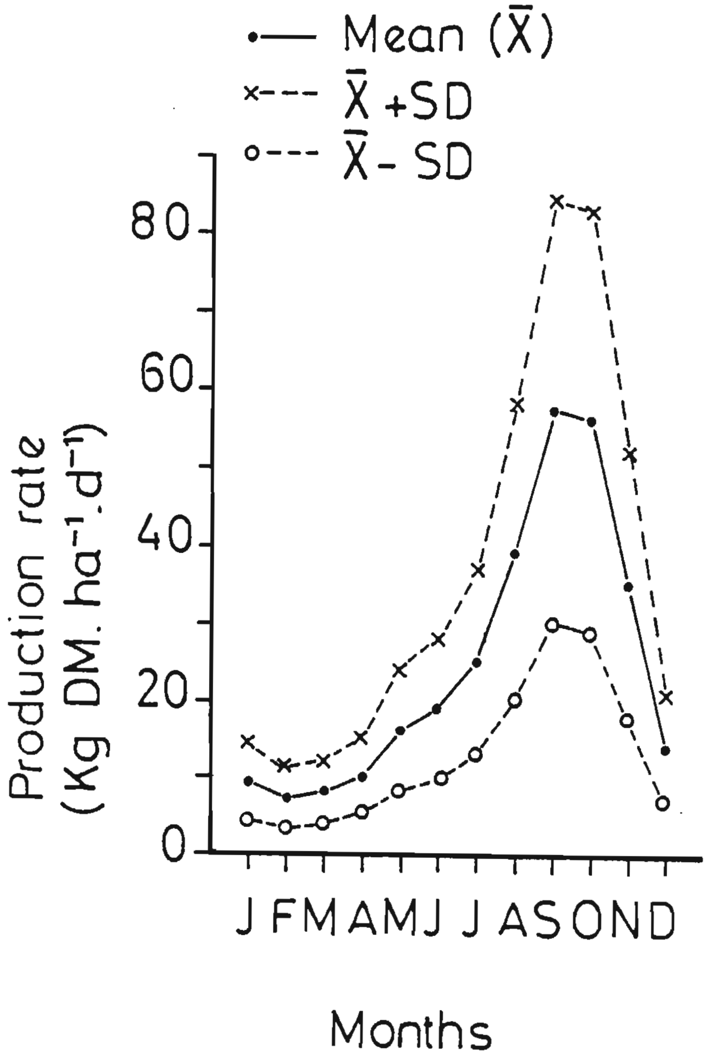


Figure 3.103 The production rate of perennial ryegrass, under dryland conditions at Outeniqua (1978-83)



Three perennial ryegrass cultivars, Ariki, Agresso and Ruanui, were evaluated at all three irrigated (Welgevallen, Outeniqua and Oudtshoorn) and one dryland (Outeniqua) site. These results are depicted in figures 3.104 to 3.107. At the three irrigated (figures 3.104 to 3.106), as well as the one dryland site, Outeniqua (figure 3.107), the three ryegrass cultivars had basically the same production pattern and rates.

3.3.10.3 Extrapolation of production rate data

The seasonal production rate data derived at the three irrigated (Welgevallen, Outeniqua and Oudtshoorn) and the dryland site (Outeniqua), were used for the development of functions for the extrapolation of the seasonal production rates to different seasons at the same sites. The functions were as follows:

$MI = R.E^{-1}$ (two-monthly means),
where R = total monthly rainfall (mm) and E = total monthly class A pan evaporation (mm);

$TI = \exp(-(T-15)^2.86^{-1})$,
where T = mean monthly air temperature (°C);

$RTI = RT.RT_{MAX}^{-1}$,
where $RT = Q_{TOT}.T^{-1}$ and RT_{MAX} = the maximum calculated RT;

$GI = MI \times TI \times RTI$.

Relationships were subsequently developed between GI and the actual production rates (APR) and used for the calculation of the potential production rates (PPR). These relationships are depicted in figure 3.108. Under dryland conditions a single relationship was developed as this

Figure 3.104 Production rate of three perennial ryegrass cultivars under irrigation at Welgevallen (1979-81)

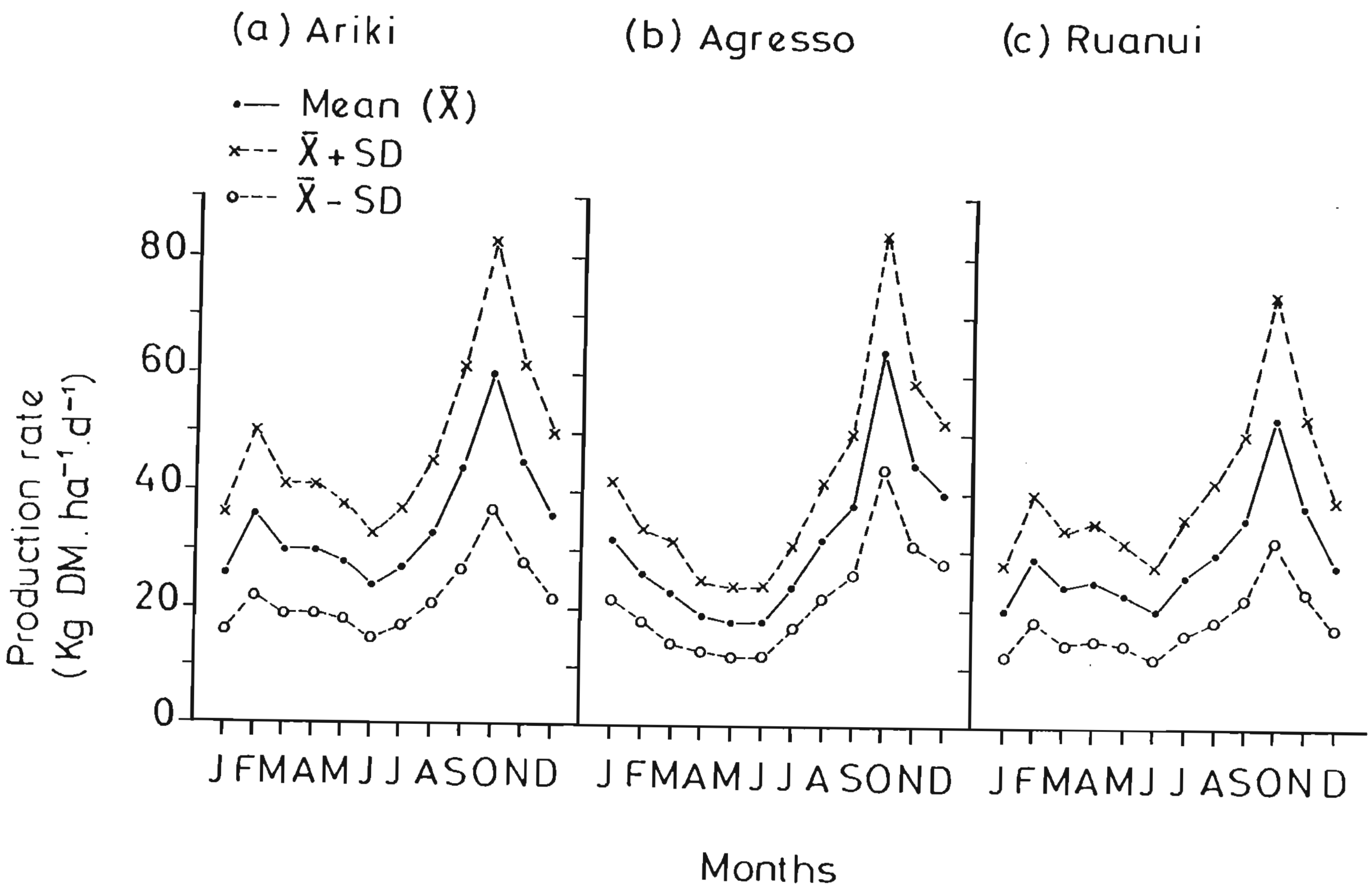


Figure 3.105 Production rate of three perennial ryegrass cultivars under irrigation at Outeniqua (1978-83)

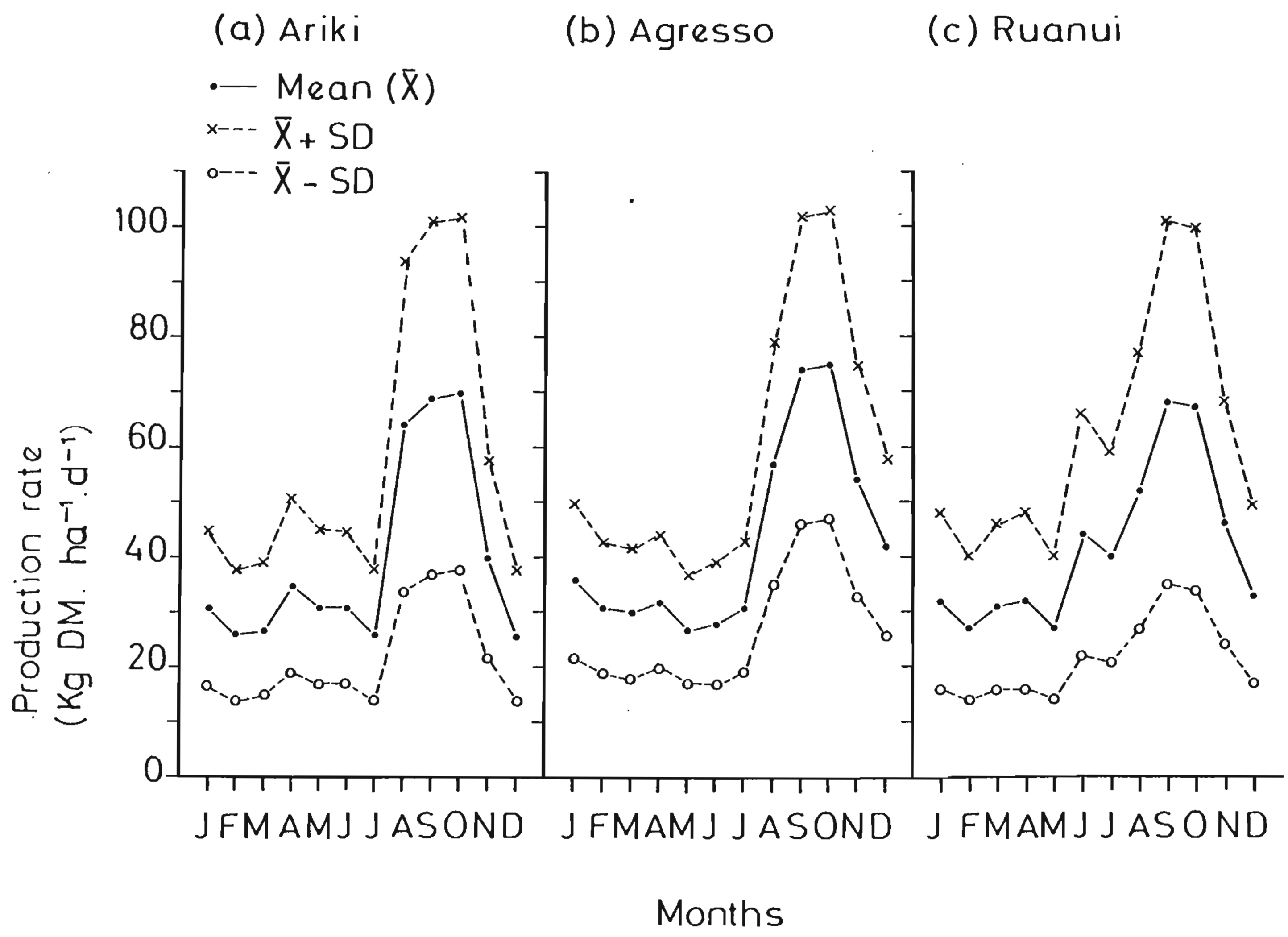


Figure 3.106 Production rate of three perennial ryegrass cultivars under irrigation at Oudtshoorn (1978-84)

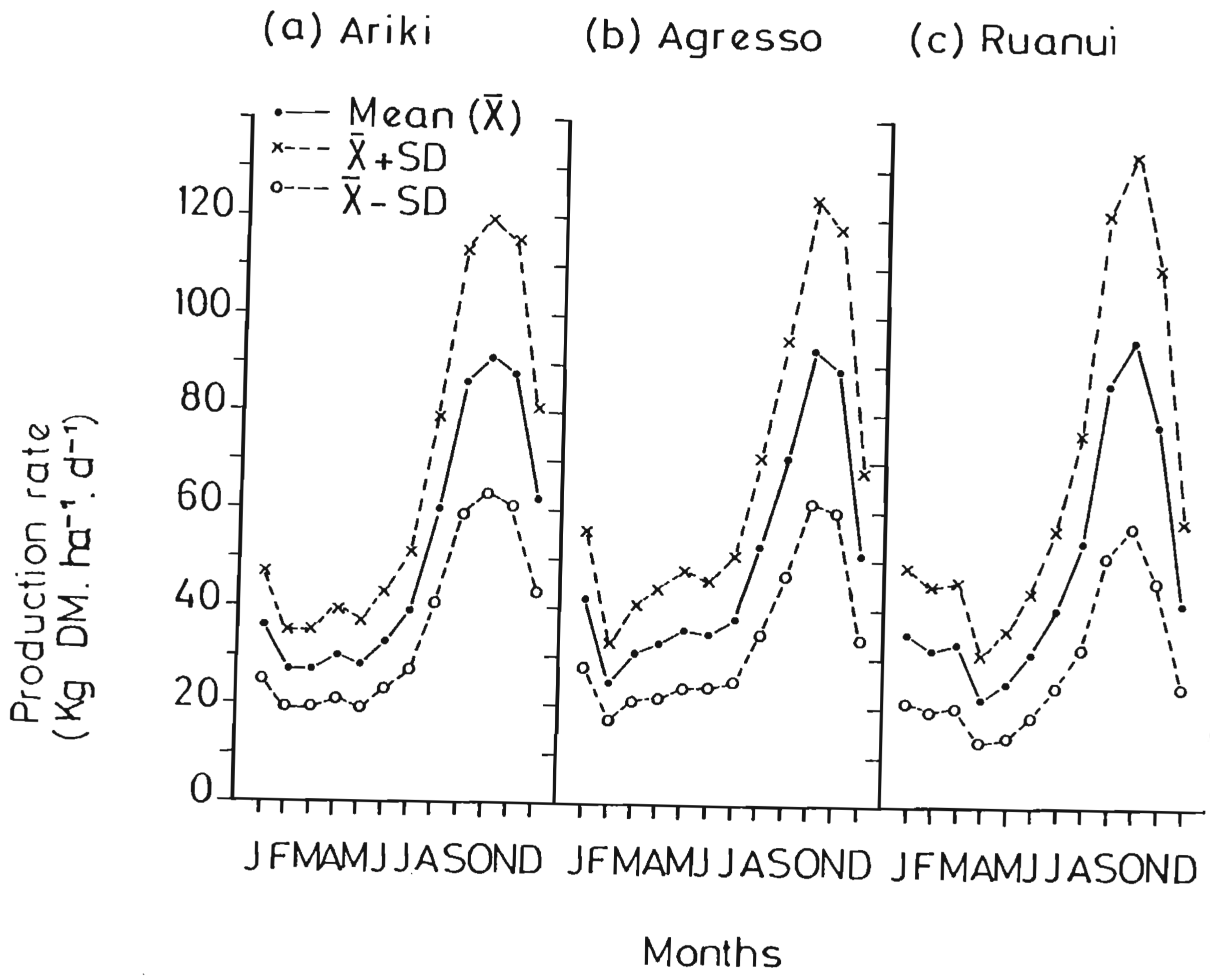


Figure 3.107 Production rate of three perennial ryegrass cultivars under dryland at Outeniqua (1978-83)

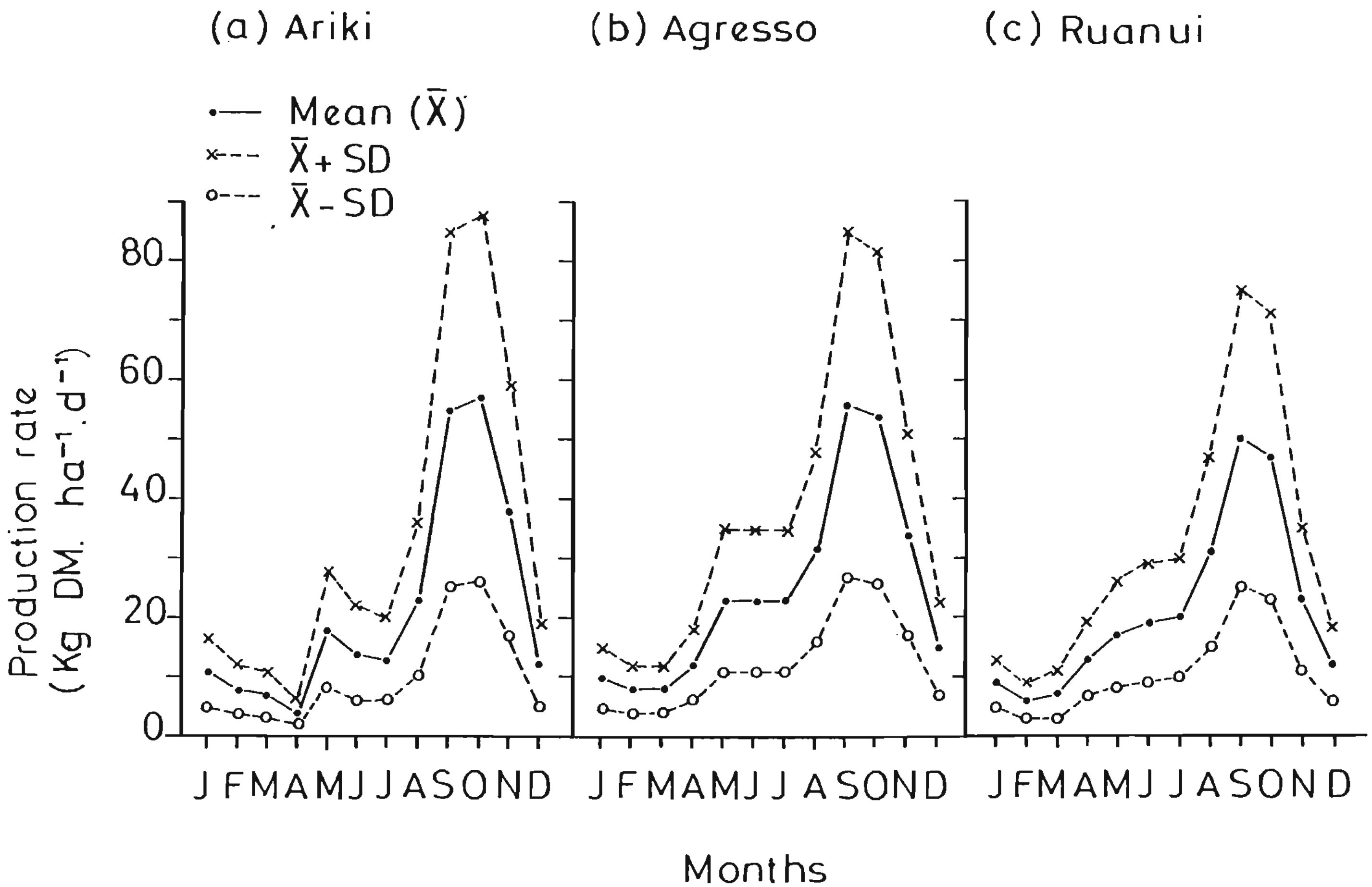
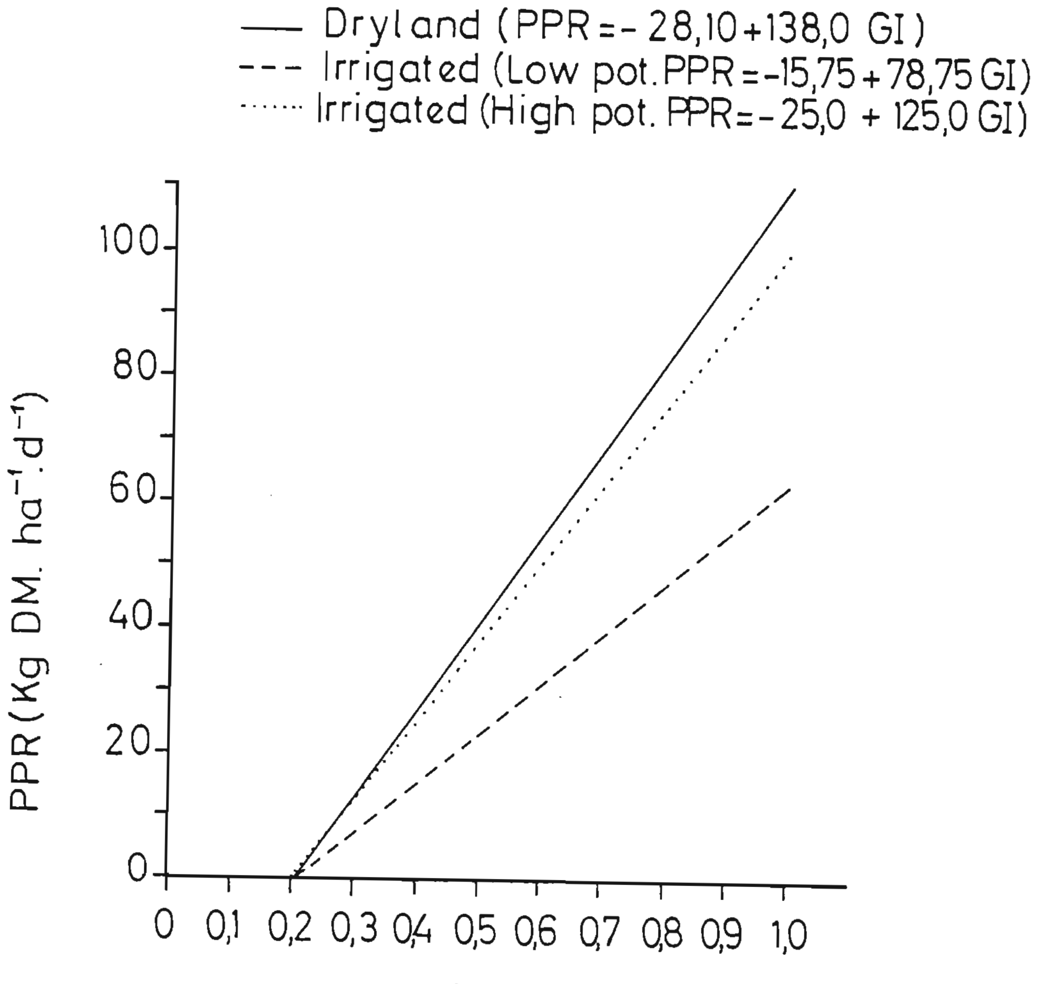


Figure 3.108 Relationship between the growth index (GI) and the potential production rate (PPR) of perennial ryegrass under dryland and irrigation



species was evaluated only at one dryland site. The following function was derived for use under dryland:

PPR = -28,1 + 138,0GI

Under irrigation, however, more than one site was used and, as soil had a large influence on seasonal production, two separate functions had to be developed. One function was developed for a high potential soil, represented by the Oakleaf soil form of the Oudtshoorn trial site, and one for a low potential soil, as represented by the Estcourt and Sterkspruit soils of the Welgevallen and Outeniqua trial sites, respectively. The following functions were derived:

PPR (high potential) = -25,0 + 125,0GI
PPR (low potential) = -15,75 + 78,75GI.

For the validation of the above mentioned functions, data acquired during the last season at all sites was excluded so as to be able to use it for this purpose. As a first step, the mean monthly PPR and APR values were compared over the whole trial period at each site under dryland, as well as under irrigation. These results are depicted in figure 3.109.

The PPR values followed those of the APR very well and in all cases the correlations between the two sets of data were highly significant. The results were very promising, but the functions had to be validated even further. The PPR and APR values for data which had not been used during the development phase were, therefore, compared at Outeniqua (irrigated and dryland) and Oudtshoorn. These results are depicted in figure 3.110.

The PPR values deviated more from the APR values than had been the case with the long-term data. The results were,

Figure 3.109 Comparison of actual (APR) and predicted potential (PPR) production rates at three irrigated and one dryland site, over the whole experimental period

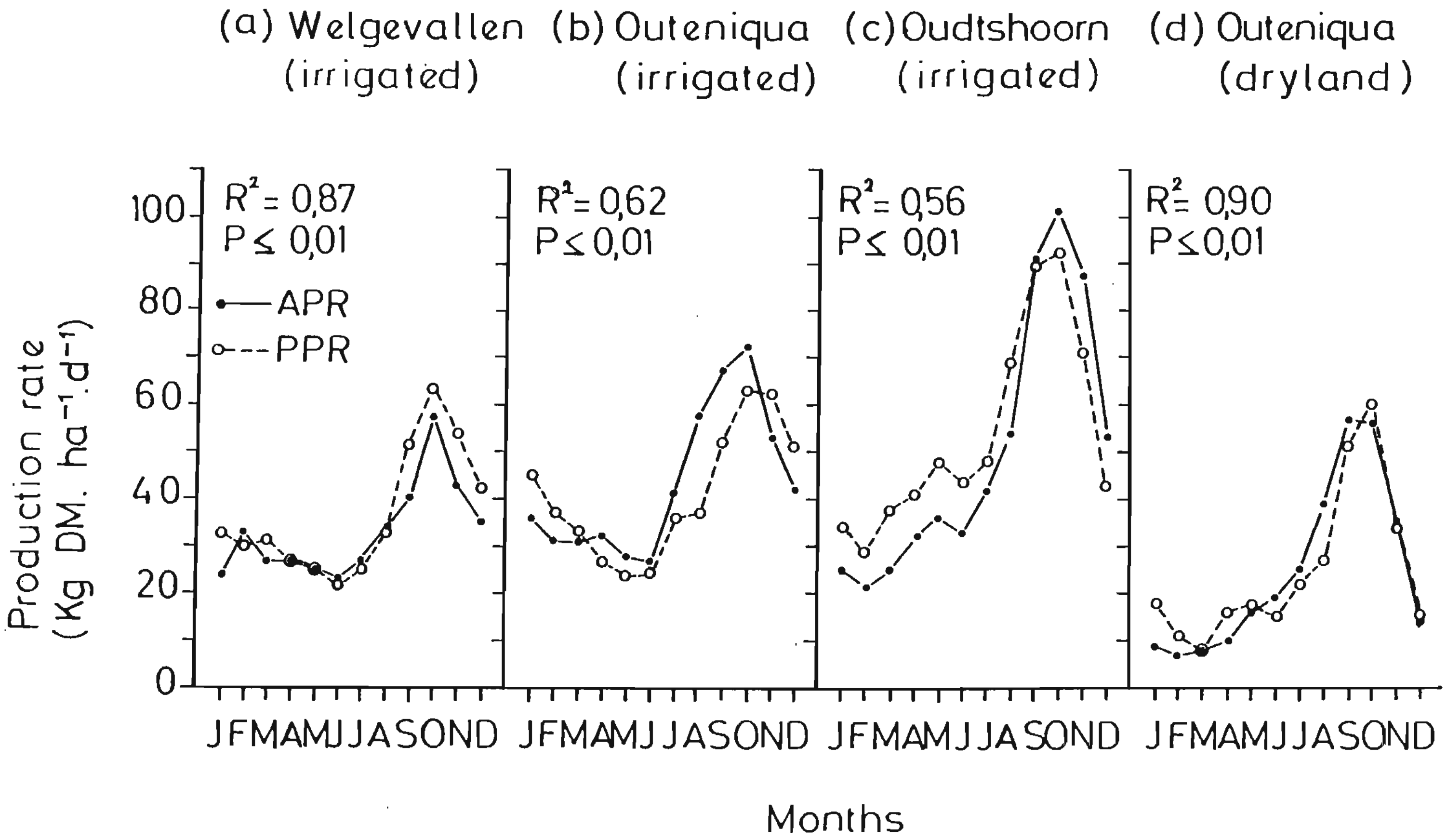
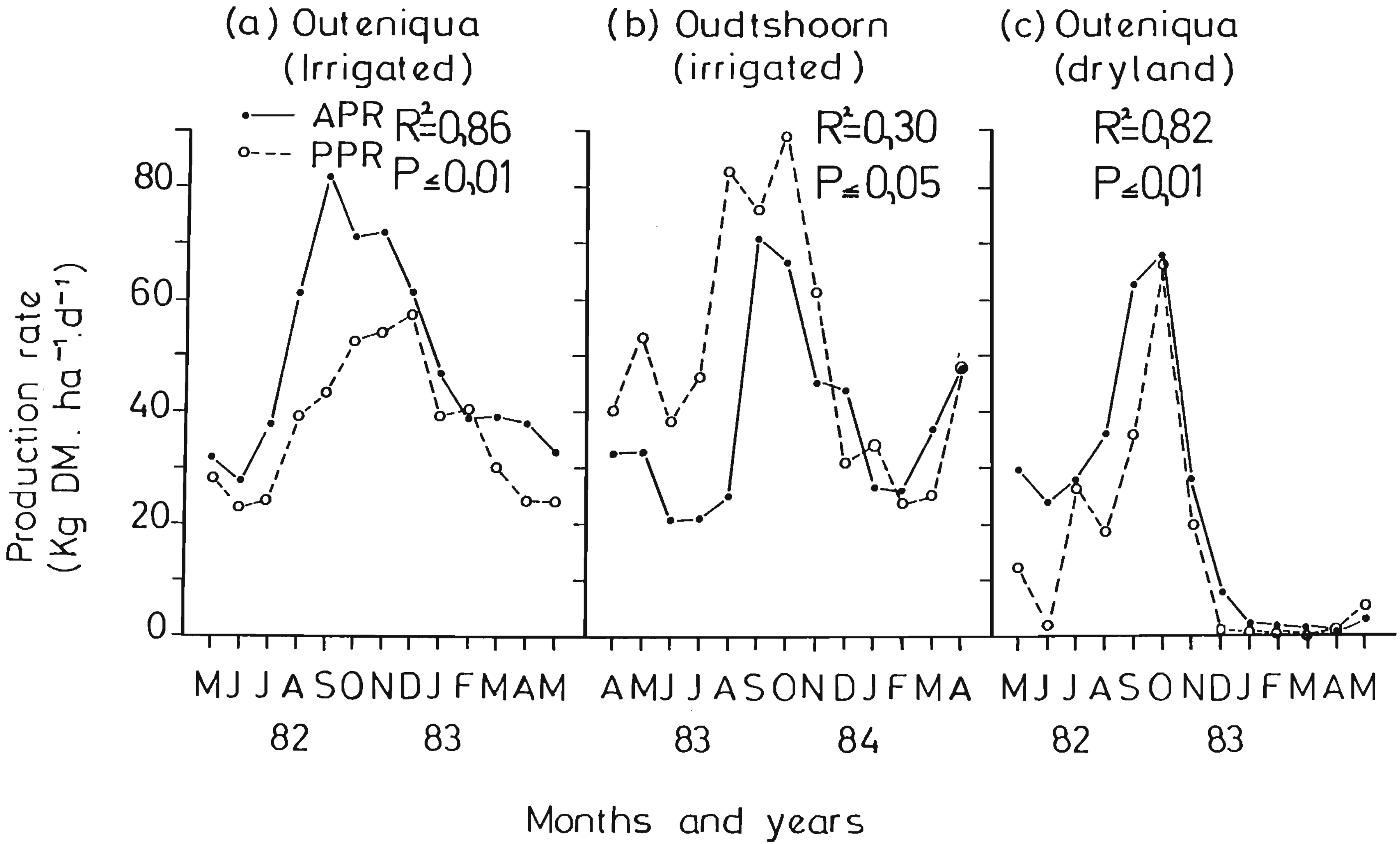


Figure 3.110 Comparison of the actual mean monthly (APR) and the potential mean monthly (PPR) production rate at two irrigated and one dryland site, using data which had not been utilised during the development phase



however, still satisfactory and resulted in significant correlations in all cases.

The models predicted the APR values satisfactorily enough to enable their use for the prediction of the long-term production potential at each of the sites, using long-term mean monthly climatic data as input. The derived curves are depicted in figure 3.111.

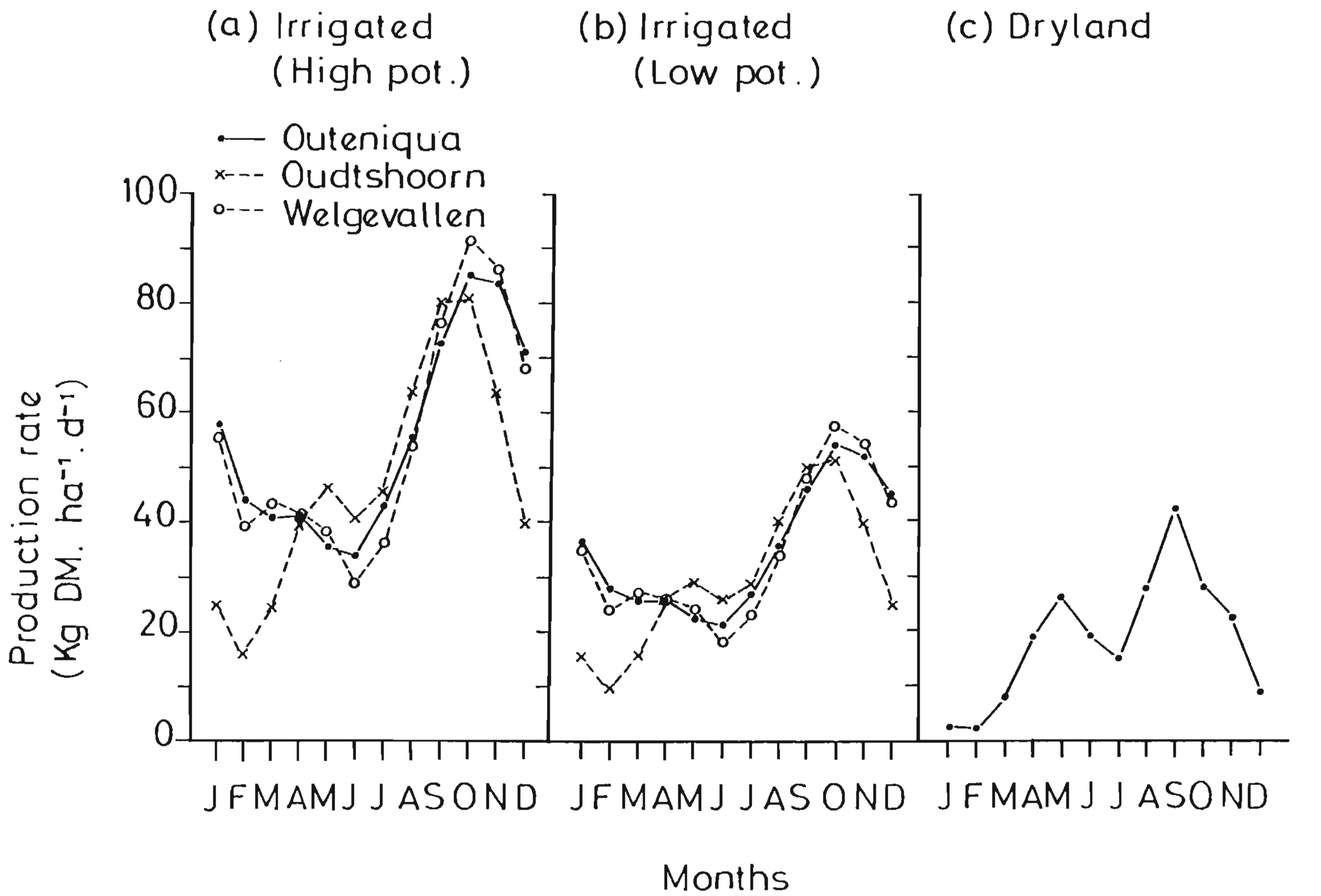
Soil differences clearly has a large influence on the predicted PPR values. The seasonal production pattern derived for Oudtshoorn, however, differs quite substantially from that derived at the other two irrigated sites, indicating a large influence of climate. The PPR values derived for Outeniqua (irrigated) and Welgevallen are identical, but the values derived for Oudtshoorn are much lower during the period October to March. At Oudtshoorn the derived PPR values are lowest during February but at the other two sites the lowest PPR values occur during June. The peak production rates, however, occur at about the same time at all irrigated sites, during October.

Under dryland conditions at Outeniqua, perennial ryegrass has two distinct peaks in its seasonal production curve, the lowest occurring during May and the highest during September. The lowest PPR values for this site were calculated for January and February and a second minimum seems to occur during July.

3.3.10.4 Discussion and conclusions

In the cutting frequency trials, the response of perennial ryegrass to cutting frequency was significant at only one site (Welgevallen) and it would seem, therefore, that this grass is not very sensitive to cutting frequency.

Figure 3.111 Long-term potential production rate (PPR) of perennial ryegrass predicted, using the derived functions and long-term mean climatic data



The production rates of all perennial ryegrass cultivars evaluated were lowest during summer at all three irrigated sites, as well as at the dryland site at Outeniqua. Perennial ryegrass was found to be low producing during summer and autumn, but an early increase in production rate during late winter (July) and spring, resulted in a relatively high production during that period.

Three perennial ryegrass cultivars, Ariki, Ruanui and Agresso, were evaluated at all sites and it was found that they had basically the same seasonal production pattern and rates at all the sites.

The production rates determined in the cutting trials were used to develop functions depicting the relationship between mean monthly climatic data and production rates. Under dryland conditions, one function was used to describe the relationship between GI and the actual production rate (APR), and used to predict the potential production rate (PPR). Under irrigation, however, soil had such an important influence on the relationship that two separate functions were needed.

The functions were validated by comparing the PPR values with those of APR for the whole trial period, as well as with new data which had not been used during the development phase. The results were very promising and the APR and the PPR values were very highly correlated at all sites. It was, therefore, concluded that the functions could be effectively utilised for the prediction of long-term mean monthly PPR values, using long-term climatic data as input.

The functions were, therefore, subsequently used to predict the long-term PPR at each site, using long-term monthly mean climatic data as input. Under irrigation, soil potential has about as a great an influence on the PPR as climate.

The PPR values derived for the two irrigated sites, Welgevallen and Outeniqua, are identical, but the values derived for Oudtshoorn suggests that high temperatures depressed production during summer, but yields were high in winter. This, therefore, indicates that this grass should be utilised only in irrigated pastures in the cooler areas of the WRR.

Under dryland conditions at Outeniqua the PPR values are lowest during summer. The highest PPR values were recorded during autumn and spring at this site. The production rates of perennial ryegrass are, however, very low under dryland conditions and the value of this grass under dryland in the WRR is, therefore, doubtful.

3.3.11 Annual ryegrass

3.3.11.1 Influence of cutting frequency

The mean production rate (Kg DM.$ha^{-1}.d^{-1}$) of a ryegrass with an annual growth habit in the Winter Rainfall Region (cv Midmar) in two irrigated (Outeniqua and Oudtshoorn) and one dryland (Outeniqua) trial, cut at three frequencies (four-, six- and eight-weekly), is depicted in figure 3.112. At none of the sites did annual ryegrass respond significantly to cutting frequency.

3.3.11.2 Seasonal production

Only one ryegrass cultivar with an annual growth habit in the Winter Rainfall Region was evaluated at all sites, i.e. cv Midmar, and these results will be used in subsequent discussions. The mean seasonal production rates (Kg DM. $ha^{-1}.d^{-1}$) of Midmar in cutting trials at three irrigated sites (Welgevallen, Outeniqua and Oudtshoorn) and one dryland site (Outeniqua), are depicted in figures 3.113 and

Figure 3.112 Influence of cutting frequency on the mean production rate of annual ryegrass under irrigation and dryland at Outeniqua (1981-83) and Oudtshoorn (1981-84) (* LSD's for dryland and irrigated trials)

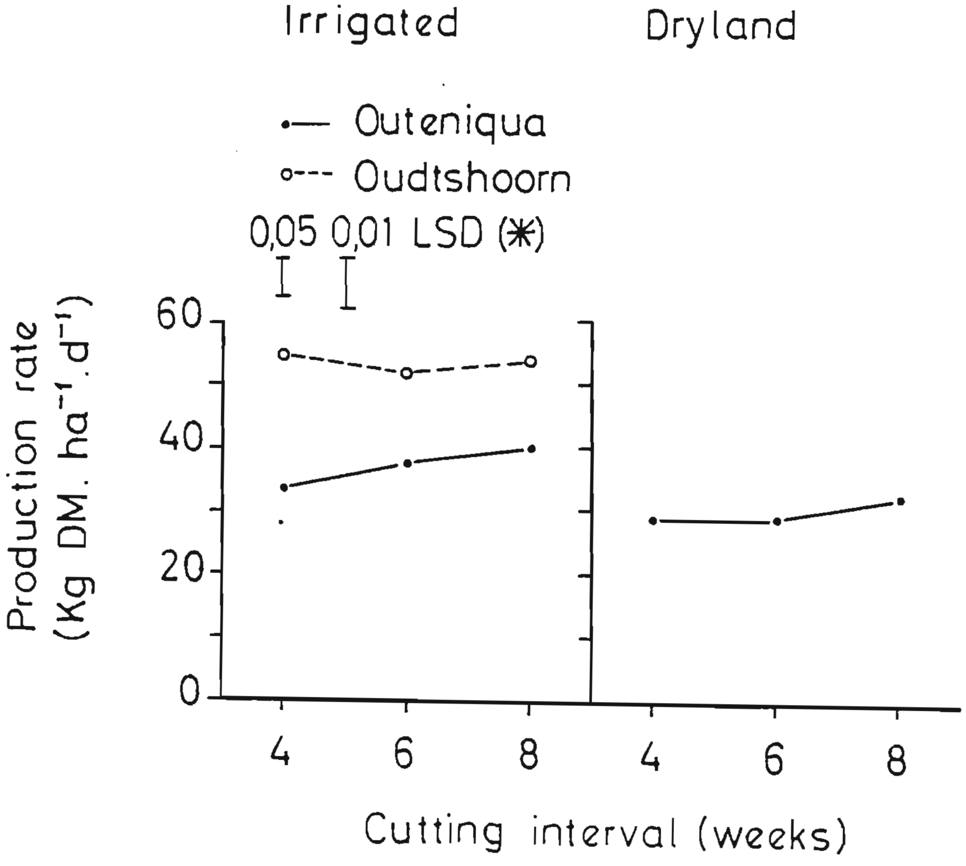
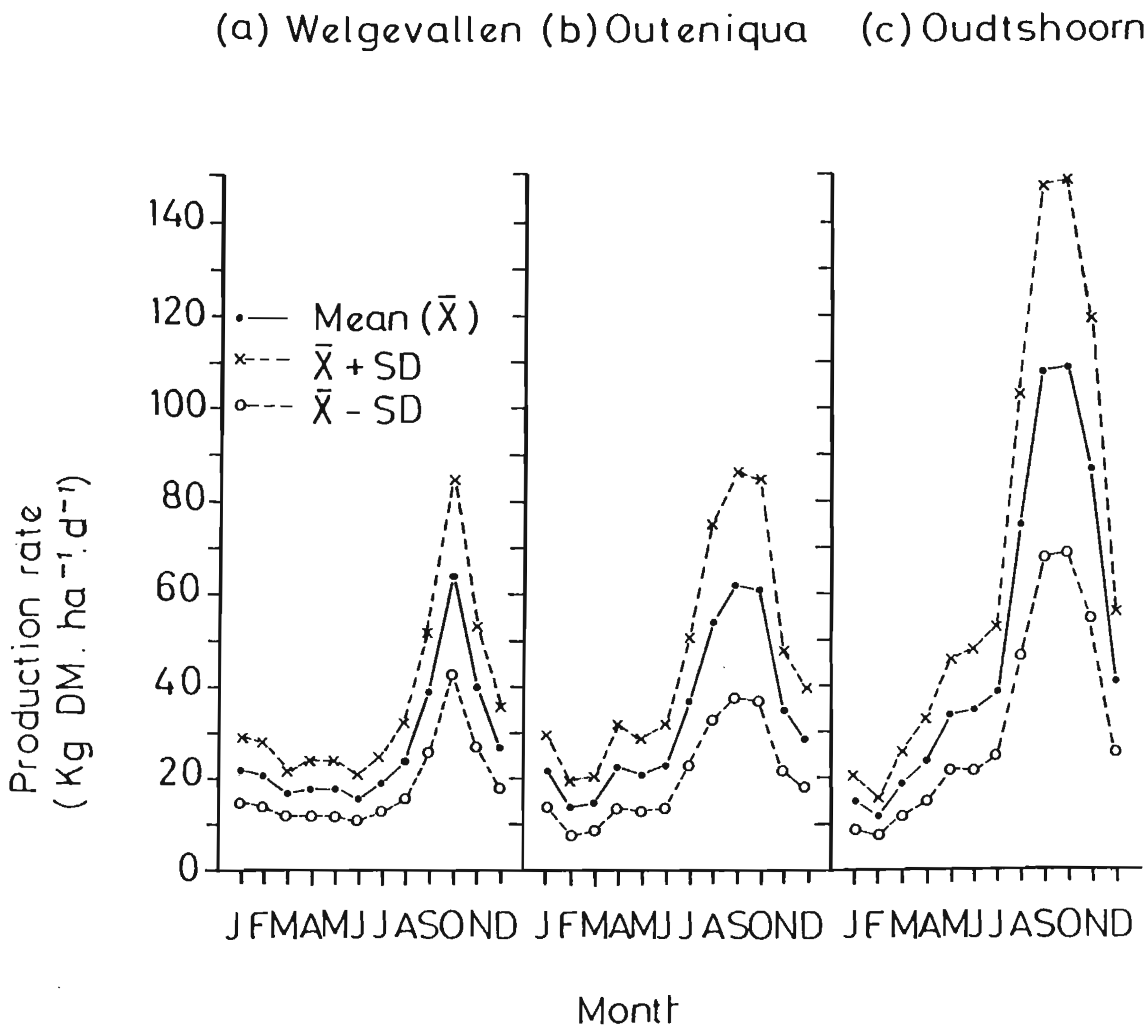


Figure 3.113 The production rate of annual ryegrass (cv Midmar) under irrigation at Welgevallen (1977-79), Outeniqua (1978-83) and Oudtshoorn (1978-84)



3.114 respectively. Also indicated are the standard deviations, calculated for each site, which indicate the range of seasonal variation in the production rates.

The production pattern of annual ryegrass seemed to differ slightly at the three irrigated sites (figure 3.113). At Welgevallen and Outeniqua (irrigated) the production rates and production patterns were, however, very similar and at both, production was very low during the whole of the period January to June/July. It increased during July/August, reached a peak during September/October and decreased sharply thereafter. The production rates were highest at Oudtshoorn and at this site the lowest production rates occurred during January and February, but started to increase early in March, attaining a very high peak during September and October.

In the dryland trial at Outeniqua (figure 3.114), the production rates of annual ryegrass were very low during the period December to April. They started to rise in late April and rose steadily during subsequent months to a sharp peak during September.

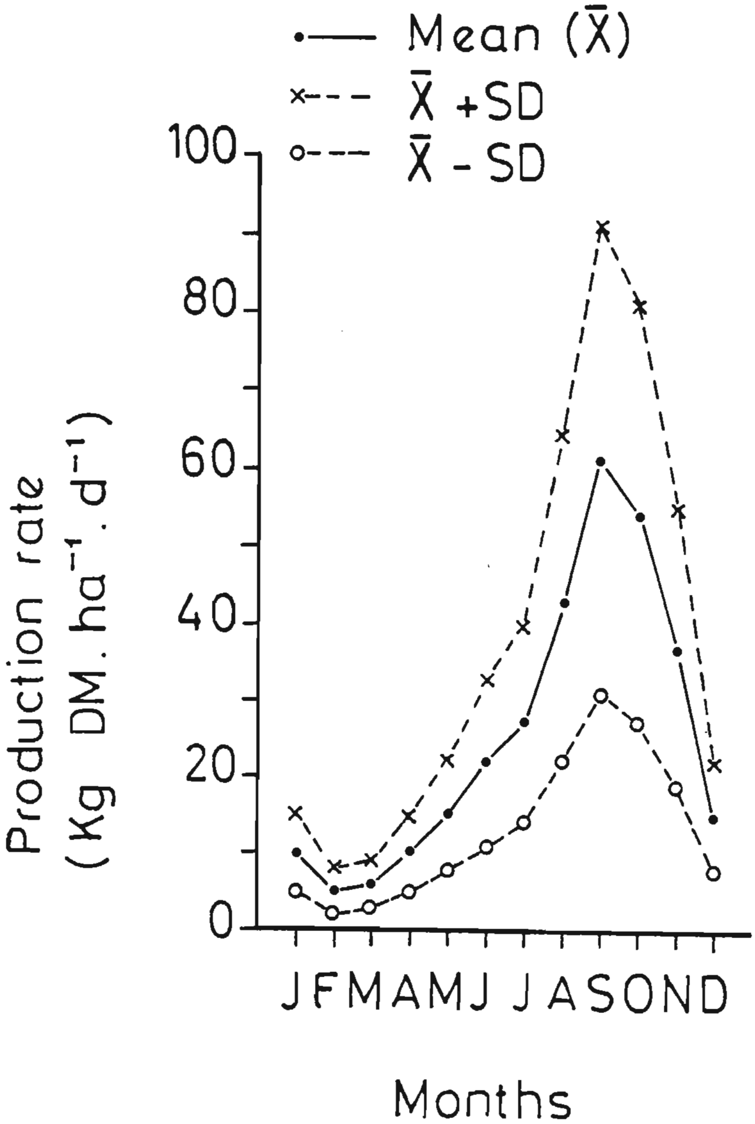
3.3.11.3 Extrapolation of production rate data

The seasonal production rate data derived at three irrigated (Welgevallen, Outeniqua and Oudtshoorn) and one dryland site (Outeniqua), were used for the development of functions for the extrapolation of the seasonal production rates to different seasons. The following functions were derived:

$MI = R.E^{-1}$ (two-monthly means),
where R = total monthly rainfall (mm) and E = total monthly class A pan evaporation (mm);

$TI = \exp(-(T-13)^2.66^{-1})$,

Figure 3.114 The production rate of annual ryegrass (cv Midmar) under dryland conditions at Outeniqua (1978-83)



where T = mean monthly air temperature (°C);

$RI = Q_{TOT}.13^{-1}$,
when $Q_{TOT} \leq 13$ and

$RI = 13.Q_{TOT}^{-1}$,
when $Q_{TOT} > 13$, where Q_{TOT} = mean monthly daily solar radiation ($MJ.m^{-2}.d^{-1}$);

$RTI = RT.RT_{MAX}^{-1}$,
where $RT = Q_{TOT}.T^{-1}$ and RT_{MAX} = maximum calculated RT;

$GI = MI \times TI \times RI \times RTI$.

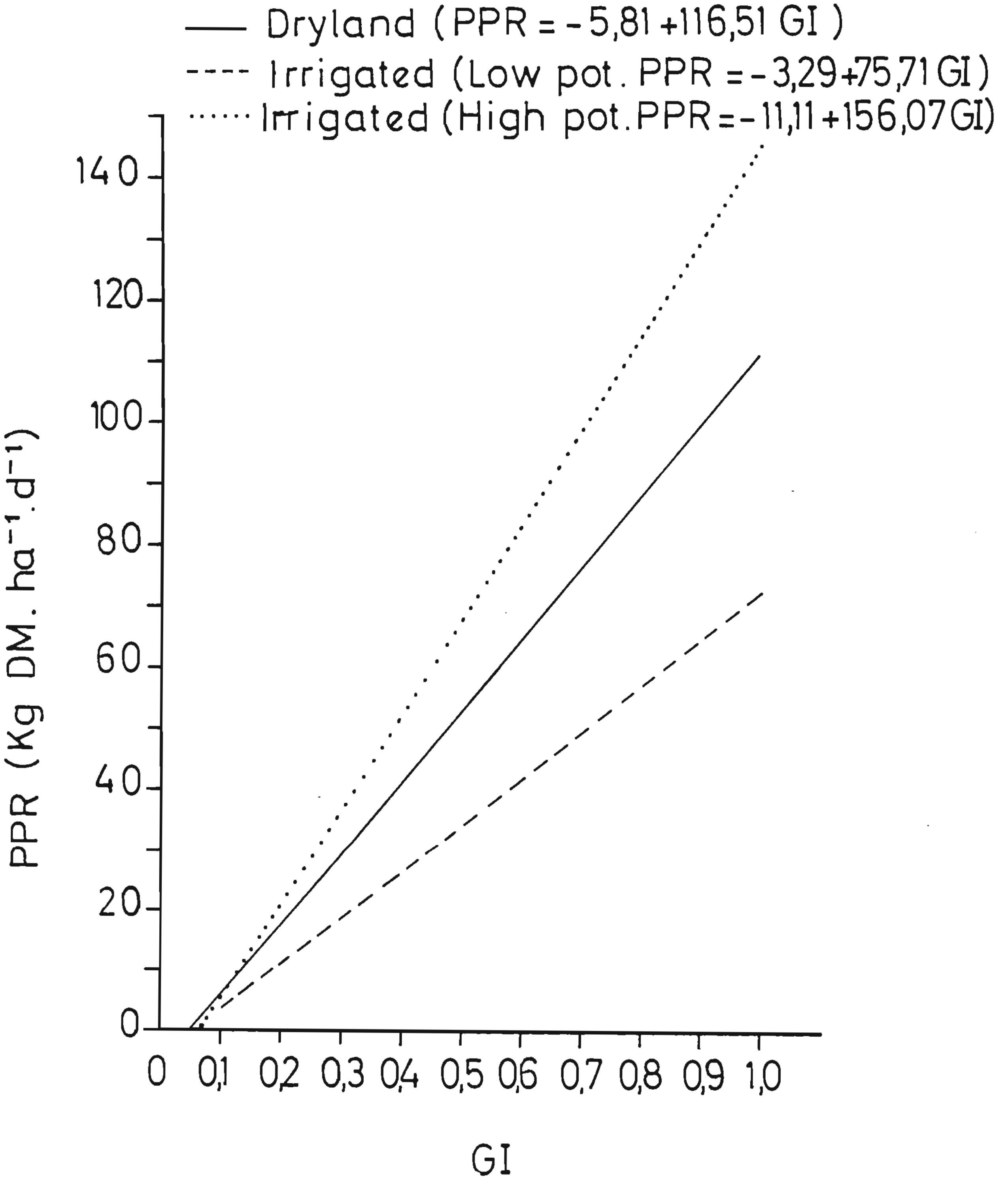
Relationships were subsequently developed between GI and the actual production rate (APR) and used for the calculation of the potential production rate (PPR). These relationships are depicted in figure 3.115. Under dryland conditions a single function was developed, as the species was only evaluated at one site. This function is as follows:

$$PPR = -5,81 + 116,51GI$$

Under irrigation, however, soil had such a large influence on the seasonal production rate that two separate functions had to be developed. One function was developed for a high potential soil, represented by the Oakleaf soil form of the Oudtshoorn trial site. Another function was developed for a low potential soil, using data acquired at the Outeniqua and Welgevallen trial sites on Estcourt and Sterkspruit soil forms, respectively. The two functions are as follows:

$$PPR(\text{high potential}) = -11,11 + 156,07GI$$
$$PPR(\text{low potential}) = -3,29 + 75,71GI$$

Figure 3.115 Relationships between the growth index (GI) and the potential production rate (PPR) for annual ryegrass under dryland and irrigation



For the validation of the above mentioned functions, data acquired during the last season at all trial sites were excluded so that they could be used for this purpose. As a first step, the PPR and APR values were, however, compared over the whole trial period at each trial site. These results are depicted in figure 3.116. The PPR values followed those of the APR very well and the correlations were highly significant in all cases.

The above mentioned results are very promising, but the functions had to be validated even further, using data which had not been utilised during the development phase. These results are depicted in figure 3.117. The PPR values deviated much more from those of the APR than had been the case with the longer term data. At Oudtshoorn the deviations were the largest and, as the trend of the two curves also differed quite significantly, the correlation was not significant. Under irrigation, as well as under dryland at Outeniqua, the PPR values also deviated from the APR values, but as the two sets of data had basically the same trend, they were highly significantly correlated with the APR values.

Bearing in mind the simplicity of the above mentioned models, the results were very promising. The models were, futhermore, never intended to be used for the prediction of actual monthy PPR values, but rather for the prediction of long-term PPR values, using long-term mean monthly climatic data as input. The derived functions were, therefore, used in this way to derive the curves depicted in figure 3.118.

Very large differences in predicted PPR values, due to variations in soil potential between sites, are obvious under irrigation. However, the differences due to variations in climate, are equally large. During the period

Figure 3.116 Comparison of actual (APR) and predicted potential (PPR) production rates at three irrigated and one dryland site over the whole experimental period

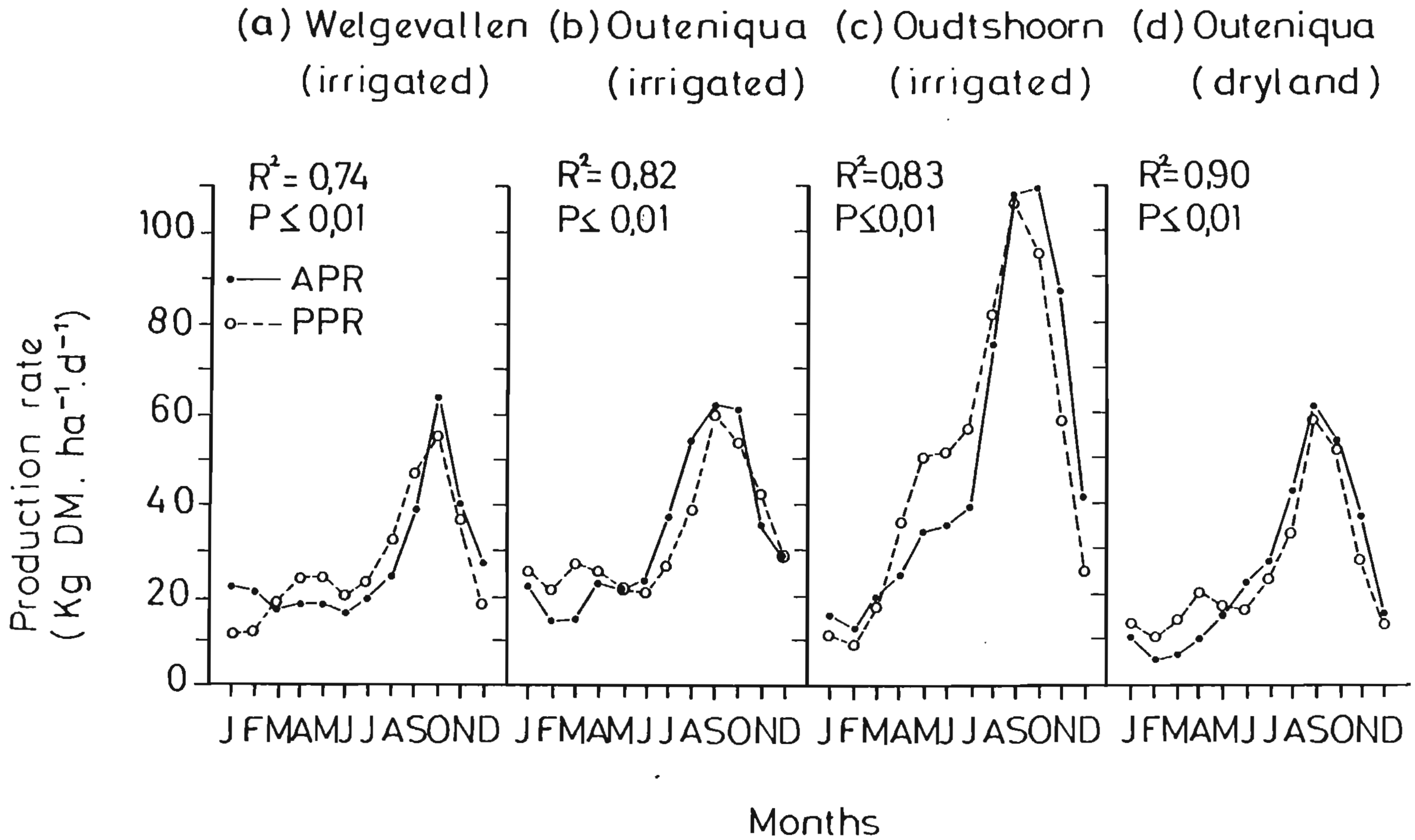


Figure 3.117 Comparison of actual (APR) and predicted potential (PPR) production rates at two irrigated and one dryland site, using data which had not been utilised during the development phase

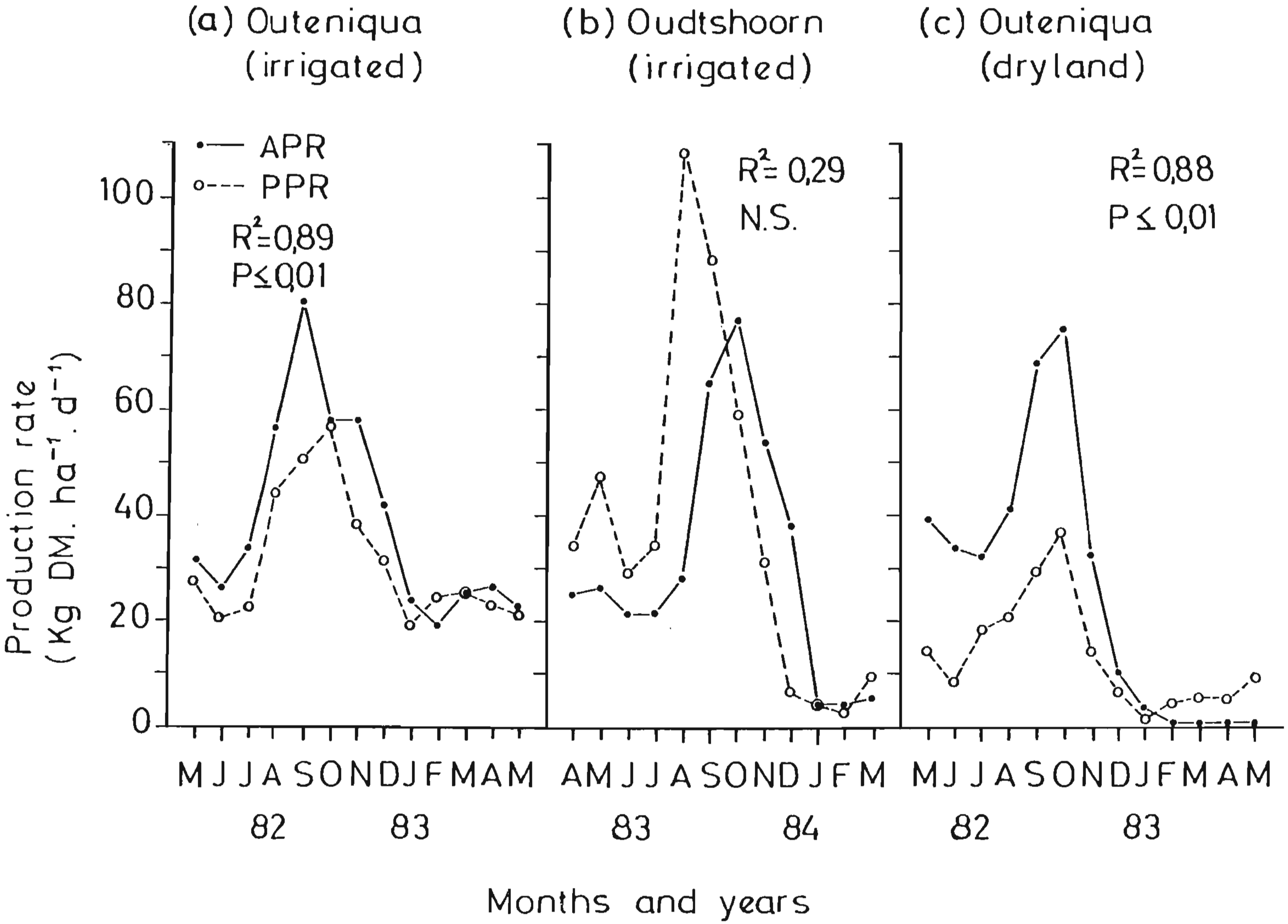
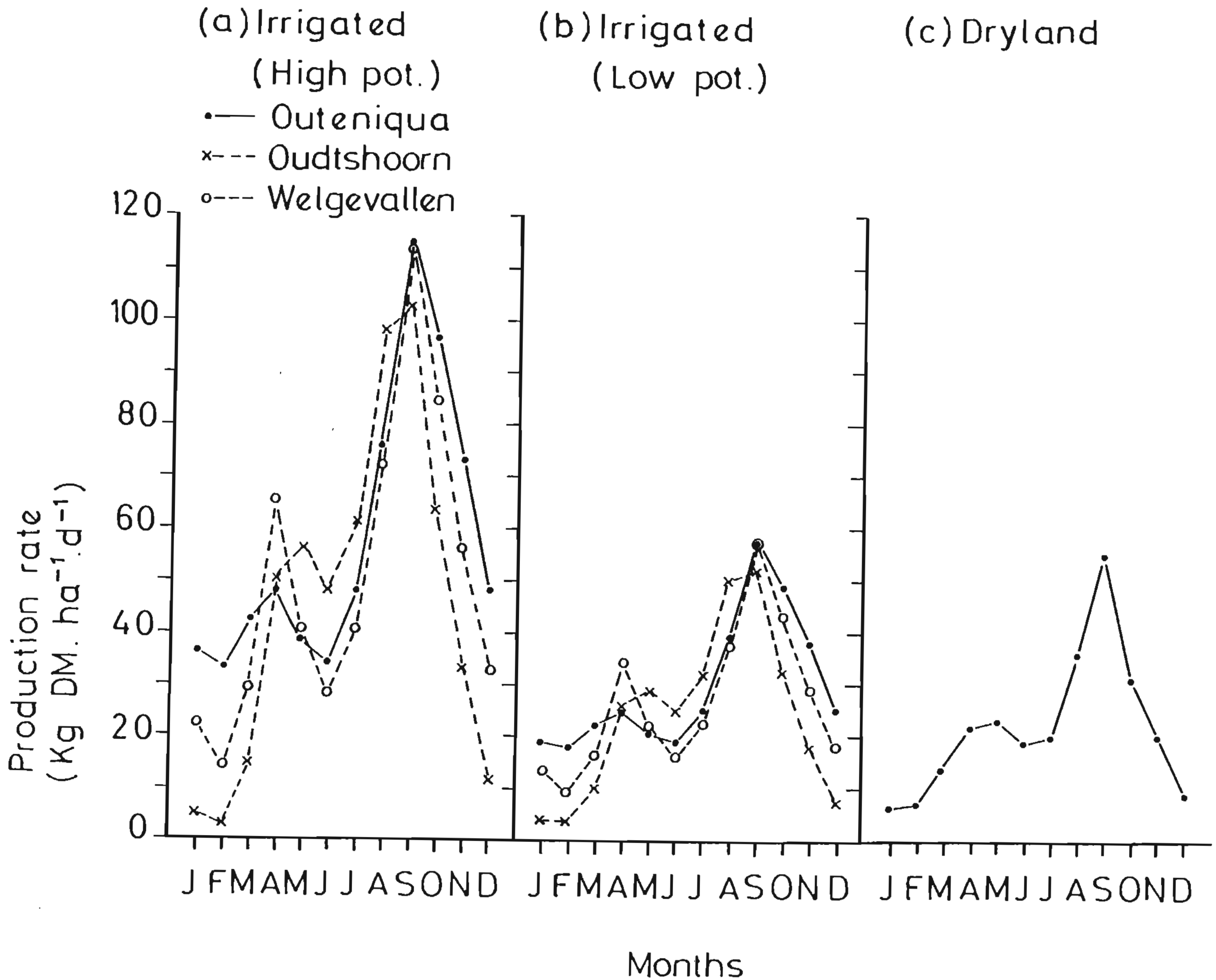


Figure 3.118 Long-term potential production rate (PPR) of annual ryegrass predicted, using the derived functions and long-term mean climatic data



October to March the PPR values are high at Outeniqua and much lower at Oudtshoorn and Welgevallen, with the lowest values occurring at Oudtshoorn. During winter (May to August) the values are, however, highest at Oudtshoorn. At all sites the lowest values occur during summer (December to February/March) and the highest during October. A pronounced second period of low production occur during June at Welgevallen and Outeniqua. At Oudtshoorn a much less pronounced low occurs during this period.

Under dryland at Outeniqua, the predicted PPR values were high during the period April to November, with the highest values occurring during September. During summer, however, the PPR values were very low.

3.3.11.4 Discussion and conclusions

The results of the cutting frequency trials indicated that annual ryegrass is very insensitive to cutting frequency.

Seasonal production rates, derived in the cutting trials, indicated that the production rates of annual ryegrass are generally very low during summer (January), but high during winter and spring (September/October) under dryland, as well as under irrigation.

For the successfull extrapolation of seasonal production rates, using mean monthly climatic data as input, a fourth climatic index, RTI, was introduced. As this species was evaluated at only one dryland trial site, only one relationship between GI and APR was needed. Under irrigation, however, soil potential played such an important role that two functions were needed, i.e. one for a high potential and one for a low potential soil.

Using the functions developed for the extrapolation of seasonal production rates and using the mean monthly climatic data of the whole trial period as input, the calculated PPR values were compared with the mean APR values derived over the same period. All correlations were highly significant. When the functions were further validated, using new data which had not been used during the development phase, it was found that the correlations were lower but, with the exception of one site (Oudtshoorn), significant. The results were, however, still very promising, as the relatively simple functions were never intended to be used for the prediction of the PPR values on an annual bases, but rather for the prediction of long-term values, using long-term mean monthly climatic data as input.

The success of the validation exercise prompted the use of the functions for the prediction of the long-term PPR values at each trial site, using long-term mean monthly climatic data as input. It was found that the lowest PPR values seem to occur during summer at the irrigated, as well as the dryland site (Outeniqua). The highest values occur during September/October, but the values are generally very high during winter and indicative of the high winter production potential of the species.

Annual ryegrass should, therefore, due to its high winter production potential, be able to make a very important contribution to the seasonal production of temperate grass or grass/legume pasture mixtures in the WRR. The occurrence of annual ryegrass toxicity, however, limits its use and it is generally only used in short term pastures which are prevented from setting seed. Another factor which limits its use in the WRR is the ever present danger of the grass becoming a weed in the subsequent wheat crop.

4. DETERMINATION OF THE ANIMAL PRODUCTION POTENTIAL OF PASTURE MIXTURES IN THE SOUTH COAST SUB-REGION

4.1 Introduction

In this chapter an account will be given of the results of four grazing trials, executed over a period of six years (1979 to 1985) at two experimental stations, Tygerhoek and Outeniqua, in the South Coast sub-region. In a pasture research program the first phase would normally consist of the evaluation of various pasture species in plot trials. Grazing animals would therefore be introduced only in later phases of the program. However, when this program was initiated, there were already a large number of very successful pasture species and mixtures in general use within the Winter Rainfall Region. Very little was, however, known of their relative animal production potential and/or management requirements.

The four grazing trials were, therefore, executed simultaneously with the plot trials, the main objectives being to evaluate pasture mixtures already in use, to determine their relative animal production potential and also to shed some light on certain aspects of pasture management. Also, these trials were needed to provide much needed data for the development of pasture:animal production functions which could be used for the further development of the climate:pasture production models discussed in Chapter 3 into a larger climate:pasture:animal production model.

4.2 Trial sites

Four trials were executed on two sites. The sites, the trials executed at each, and their duration are indicated in table 4.1.

TABLE 4.1 SITES OF THE FOUR GRAZING TRIALS

Trial No	Site	*Type of trial	Duration	Soil form (and parent material)
1	Tygerhoek	Dryland	1980-1984	Mispah (shale)
2	Tygerhoek	Dryland	1983-1985	Glenrosa (shale)
3	Tygerhoek	Irrigated	1981-1984	Glenrosa (shale)
4	Outeniqua	Irrigated	1984-1985	Estcourt (granite)

*For more details see also table 2.1

4.3 Objectives and treatments

4.3.1 Trial 1: Determination of the relative animal production potential of medic and lucerne pastures under dryland at Tygerhoek

As has already been indicated in Chapter 3, lucerne and medics are the two main pasture legumes used under dryland in the South Coast sub-region. Both pasture types are used in the same manner, i.e. in rotation with wheat. The philosophy behind the use of these pastures is therefore similar to that of the subterranean clover or medic pasture-wheat rotation systems used in the wheat-sheep zones of Australia (White, et al, 1977).

However, as the South Coast sub-region receives a considerable amount of summer rainfall, lucerne was the first legume to be introduced. This occurred during the 1930's (Sim, 1958). Medic and subterranean clover pastures were only introduced during the middle 1960's (Wassermann, pers com).

In the Department of Agriculture and Water Supply very clear cut views exist as to the relative roles of lucerne and medic pastures within the wheat-sheep industry. Medics are seen as short term pastures and mainly suitable as pastures for periods of one to three or at the most five years. Lucerne, however, is recommended for longer term pastures, i.e. five to ten or even 15 years. In practice, however, considerable controversy has existed as to the relative animal production potential of lucerne and medic pastures, as their relative animal production potential has never been determined. This information is therefore clearly very important for planning purposes, and this formed the main objective of this trial.

The composition of the two pastures, the sowing rate of each component and the stocking rates which were applied, are indicated in Table 4.2. The trial had no replicates and pastures and stocking rates were allocated randomly to the respective camps. Due to the lack of replication, the pasture types were largely compared by fitting regression functions between stocking rate and the respective parameters. In cases where this was not possible, as with the seasonal available pasture material, only the general trends will be discussed.

4.3.2 Trial 2: Determination of the influence of grass control measures on the animal production potential of dryland medic, lucerne and subterranean clover pastures at Tygerhoek

A number of grass and broad leaved annuals ingress into dryland legume pastures in both the Swartland and the South Coast sub-regions of the Winter Rainfall Region (Le Roux, 1983). This also seems to be a major problem in the Australian dryland legume pastures (Myers & Squires, 1970; Campbell, et al, 1972; Cocks, 1975; Reeves & Smith, 1975; Venn, 1984). In the Winter Rainfall Region, the grasses involved are mainly *Lolium* spp. (*L. rigidum* and *L. multiflorum*), *Hordeum murinum* and *Bromus diandrus*. The broad leaved species are mainly *Erodium moschatum* and *Arctotheca calendula* (only Swartland), and a very small proportion of *Emex Australis*.

Some of the annuals, such as the *Lolium* spp. and also *Erodium moschatum*, are valuable grazing plants and contribute a large proportion of the winter grazing on lucerne, as well as medic pastures. Other species such as *Hordeum murinum*, *Bromus diandrus* and *Emex australis* may, however, have serious detrimental effects on the grazing animal (Campbell, et al, 1972; Dane, 1979). Since the

TABLE 4.2 TRIAL 1 : SPECIES AND CULTIVAR COMPOSITION OF THE PASTURES AND TREATMENTS

Pasture composition	Seeding rate ($kg.ha^{-1}$)	Grazing methods	Stocking rate *($EU.ha^{-1}$)
Lucerne pasture: cv S A Standard	10	Two camp system, monthly rotation	4; 5; 6; 7 and 8
Medic pasture: cv's Jemalong Cyprus Borung Harbinger	 4 4 4 4	 Continuous	 3; 4; 5; 6 and 7

*EU = ewe-unit (one ewe plus one lamb)

development of annual ryegrass toxicity in this region, however, the annual ryegrasses also pose a problem in some instances (Stynes & Wise, 1980; Schneider, 1981).

The relative proportion of the above-mentioned species differ quite largely between different localities and pastures. The proportions are determined by site differences, but also by previous weed control practices in the pasture itself, the type of rotation and the cultivation and weed control practices during the wheat phase, as well as the length of the pasture phase. The major problem species are the grass weeds, as they are also major weeds in the subsequent wheat crop (Barrett & Campbell, 1973; Reeves & Smith, 1975; Appleby, et al, 1976; Reeves, 1976), and can also carry over root diseases of wheat (Cocks, 1975; Walker, 1975; Reeves & Smith, 1975; Venn, 1984).

In recent years very effective grass killers have, however, become available (Cairns, 1979; Dane, 1979; Le Roux, 1983; Venn, 1984). The most important question from a pasture viewpoint is, however, whether it is necessary to remove the grasses from a pasture, especially when the cost of chemical weed killers is taken into consideration. Also, the nature of the effect of the removal of the grasses on the composition and life span of the pastures and on the production of the grazing animals has not to-date been established experimentally. In the light of findings by Myers & Squires (1970) and Reeves & Smith (1975) that the ingress of volunteer grasses could be controlled by pasture management in irrigated pastures, it was also of interest to know what effect stocking rate would have on the botanical composition of dryland pastures. This trial was therefore conducted with the main purpose of answering some of these questions.

The composition of the pastures, the sowing rate of each component and the treatments applied, are indicated in Table 4.3. The camps were grouped into four blocks to which the stocking rates were allocated at random and within which the different pasture types and weed control treatments were also randomly allocated. This outlay enabled the use of the four stocking rates as blocks in the subsequent analysis of the data, as well as the fitting of regressions over the stocking rates.

4.3.3 Trial 3: Determination of the grazing capacity and animal production potential of a complex irrigated grass/legume pasture at Tygerhoek

The Winter Rainfall Region is well known for its large area under dryland legume based pastures. Not so well known, however, is the relatively large area under irrigated grass/legume pastures used for dairying and prime lamb production. These pastures generally form part of larger fruit or wine producing farming systems, and often comprise the sole source of feed on any particular farm.

For a number of years complex, but very successful, irrigated grass/legume mixtures (Pienaar & Volschenk, 1970; Wassermann, 1981) have been in use in the Winter Rainfall Region. These mixtures consisted mainly of varying proportions of the legumes: lucerne, white and red clover and the temperate grasses: tall fescue, cocksfoot and ryegrass.

The management requirements, grazing capacity and animal production potential of such mixtures have, however, never been determined, and advisory work has been largely based on guesswork, supported by what relevant literature is available. The main objective of this trial was therefore to determine the animal production potential of such a

TABLE 4.3 TRIAL 2 : SPECIES AND CULTIVAR COMPOSITION OF THE PASTURES AND THE TREATMENTS(**)

Pasture composition	Seeding rate ($kg.ha^{-1}$)	Grazing method	*Weed control treatment
Lucerne cv. S A Standard	20	Two camp system, monthly rotation	No control (C)
			Grass control (G)
Medic cv. Jemalong	7	Continuous	No control (C)
Cyprus	7		Grass control (G)
Borung	7		
Subterranean clover cv. Woogenellup	10	Continuous	No control (C)
Seaton Park	10		Grass control (G)

* Weed control: 1982 (establishment): Dinoseb (0,90 kg $ai.ha^{-1}$) for broad leaved weed control on all treatments.
1983 : Fluazifop-butyl (0,25 kg $ai.ha^{-1}$) for grass control on G-treatments.
1984 : Propyzamide (0,74 kg $ai.ha^{-1}$) for grass control on G-treatments.

** Four stocking rates were applied: 6; 8; 10 and 12 $SU.ha^{-1}$ (one SU = one dry small stock unit) on all pastures and all weed control treatments during the period 1983 to 1985.

pasture under two pasture management regimes and also to determine its seasonal grazing capacity.

The composition of the pasture, the sowing rate of the different components, as well as the treatments which were applied, are indicated in Tables 4.4 and 4.5. A random blocks design was used, with two blocks, and with grazing treatments and stocking rates and/or grazing pressures allocated randomly to camps within each block. However, as the stocking rates were changed during the last season the results of part of the trial could not be compared by analysis of variance and regression techniques had to be employed. In cases where this was not possible, as with the analysis of pasture production rates, the general trends only were discussed.

4.3.4 Trial 4: Determination of the grazing capacity and animal production potential of a number of irrigated pure grass and grass/legume pasture mixtures at Outeniqua

In trial 3 a complex irrigated grass/legume mixture, which had been in use for a number of years, was evaluated. Trial 4 was designed to take the evaluation one step further, with the main objective to evaluate simpler mixtures of species which had indicated promise in the first phase of evaluation, as discussed in chapter 3.

The main objectives was therefore to determine the seasonal grazing capacity and animal production potential of these pastures and subsequently, the development of pasture production systems based on mixtures. The composition and the sowing rate of each component, as well as the treatments which had been applied in this trial are indicated in Tables 4.6 and 4.7.

TABLE 4.4 TRIAL 3 : SPECIES AND CULTIVAR COMPOSITION OF THE PASTURE

Pasture composition	Seeding rate ($kg.ha^{-1}$)
Lucerne cv. S A Standard	3
Red clover cv. Kenland	3
White clover cv. Ladino	3
Tall fescue cv. Kentucky 31	4
Cocksfoot cv. Hera	4
Perennial ryegrass cv. Agresso	4

TABLE 4.5 TRIAL 3 : TREATMENTS

Grazing method	Period	Stocking rate **($EU.ha^{-1}$)	Grazing pressure **($Kg\ DM.SU^{-1}.d^{-1}$)
Continuous	1981-1983	25,7; 30,9 and 36,0	-
	1983-1984	28,3; 30,9 and 33,4	-
Rotational *(6 camp system)	1981-1983	25,7; 30,9 and 36,0	-
	1983-1984	33,4; 36,0 and 38,6	-
Variable stocking rates (put-and-take) *(6 camp system)	1981-1984	-	1,5; 2,25 and 3,0

* Weekly rotation
** EU = ewe-unit (one ewe plus one lamb)
SU = dry sheep-unit

TABLE 4.6 TRIAL 4 : SPECIES AND CULTIVAR COMPOSITION OF THE PASTURES

No	Pasture composition	Seeding rate ($kg.ha^{-1}$)	No	Pasture composition	Seeding rate ($kg.ha^{-1}$)
1	White clover cv Ladino	2,5	4	Perennial ryegrass cv	
	Haifa	2,5		Ruanui	5
				Agresso	5
	Perennial ryegrass cv				
	Ruanui	5	5	Tall fescue cv Demeter	5
	Agresso	5		Kentucky 31	5
2	White clover cv Ladino	2,5	6	Lucerne cv S A Standard	10
	Haifa	2,5			
	Tall fescue cv Demeter	5		Tall fescue cv Demeter	5
	Kentucky 31	5		Kentucky 31	5
3	White clover cv Haifa	2,5	7	Lucerne cv S A Standard	10
	Ladino	2,5			
	Cocksfoot cv Hera	5		Cocksfoot cv Hera	5
	Currie	5		Currie	5

TABLE 4.7 TRIAL 4 : TREATMENTS

Grazing method	Length of rest period	Grazing pressure ($kg\ DM.SU^{-1}.d^{-1}$)*
5 camp system	4 weeks	Autumn, winter and spring: 1,65 Summer : 1,55
7 camp system	6 weeks	Autumn, winter and spring: 1,65 Summer : 1,55

* Grazing pressure based on green material only; 1 SU = a 45 kg livemass

As the evaluation of the maximum possible number of treatments was of paramount importance, the seven pastures and two management regimes were not replicated in the normal manner. For the efficient sampling of soil and site variations within the trial area, the following procedure was, however, adopted. The whole trial area was divided into 84 (seven pasture types x (5 + 7)) individual camps. These camps were allocated to 12 groups of seven camps each and a management regime (a five or a seven camp system) was randomly allocated to each group. Within each group of seven camps the seven pastures types, which were eventually evaluated, were randomly allocated. This resulted in an even distribution of treatments as single camps over the whole trial area.

The different treatments, i.e. two grazing management systems and seven pasture mixtures, were compared using analysis of variance. The legume contents, production rates and seasonal grazing capacities of the treatments were compared, using the values derived on the individual camps as replications, while the animal production data, i.e. wool production per tester animal, and per hectare, the ADG and the meat production per hectare of the treatments, were compared, using the individual animals as replicates. These latter comparisons were, strictly speaking, not entirely valid. However, as the testers, the permanent group on which the measurements were taken, comprised a relatively small random group of animals within a larger group of fillers, it was accepted that the individual testers were completely independent and randomly chosen and allocated to each treatment and subsequently did not interact with one another.

4.4 Methods

4.4.1 Soil preparation and pasture establishment

The soil of each trial site was fertilized with the appropriate levels of P and lime based on soil analysis (Beyers, 1983). As has already been indicated (table 4.1), the majority of the trials, i.e. those at Tygerhoek, were executed on soils of shale parentage and no K fertilization was therefore needed. The trial at Outeniqua was, however, established on a soil of granite origin. On this site more frequent applications of K, also based on soil analysis, were therefore needed. No N fertilization was applied to any of the legume or grass/legume pastures, but at Outeniqua (trial 4), the pure grass pastures were fertilized with N at a rate of 600 kg $N.ha^{-1}.A^{-1}$ in two-monthly applications of 100 kg $N.ha^{-1}$.

Seeding was done during either April or May in the case of the two dryland trials at Tygerhoek and the irrigated trial at Outeniqua (trials 1; 2 and 4), or September, in the case of the irrigated trial at Tygerhoek (trial 3). Before sowing the soils were well cultivated to produce a fine seedbed. The seed was subsequently sown on top of the soil surface and harrowed very lightly to ensure a shallow seeding depth. Before sowing, all legume seeds were inoculated with the appropriate commercial Rhizobia to ensure effective nodulation and nitrogen fixation.

4.4.2 Weed and pest control

Before sowing all legume seeds were treated with dimethoate (Staphorst & Strijdom, 1974; Bot, et al, 1984) as protection against possible damage by red legged earth myte (Halotydeus destructor), but during subsequent seasons only the dryland medic and lucerne pastures were sprayed for the control of red legged earth myte during autumn, and the pea aphid (Acerthosiphon pisum) during late winter.

In the first dryland trial at Tygerhoek (trial 1) weed control measures were limited to two treatments to control grass infestation, using propyzamide (0,74 kg ai.ha^{-1}). No weed control measures were, however, necessary in the irrigated trials at Tygerhoek and Outeniqua (trials 3 and 4) and in the second dryland trial at Tygerhoek (trial 2) the measures were limited to the treatments indicated in table 4.3.

4.4.3 Irrigation

In the two irrigated trials at Tygerhoek and Outeniqua (trials 3 and 4), all irrigations were applied by means of a permanent overhead sprinkler systems at rates of 25 to 30 mm per application. Generally from one to two applications per week sufficed, but the number of applications was largely determined by evapotranspiration rates, measured by tensiometer readings at strategic locations within the trials.

4.4.4 Determination of the available pasture material, the rate of pasture production and intake, as well as the botanical composition of the available pasture material

Before discussing the methods used to determine the above mentioned parameters, it is appropriate to discuss certain definitions and terms which will be used in the text. The term total available pasture material will mean all dead plus all living (green) material on and above the soil surface. Dry material means all senescent material. Green material would mean all actively growing material.

In the two dryland trials at Tygerhoek (trials 1 and 2), the low availability of grazing material during summer necessitated the use of a method similar to that developed by Hutchinson (1967) to determine the available grazing material. This method consisted of taking a large number (20 to 30.ha^{-1}) of small (100 mm diameter) cores randomly within each pasture. The small size of the samples allowed the accurate removal of all grazeable material on the very short, and often completely dry, pastures during summer. Although, the variation between samples was rather large, the method allowed an apparently accurate determination of the seasonal trends in available pasture material, as well as the botanical composition of the material.

The pastures of the dryland trials at Tygerhoek were sampled monthly and each sample was fractionated into pods (in the case of medic and subterranean clover pastures), other dry material and green material. At fixed time intervals (twice annually during the growing season in trial 1, and monthly for 12 months of the year in trial 2) the green fraction was further fractionated into legume, broad leaved weed and grass fractions. The fractionated samples were thoroughly rinsed, using clean running water, to ensure the removal of all soil contamination, dried to constant weight at 60°C and weighed.

In the case of the two irrigated trials (trials 3 and 4) at Tygerhoek and Outeniqua, the available pasture material was estimated using a standard disc meter (Castle, 1976; Bransby & Tainton, 1977; Mitchell, 1982; Stockdale, 1984; Stockdale & Kelly, 1984). The meter was calibrated by cutting samples to ground level under the disc at monthly (trial 4, the irrigated trial at Outeniqua) to three-monthly (trial 3, the irrigated trial at Tygerhoek) intervals. The calibration curves which were used in trials 3 and 4, are indicated in figures 4.1 to 4.4.

Figure 4.1 Calibration curves depicting the relationship between disc meter height (cm) and the total available pasture material (M $ton.ha^{-1}$) in trial 3 at Tygerhoek

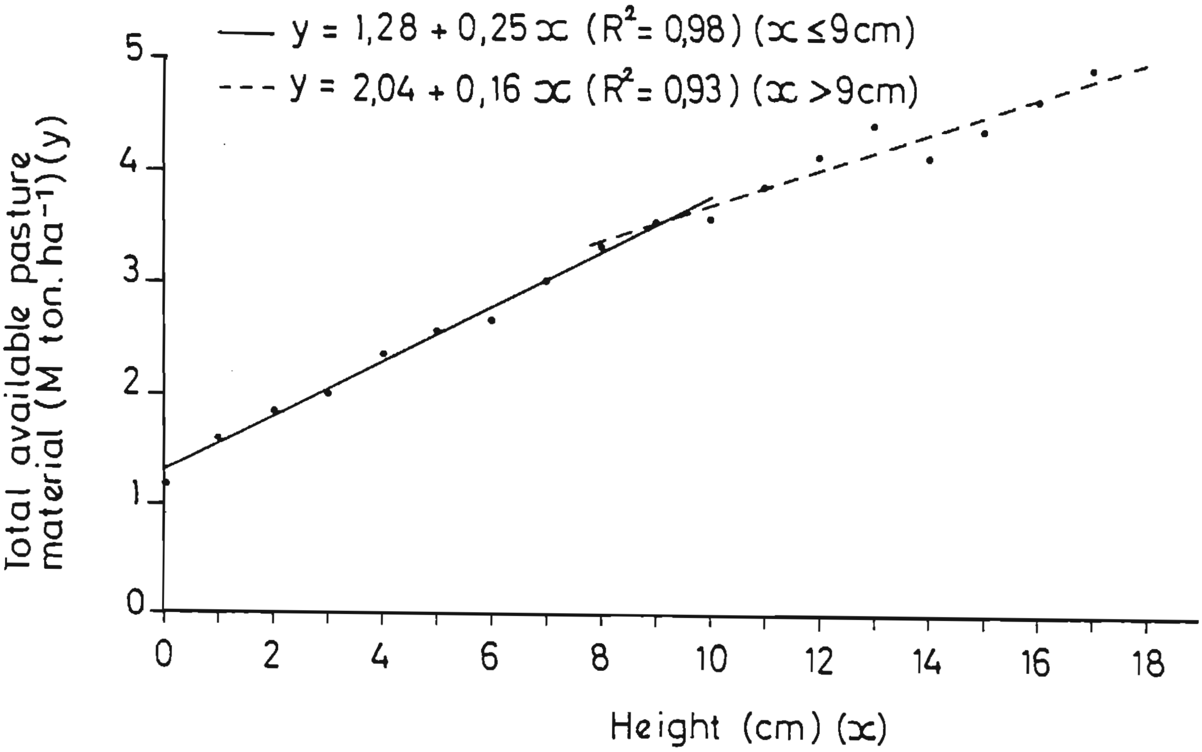


Figure 4.2 Calibration curves depicting the relationship between disc meter height (cm) and the total available green pasture material (M ton.ha^{-1}) on the white clover plus ryegrass (A), white clover plus fescue (B) and white clover plus cocksfoot (C) pasture mixtures in trial 4 at Outeniqua

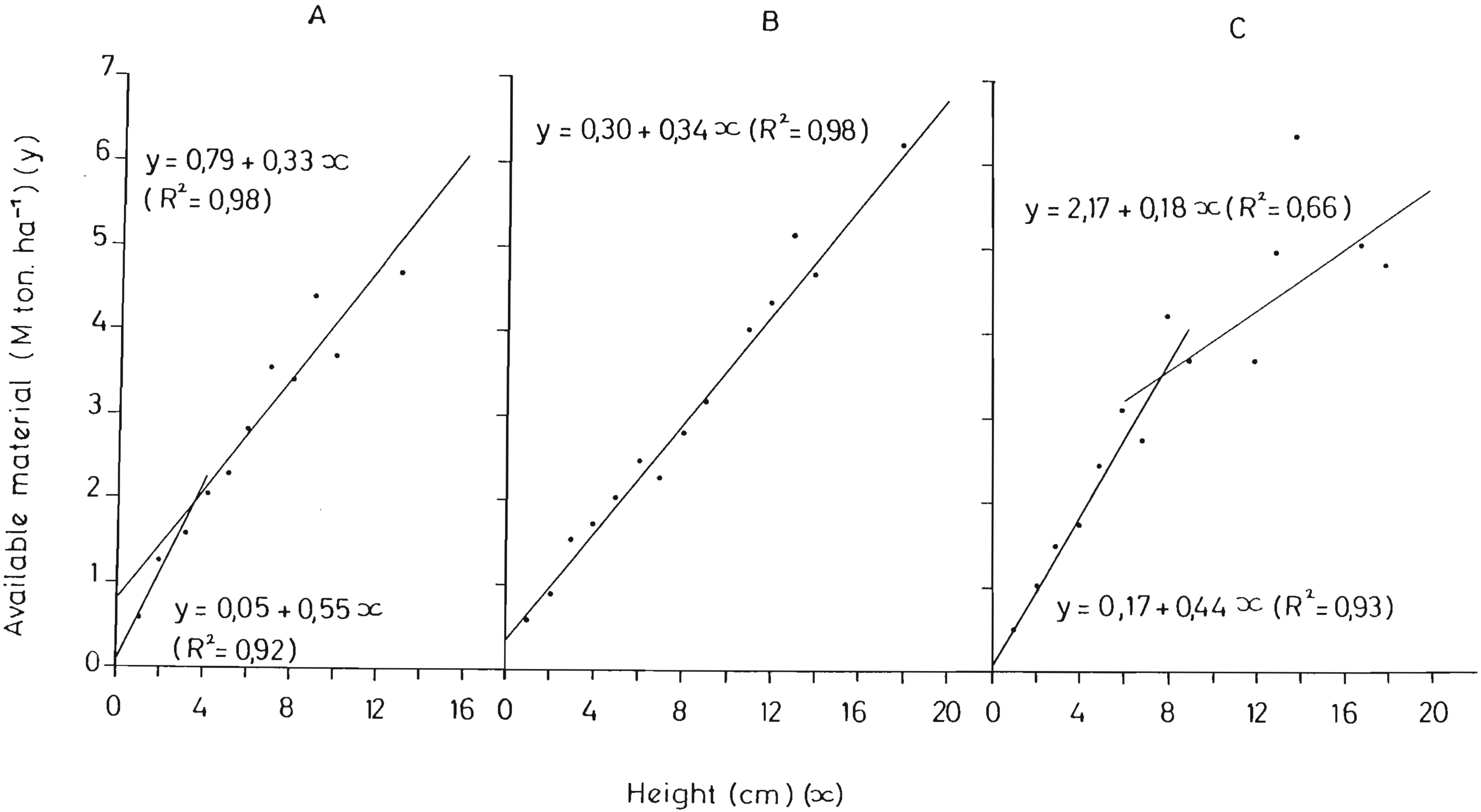


Figure 4.3 Calibration curves depicting the relationship between the disc meter height (cm) and the total available green pasture material (M ton.ha^{-1}) on the pure fescue (A) and lucerne plus fescue (B) pasture mixtures in trial 4 at Outeniqua

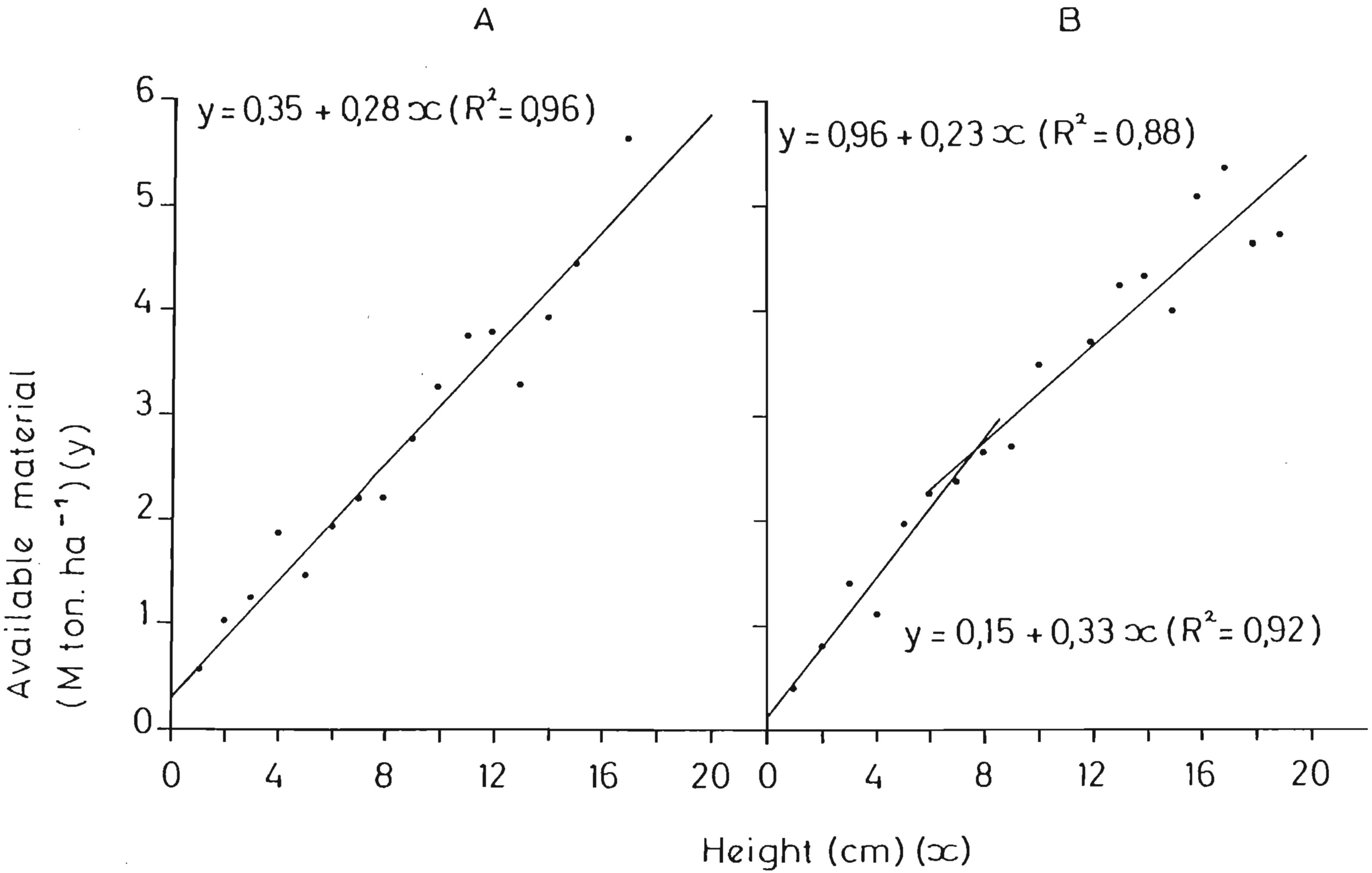
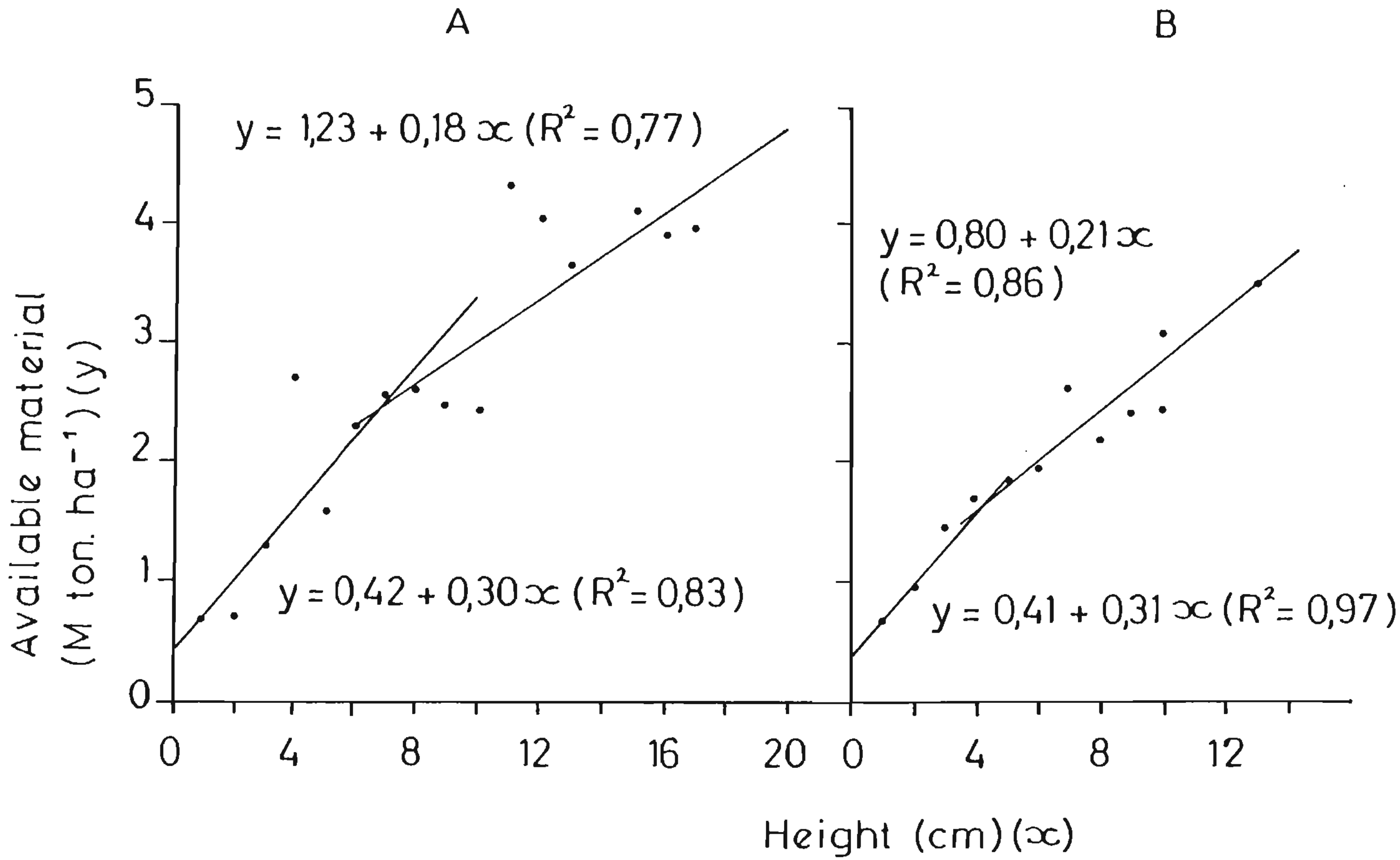


Figure 4.4 Calibration curves depicting the relationship between the disc meter height (cm) and the total available green pasture material (M $ton.ha^{-1}$) on the lucerne plus cocksfoot (A) and pure ryegrass (B) pasture mixtures in trial 4 at Outeniqua



In the irrigated trial at Tygerhoek (trial 3) only one calibration curve was used, but in the irrigated trial at Outeniqua (trial 4) a separate calibration curve had to be determined for each of the seven pasture mixtures. The actual data indicated in the figures are the means of each height class and are the values which were used for fitting the curves. A distinctive feature of a majority of the curves was the fact that they actually consisted of two separate curves. This can be explained by the fact that the resilience of the pasture material increased as it grew taller and the available material increased. A number of non-linear curves were evaluated, but the best fits were eventually obtained when two linear regression functions were fitted to each data set. At Tygerhoek satisfactory results were obtained by using the total available pasture material as basis. At Outeniqua, however, better results were obtained with curves based on the total available green material.

The cut samples were fractionated and the botanical composition determined, as in the case of the dryland pastures.

After calibration, the pasture meter was used to estimate intake in the irrigated trial at Tygerhoek (trial 3) and pasture growth rate in both the irrigated trials at Tygerhoek and Outeniqua (trials 3 and 4), by combining the use of the disc meter with the use of exclosure cages. Four cages ($1m^2$) were used in the smaller rotationally grazed camps in the irrigated trials at Tygerhoek and Outeniqua (trials 3 and 4) and eight in the larger continuously grazed camps in the irrigated trial at Tygerhoek (trial 3). Disc meter readings were taken monthly on the continuously grazed camps and the cages subsequently shifted to new positions. On the rotationally grazed camps the readings were taken weekly, i.e. when the grazing animals were shifted to a new camp, and the cages then also shifted to the new camps. At each estimation the available material inside and outside the cages was estimated in the camps which had just been grazed. Three readings were taken within each cage. On the rotationally grazed camps, 10 readings and on the continuously grazed camps, 30 readings were taken outside the cages. The mean available material at each reading was then calculated using the calibration curves, and the intake and growth rate calculated by means of a computer program which had been developed for this purpose, using the following functions:

Intake rate ($kg.SU^{-1}$ or $EU^{-1}.d^{-1}$)

$$= ((DM_{in} - DM_{out2}).PER_2^{-1}).NUM^{-1};$$

Pasture production rate ($kg.ha^{-1}.d^{-1}$)

$$= (DM_{in} - DM_{out1}).PER_1^{-1};$$

where,

DM_{in} = mean available pasture material inside cages ($kg.ha^{-1}$);

DM_{out1} = mean available pasture material outside cages during the previous estimation ($kg.ha^{-1}$);

DM_{out2} = mean available pasture material outside cages during present estimation ($kg.ha^{-1}$);

PER_1 = period between measurements (grazings);

PER_2 = grazing period (in continuously grazed situations PER_1=PER_2);

NUM = number of EU or $SU.ha^{-1}$;

EU = a ewe-unit (one ewe + one lamb);

SU = a dry sheep-unit;

4.4.5 Experimental animals

Merino sheep are widely used on dryland pastures in the South Coast sub-region. This fact, as well as the fact that a large number of Merino's were available for the trials, led to a decision to use this type of animal for all the trials at Tygerhoek (trials 1; 2 and 3). However, in other parts of the region, e.g. the Swartland and also under irrigation, S A Mutton Merino's, or even dairy cattle, would perhaps have been more appropriate. For this reason, and also because the Merino's do not adapt very well to the humid climate of Outeniqua, trial 4 at Outeniqua was undertaken with S A Mutton Merino's.

In the first dryland trial at Tygerhoek (trial 1) and part of the irrigated trial at the same site (trial 3), reproducing animals with one lambing season were used. In the dryland trial (trial 1) the ewes lambed during autumn (May), with weaning during late winter (August), and in the irrigated trial at Tygerhoek (trial 3), lambs were dropped during spring (September), with weaning during late summer (February). To ensure that differences in lambing and weaning percentage did not influence the stocking rates actually applied, ewes out of a reserve group were used as replacements at the end of each lambing period, to ensure a 100% weaning percentage. Ewes of which lambs died during the course of the season, were also replaced out of this group. Care was taken to ensure that replacement ewes and lambs were of the same mass as those which were being replaced.

The second dryland trial at Tygerhoek (trial 2), part of the irrigated trial at Tygerhoek (trial 3) and also the irrigated trial at Outeniqua (trial 4), were conducted with dry animals, which generally comprised a mixture of ewes and hoggets. In the dryland trial at Tygerhoek (trial 2) the stocking rates were fixed, but in the two irrigated trials at Tygerhoek and Outeniqua (trials 3 and 4), a put-and-take system was used, and this required a permanent (tester) group, as well as a variable (filler) group of animals

(Petersen & Lucas, 1968; Wheeler, et al, 1973). In the irrigated trial at Tygerhoek (trial 3), the same animals were used as testers throughout the whole trial period. At Outeniqua (trial 4), however, the testers were annually replaced with a new group of young growing animals. In the second dryland trial at Tygerhoek (trial 2) experimental animals were replaced annually by a younger group. In all three trials animals which died during the course of the season were replaced by animals of the same age and weight class.

4.4.6 Animal measurements

Wool production was determined annually in all four trials by shearing during either May in all the trials at Tygerhoek (trials 1; 2 and 3) or August in the irrigated trial at Outeniqua (trial 4). In the trials at Tygerhoek with fixed stocking rates (trials 1; 2 and part of 3) the wool yield of all experimental animals was determined, but in the trials with variable stocking rates, i.e. in part of the irrigated trial at Tygerhoek (trial 3) and in the irrigated trial at Outeniqua (trial 4) only the wool yield of the tester group was determined.

All animals were weighed monthly and the mean mass increase of the testers and the young growing animals determined. All animals (fillers) being moved on or off the camps in the put-and-take treatments of the irrigated trials at Tygerhoek and Outeniqua (trials 3 and 4), were also weighed before being added to or removed from a camp.

4.4.7 Application of grazing pressures in the put-and-take treatments

In the two irrigated trials at Tygerhoek and Outeniqua (trials 3 and 4) the grazing pressure treatments were largely based on a method used by Rattray & Jagush (1978) and the recommended feed allowances on the findings of Rattray (1978). The grazing pressures were based on weekly estimations of the available pasture material in each successive camp, using a disc meter. In the irrigated trial at Tygerhoek (trial 3), three grazing pressures or levels of feed allowance (kg $DM.SU^{-1}.d^{-1}$), were applied (table 4.5). In the irrigated trial at Outeniqua (trial 4), however, as has already been indicated, the disc meter was calibrated to predict available green material. Grazing pressures therefore had to be higher (i.e. fewer kg $DM.SU^{-1}.d^{-1}$) to achieve the relevant total dry matter availability per SU. Only one grazing pressure was, however, applied in this trial and had to be varied through the season to permit the same level of utilization (see table 4.7).

The number of sheep per camp was determined by dividing the available pasture material in that camp by the product of the grazing period (seven days) and the feed allowance (or grazing pressure in tables 4.5 and 4.7). In the irrigated trial at Tygerhoek (trial 3), the mean live mass of the tester and filler animals was about the same, and the animals were therefore allocated by simply applying the above-mentioned calculation. In the irrigated trial at Outeniqua (trial 4), however, the tester group differed in age and mass from the filler group, due to the fact that they were replaced annually. In this trial the filler animals were, therefore, allocated according to mass, with the standard being 45 $kg.SU^{-1}$.

4.4.8 Pasture management

In the two dryland trials at Tygerhoek (trials 1 and 2) the medic and subterranean clover pastures were grazed continuously. The lucerne pastures in these two trials were, however, grazed rotationally, using a two camp system.

In the latter instance rotations were based on the available pasture in the camp being grazed, but the animals were generally moved monthly. The grazing method applied to the annual pastures was based on the findings of Morley, et al (1969) and Fitzgerald (1976), who found that subterranean clover and medic pastures generally reacted best to continuous grazing. According to the results of grazing management studies executed by McKinney (1974), lucerne, however, seems to be extremely sensitive to the length of the period between grazings, while the length of the actual grazing period is not as important. A two camp grazing management system was therefore applied, as it allowed for an adequate manipulation of the length of the period of absence.

In the two irrigated trials respectively at Tygerhoek and Outeniqua (trials 3 and 4), grazing management was one of the treatments applied. On the rotationally grazed camps, animals were shifted on set time or at weekly intervals. In the trial at Tygerhoek (trial 3) the six camp system therefore resulted in a five week rest period, while the five and seven camp systems used in the trial at Outeniqua (trial 4), resulted in four and six week rest periods, respectively.

4.5 Results

4.5.1 Trial 1: Determination of the relative animal production potential of medic and lucerne pasture under dryland at Tygerhoek

For details, refer to tables 4.1 and 4.2.

4.5.1.1 Available pasture material

Due to the fact that the trial had no replications, the results on the available pasture material and the botanical composition of the available material could not be compared statistically. The basic trends over seasons and years will, however, be discussed.

The seasonal variation in the mean total available pasture material, calculated over the whole experimental period and all stocking rates, are depicted in figure 4.5. The difference in total available pasture material on the two pasture types was very small and the seasonal trend in total available pasture material was basically the same. The highest values occurred during spring and early summer (September to December) on both pastures, but thereafter the available material decreased sharply. The total available material on both pastures was low during the period April to August, with the lowest values occurring during April and July. During autumn and winter, however, the total available material tended to be slightly higher on the lucerne than on the medic pastures, but during spring and summer, the medic pastures provided more material than the lucerne pastures.

The seasonal variation in the two main components of the total available pasture material, i.e. the green material and, on the medic pastures, the pods, calculated for the whole experimental period and over all stocking rates, is depicted in figure 4.6. The seasonal available green material tended to differ greatly at times on the two pasture types. During winter (June to October) there seemed to be very little difference, but during the remainder of the season the available green material tended to be higher on the lucerne than on the medic pastures. On both pasture types, the available green material tended to be highest

Figure 4.5 Total available pasture material (M ton.ha^{-1}) meaned over the whole trial period (1980-84) and all stocking rates on the lucerne and medic pastures

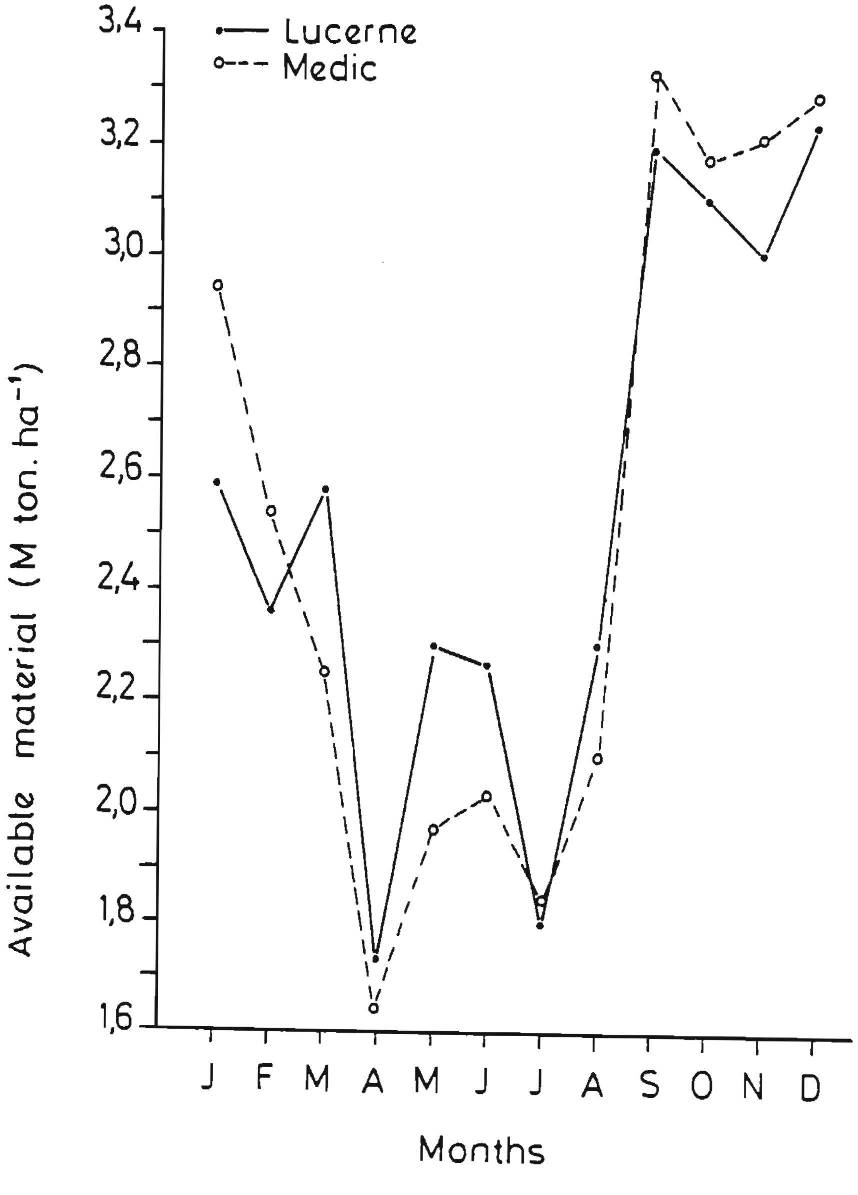
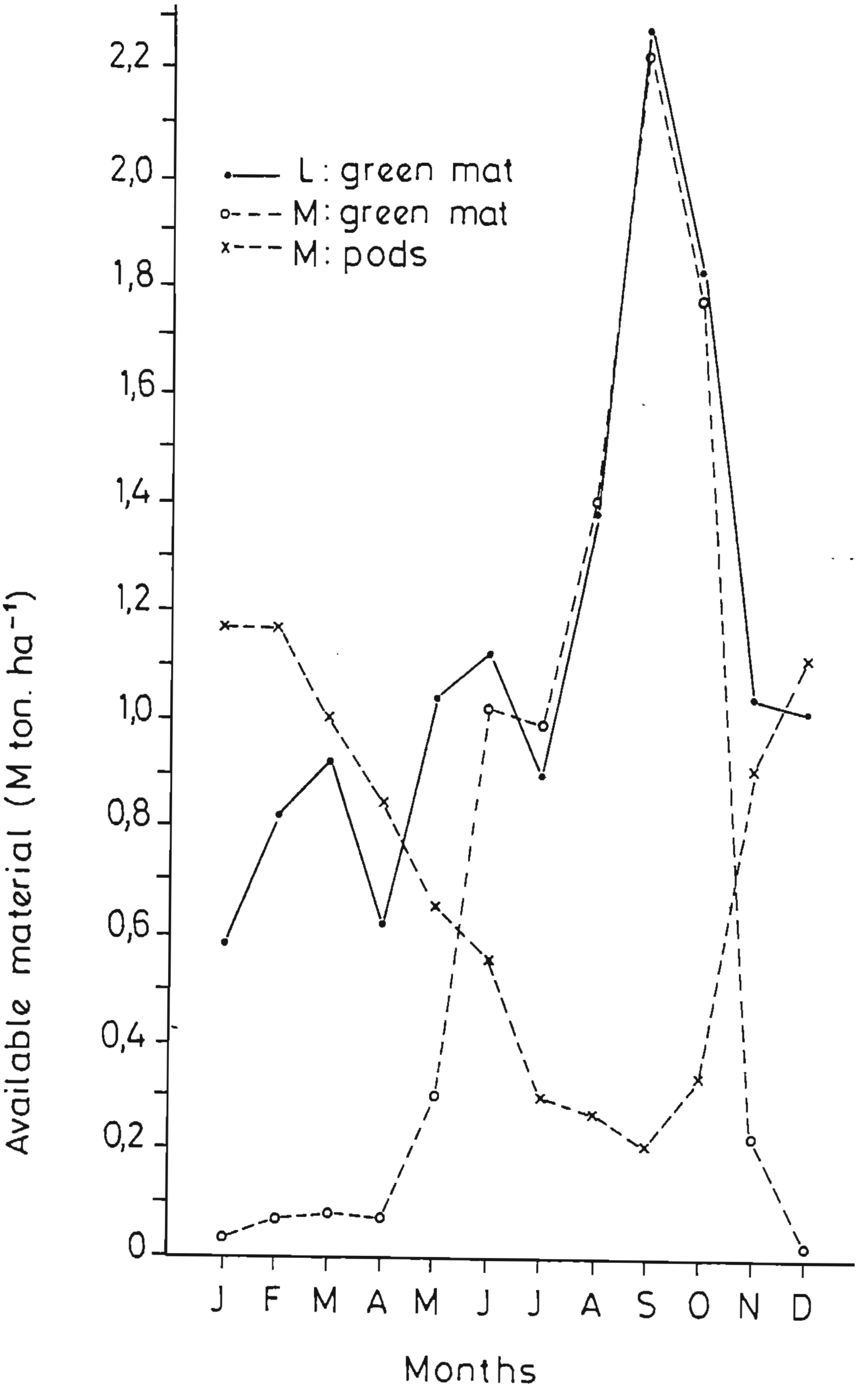


Figure 4.6 Yield components of lucerne (L) and medic (M) pastures, meaned over the trial period (1980-84) and all stocking rates



during September. The seasonal availability of pods on the medic pastures tended to be highest during the period December to February, but thereafter the availability decreased very sharply to reach a minimum during September.

Stocking rate also had an influence on the mean available green material ($kg.EU^{-1}$) as depicted in figure 4.7. The relationships depict the annual means calculated over all seasons (1980 to 1984) for the whole trial period. It is apparent that the mean available green material per ewe-unit ($kg.EU^{-1}$) was highest on the lucerne pastures. On both pasture types, however, the available green material decreased curvelinearly with an increase in stocking rate, with the greatest decrease occurring over the stocking rate range 3/4 to 5/6 $EU.ha^{-1}$.

The results of the bi-annual determinations of the botanical composition of the available green material, are depicted in figure 4.8. As has already been indicated these results could also not be compared statistically, but the general trends will be discussed. The weed control measures applied during the trial period apparently had a large influence on the botanical composition of the pastures. The first measure, during 1981, consisted of an application of propyzamide (0,74 kg $ai.ha^{-1}$), a grass killer, and a separate application of dinoseb (0,90 kg $ai.ha^{-1}$), a broad leaved weed killer. The second control measure was applied during 1983, and again consisted of an application of propyzamide. The grass content of the pastures was apparently largely depressed by these control measures and very little difference between treatments was recorded over or during seasons.

The broad leaved weed population of the pastures, however, seemed to increase during each subsequent season after the initial spraying during 1981. At the winter sampling period

Figure 4.7 The influence of stocking rate on the available green material per ewe-unit (Kg. EU^{-1}) on the lucerne (L) and medic (M) pastures, meaned over the whole trial period (1980-84) (P indicates significance of regression)

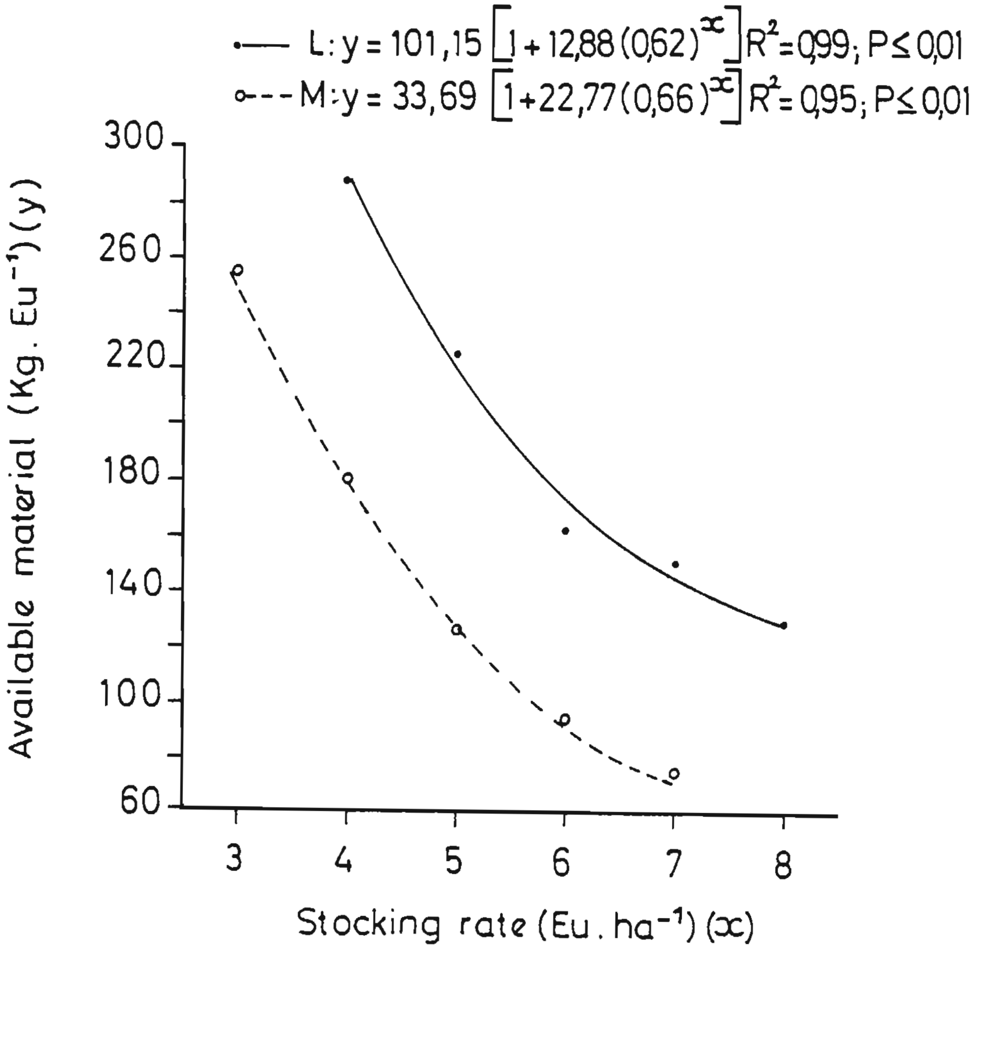
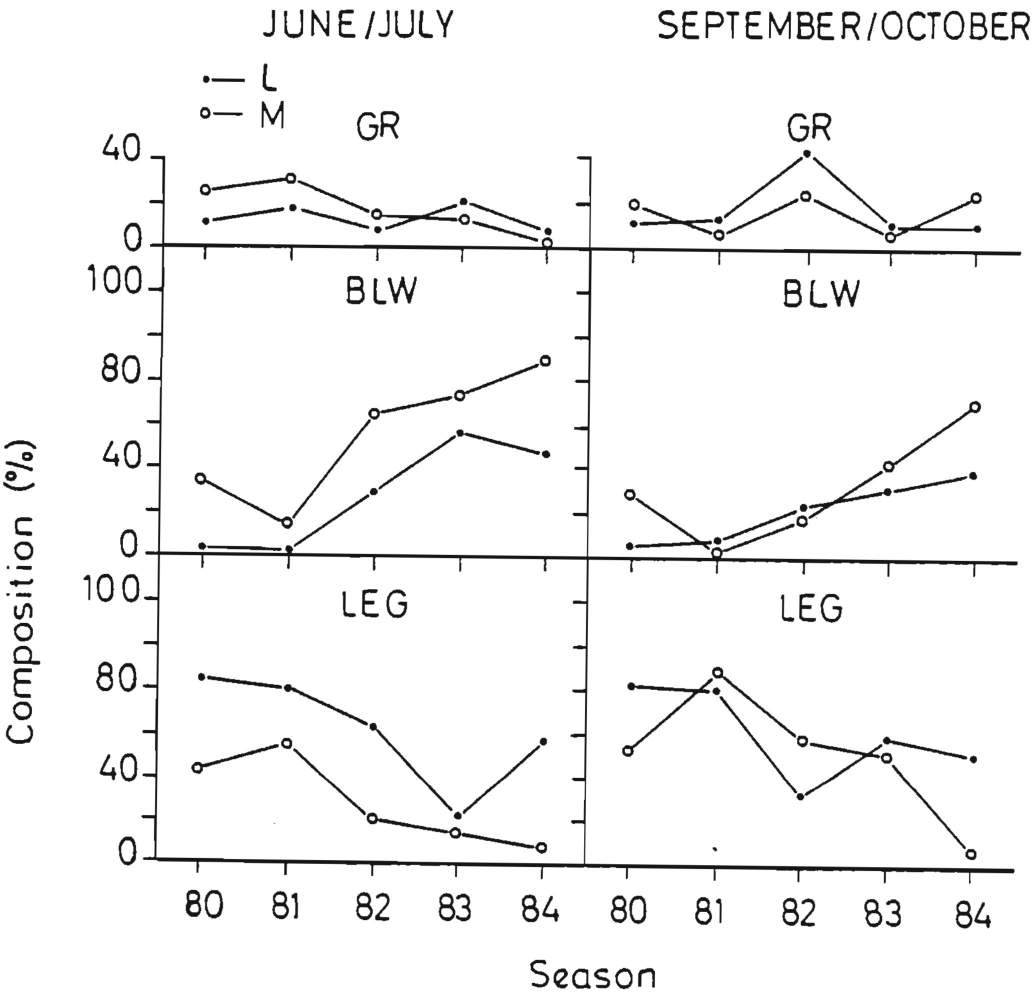


Figure 4.8 Botanical composition (%) of the green material, on the lucerne (L) and medic (M) pastures, at two sampling times during the active growing season (GR = grasses; BLW = broad leaved weeds; LEG = legumes), during successive seasons, meaned over all stocking rates



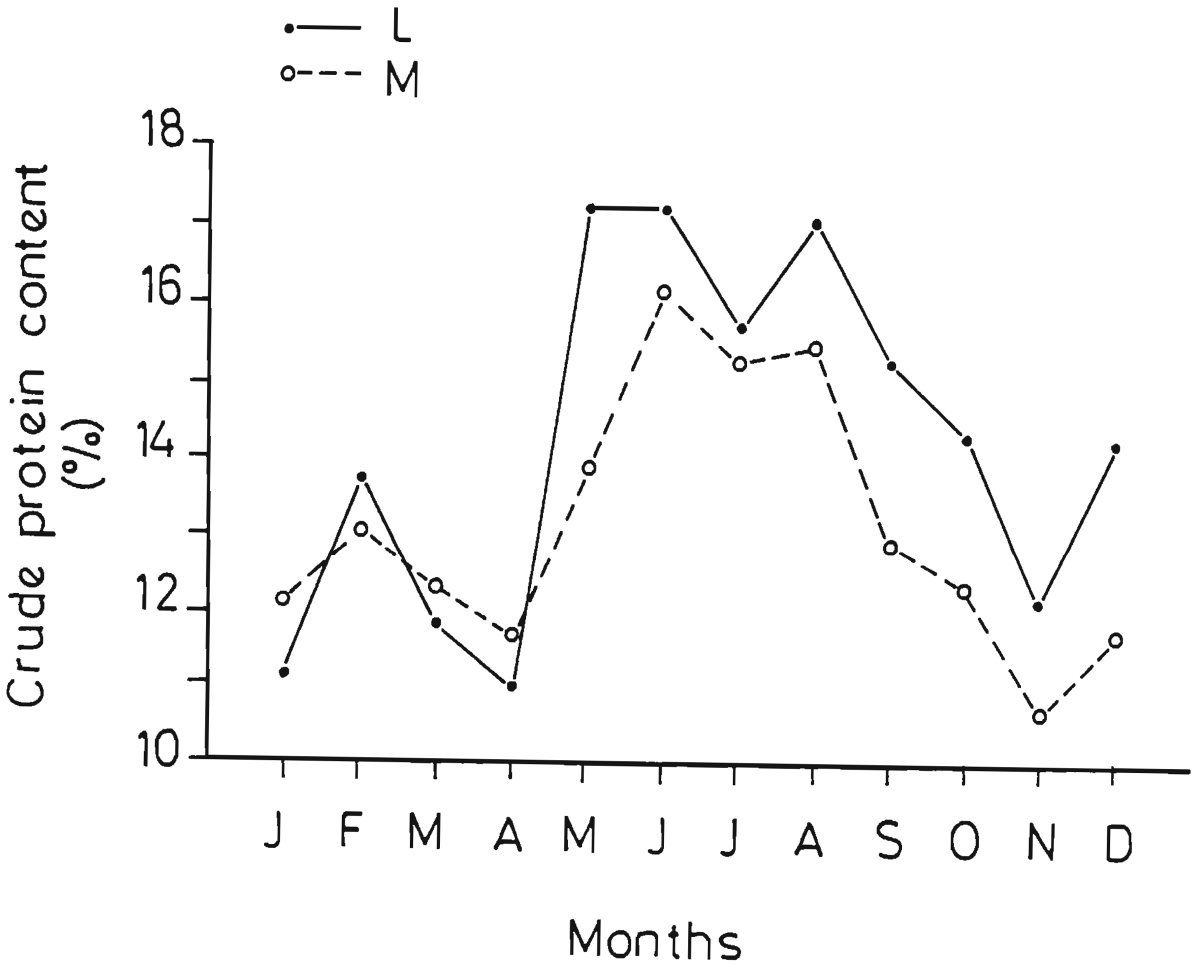
(June/July), the broad leaved weed population tended to be highest during all years on the medic pastures, but during the spring (September/October) sampling the differences were much smaller and, indeed, were not apparent during 1981 and 1982. The broad leaved population on the medic pastures, however, seemed to increase much faster than on the lucerne pastures, and this resulted in a much higher broad leaved weed content on the medic than the lucerne pastures during spring in the 1983 and 1984 seasons.

The legume content of both pasture types seemed to decrease with the age of the pasture, but tended to be higher on the lucerne than the medic pastures during the winter sampling period. In spring, the differences between the two pasture types, however, were much smaller and generally inconsistent over the trial period. Generally, however, the legume content of the medic pastures tended to decrease more with age than in the lucerne pastures.

The monthly samples of total available pasture material were bulked for each pasture type over treatments for each month of each year. These were subsequently meaned for the whole trial period. These results are depicted in figure 4.9. These results could also not be compared statistically and the general trends will be discussed. The crude protein content of both pasture types had basically the same trend and tended to be highest during the period May to August, after which a sharp decline occurred. The crude protein content tended to be low on both pasture types during the period January to April. There was little difference between the two pastures although during the period May to December, the crude protein content of the lucerne pastures tended to be higher than that of the medic pastures.

Stocking rate had a large influence on the mean legume content of the available green material on both the pasture

Figure 4.9 Crude protein (CP) content (%) of the total available pasture material on the lucerne (L) and medic (M) pastures, meaned over stocking rates and seasons (1980-84)



types. These relationships, meaned over seasons and years, are depicted in figure 4.10. In both pastures, the legume content did not decline substantially with increasing stocking rate over the low stocking rate range, but it declined rapidly as stocking rate increased beyond about 5 $EU.ha^{-1}$. Over the whole range, however, the legume content was much higher in lucerne than in medic pastures.

4.5.1.2 Wool production of the ewes

The relationships between the wool production per EU and per hectare (kg) and the stocking rate, calculated over seasons, are depicted in figure 4.11. The functions fitted to the data and the correlations and their levels of significance, are depicted in table 4.8. The wool production per EU, as well as the wool production per hectare, were much higher on the lucerne than the medic pastures. Little response to stocking rate was apparent over the range 3 to 5 $EU.ha^{-1}$, but at rates beyond 5 $EU.ha^{-1}$ a linear decrease in wool production per EU occurred on both pasture types, although the regression was not significant for the medic pastures and only significant at the 10% level for the lucerne pastures. The response to an increased stocking rate, over this latter range (5 to 7 or 8 $EU.ha^{-1}$) was, however, too small to enable the calculation of practical stocking rates for maximum wool yields per hectare. When this was done, by using the Jones & Sandland (1974) model and applying it to functions B and D in figure 4.11 and table 4.8, maximum stocking rates of 10,5 and 8,7 $EU.ha^{-1}$ respectively were found for the lucerne and the medic pastures. These rates are clearly too high, as serious fodder flow problems would develop during summer if they were applied. Medics would also be completely eradicated from pastures at such high stocking rates (see figure 4.10).

Figure 4.10 Influence of stocking rate on the legume content (%) of the available green pasture material on the lucerne (L) and medic (M) pastures, meaned over the whole trial period (1980-84) (P indicates significance of regression)

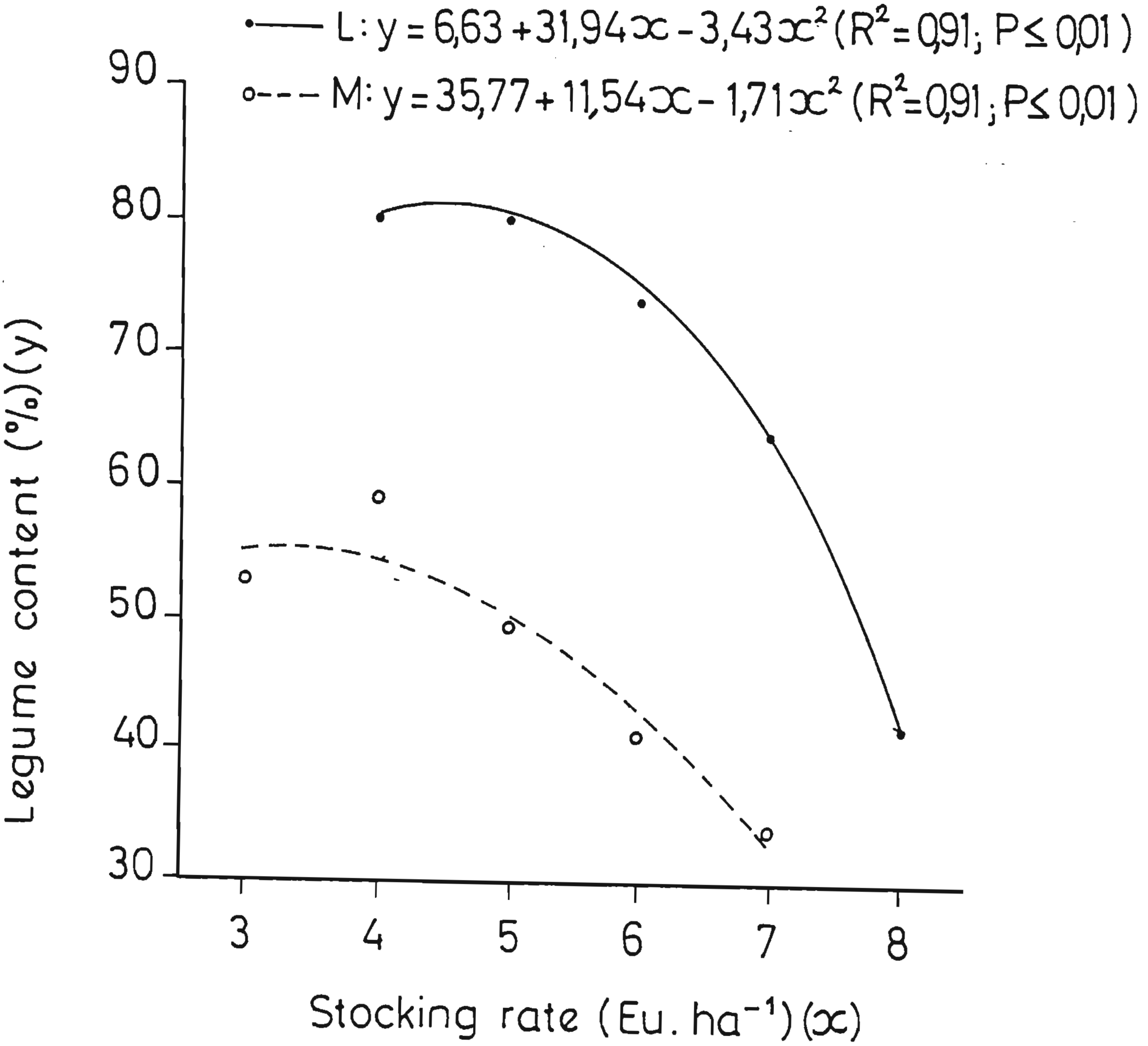


Figure 4.11 Influence of stocking rate ($EU.ha^{-1}$) on the wool yield per ewe-unit ($kg.EU^{-1}$) and per hectare ($kg.ha^{-1}$) on the lucerne (L) and medic (M) pastures, meaned over the whole trial period (1980-84) (see Table 4.8 for functions)

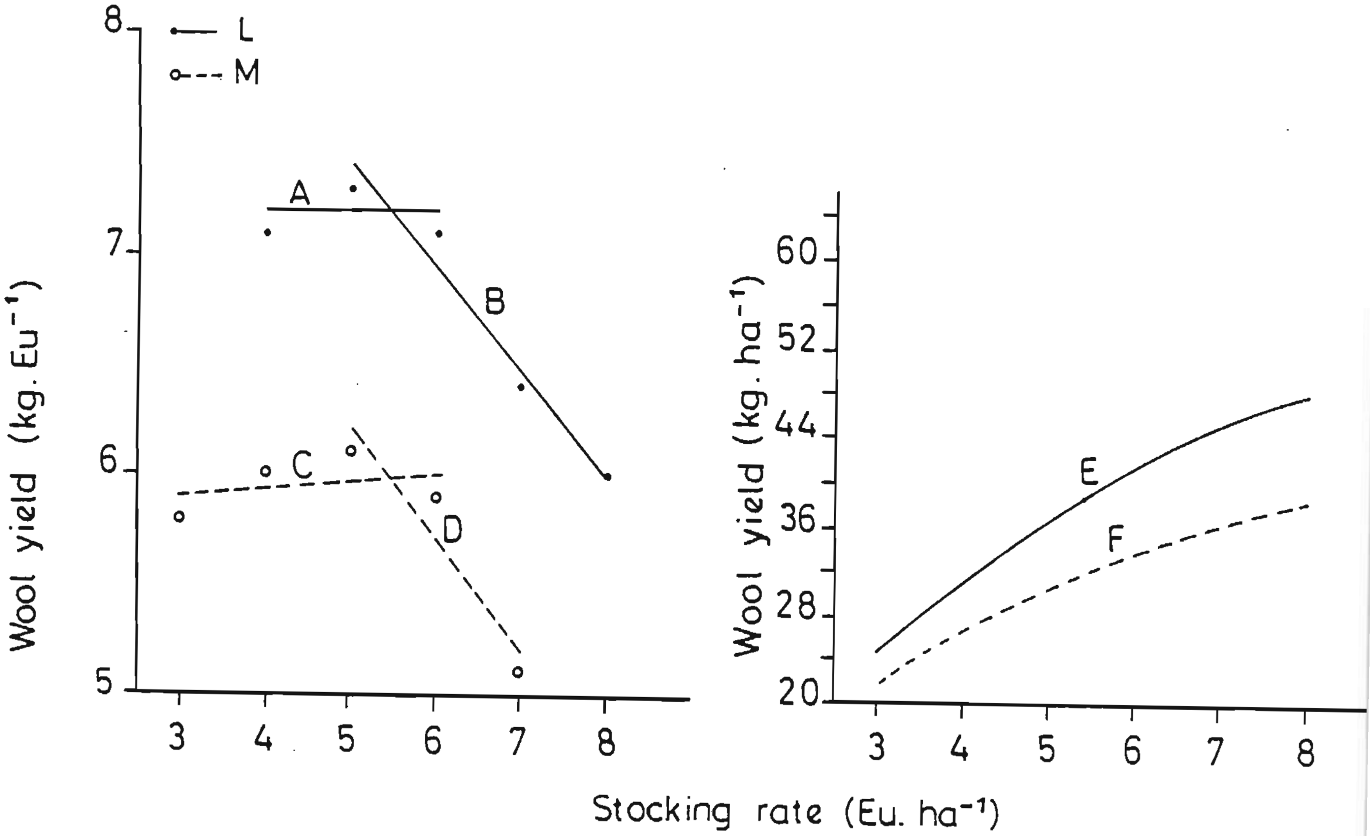


TABLE 4.8 FUNCTIONS DEPICTED IN FIGURE 4.11

Pasture type	Functions	R^2	P*
lucerne (L)	A: $y = 7,17$	0	NS
	B: $y = 9,69 - 0,46x$	0,96	0,10
	E: $y = 9,69x - 0,46x^2$	-	-
medic (M)	C: $y = 5,77 + 0,04x$	0,16	NS
	D: $y = 8,70 - 0,50x$	0,89	NS
	F: $y = 8,70x - 0,50x^2$	-	-

* P indicates significance of regression

The mean annual legume content of the available green material had a substantial influence on the wool production per EU. This relationship is depicted in figure 4.12 and was derived using data from both pasture types. There was a significant linear increase in wool production per EU with an increase in the legume content of the green material.

The wool production per EU was apparently also influenced by the total available green material per EU. The relationships, for both pasture types, are depicted in figure 4.13. The functions fitted to the data and the correlations and their levels of significance are depicted in table 4.9

The relationships were not significant, largely due to the small number of degrees of freedom, but are nonetheless of great interest. On both pasture types the wool production per EU tended to increase with an increase in available green material per EU up to a plateau, beyond which no further increase in wool production occurred. The wool production of the ewes on the medic pastures reached a plateau at 116 kg green material per EU, where the functions C and D intercept, but on the lucerne pastures a plateau was reached at 197 kg, i.e. where the functions A and B intercept. The wool production per EU per unit green material, however, clearly tended to be higher on the lucerne than on the medic pastures. This implies that the green material on the lucerne pastures is of higher quality than that on the medic pastures.

4.5.1.3 Average daily gain (ADG) and calculated meat production per hectare of lambs

The relationships between the stocking rate and the average daily gain (ADG) ($g.l^{-1}.d^{-1}$) and the meat production per hectare (kg), calculated over the whole experimental period,

Figure 4.12 Relationship between the legume content (%) of the available green material and the wool production per ewe-unit ($kg.EU^{-1}$) on the lucerne (L) and medic (M) pastures, meaned over the whole trial period (1980-84) (P indicates significance of regression)

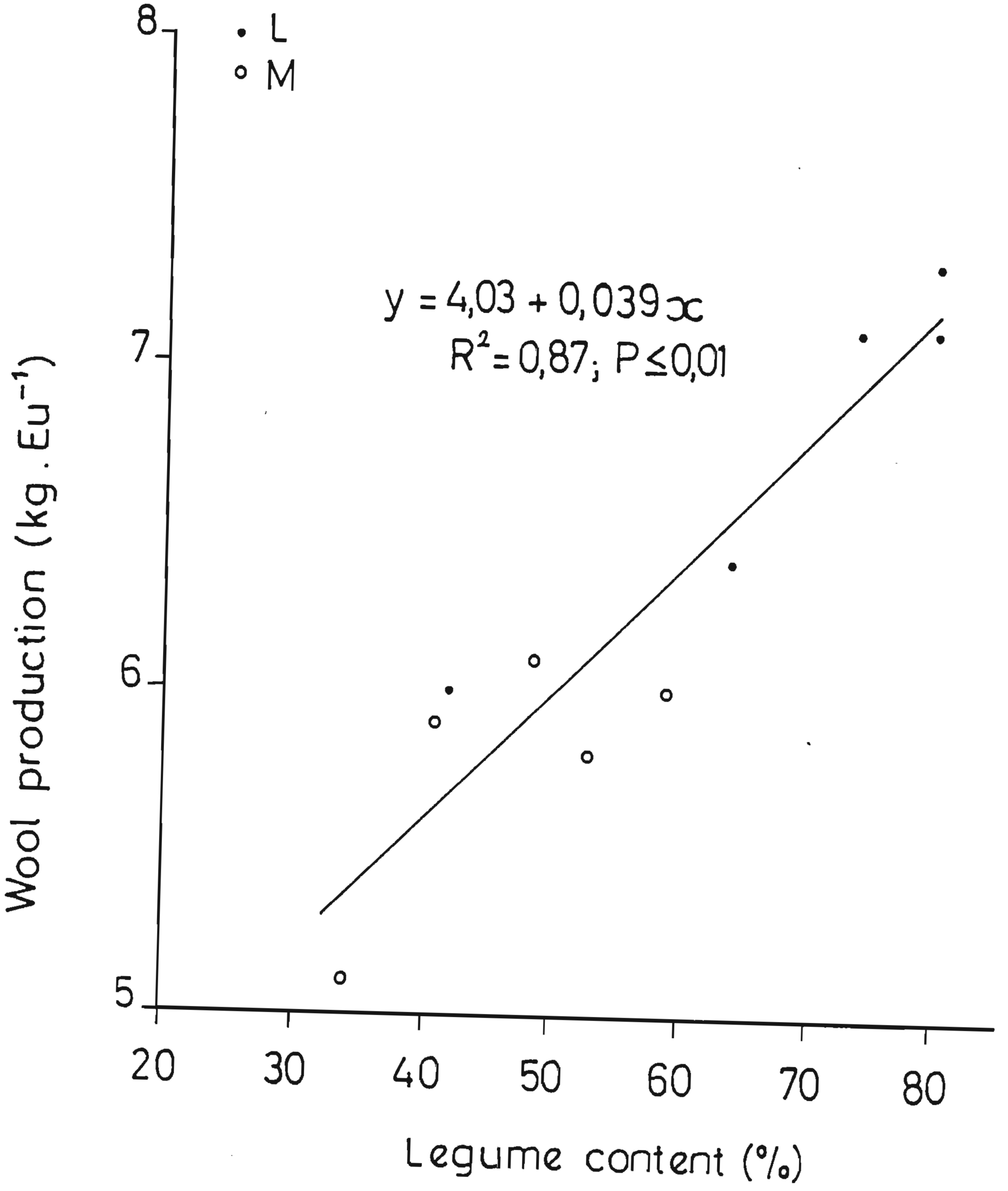


Figure 4.13 Relationship between the available green pasture material per ewe-unit ($kg.EU^{-1}$) and the wool production per ewe-unit ($kg.EU^{-1}$) on the lucerne (L) and medic (M) pastures, meaned over the whole trial period (1980-84) (see Table 4.9 for functions)

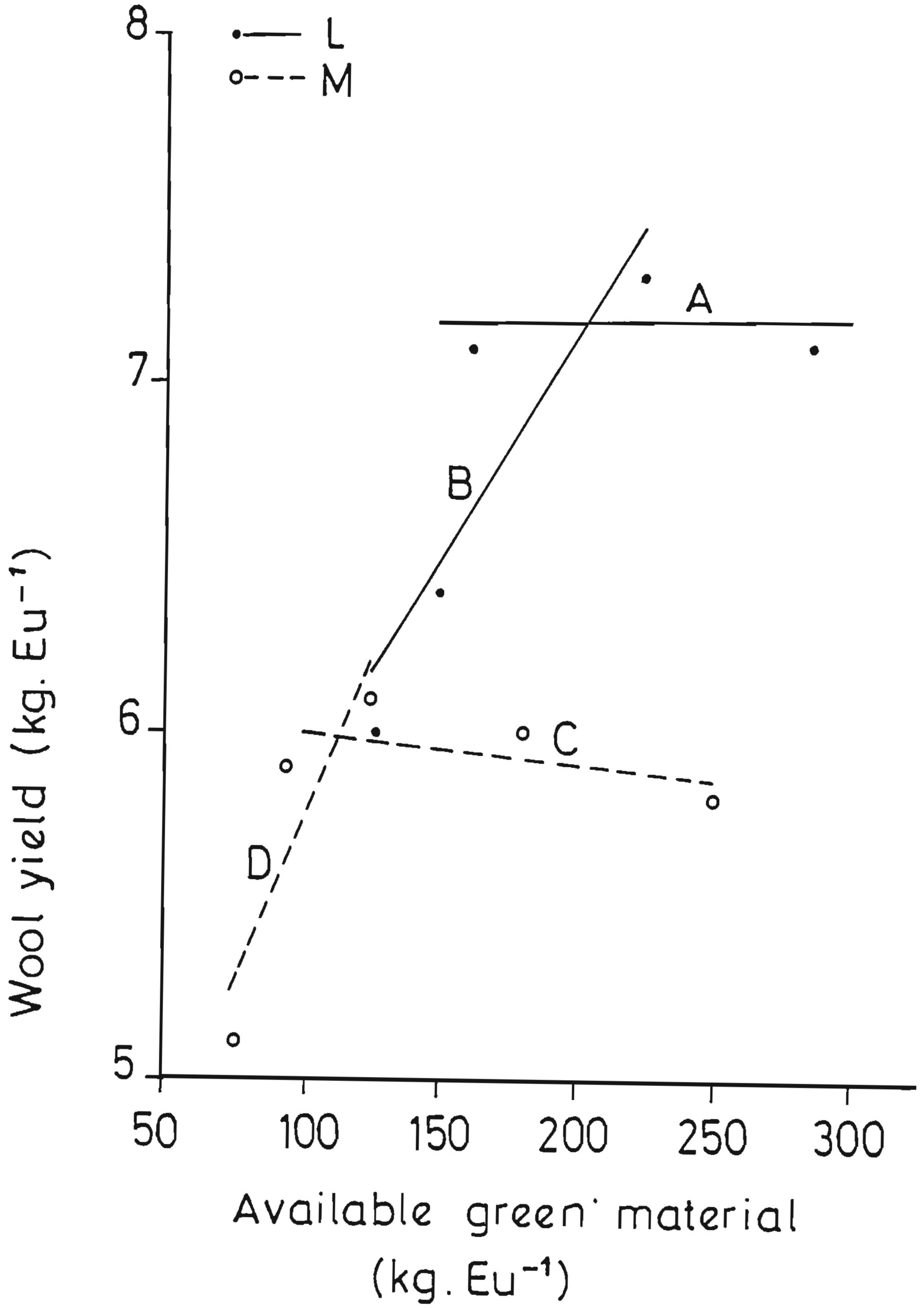


TABLE 4.9 FUNCTIONS DEPICTED IN FIGURE 4.13

Pasture type	Functions	R^2	P*
lucerne (L)	A: $y = 7,17$	0	NS
	B: $y = 4,61 + 0,013x$	0,74	NS
medic (M)	C: $y = 6,12 - 0,0001x$	0,30	NS
	D: $y = 3,81 + 0,02x$	0,80	NS

* P indicates significance of regression

are depicted in figure 4.14. The functions fitted to the data and the correlations and their levels of significance, are depicted in table 4.10. The ADG was much higher on the lucerne than on the medic pastures. The form of the relationship between the ADG and the stocking rate also differed on the two pasture types. The ADG on the lucerne pastures was sensitive to changes in stocking rate over a wide range of rates and decreased linearly with stocking rate over the whole range. The ADG on the medic pastures was, however, less sensitive to increases in stocking rate at low stocking rates. Beyond 4 to 5 $EU.ha^{-1}$ a linear decrease in ADG was, however, evident on these pastures. This response was, however, not significant.

The meat production per hectare, calculated as 47% of the total live mass gain per hectare (kg), increased linearly with an increase in stocking rate on the lucerne pastures, and only marginally curvelinearly on the medic pastures. The meat yield per hectare was also much higher on the lucerne than on the medic pastures.

When the stocking rate for maximum meat yield per hectare on each pasture, based on the ADG response to stocking rate, was calculated, using the Jones and Sandland (1974) model, the rates were higher for the medic (16,9 $EU.ha^{-1}$) than the lucerne (14,4 $EU.ha^{-1}$) pastures. This is indeed what may have been expected, from the data recorded in the plot trials, where higher available feed levels were found during winter on the medic pastures. This explanation was, however, not substantiated by the results depicted in figures 4.5 and 4.6 and would appear to result from the food provided by annual volunteer species in the lucerne pastures.

The amount of available green material had no statistically significant effect on the ADG. This is difficult to explain

Figure 4.14 Relationships between the stocking rate ($EU.ha^{-1}$) and the average daily gain (ADG) of the lambs ($g.l^{-1}.d^{-1}$) and the calculated meat production per hectare ($kg.ha^{-1}$) on the lucerne (L) and medic (M) pastures, meaned over the whole trial period (see Table 4.10 for functions)

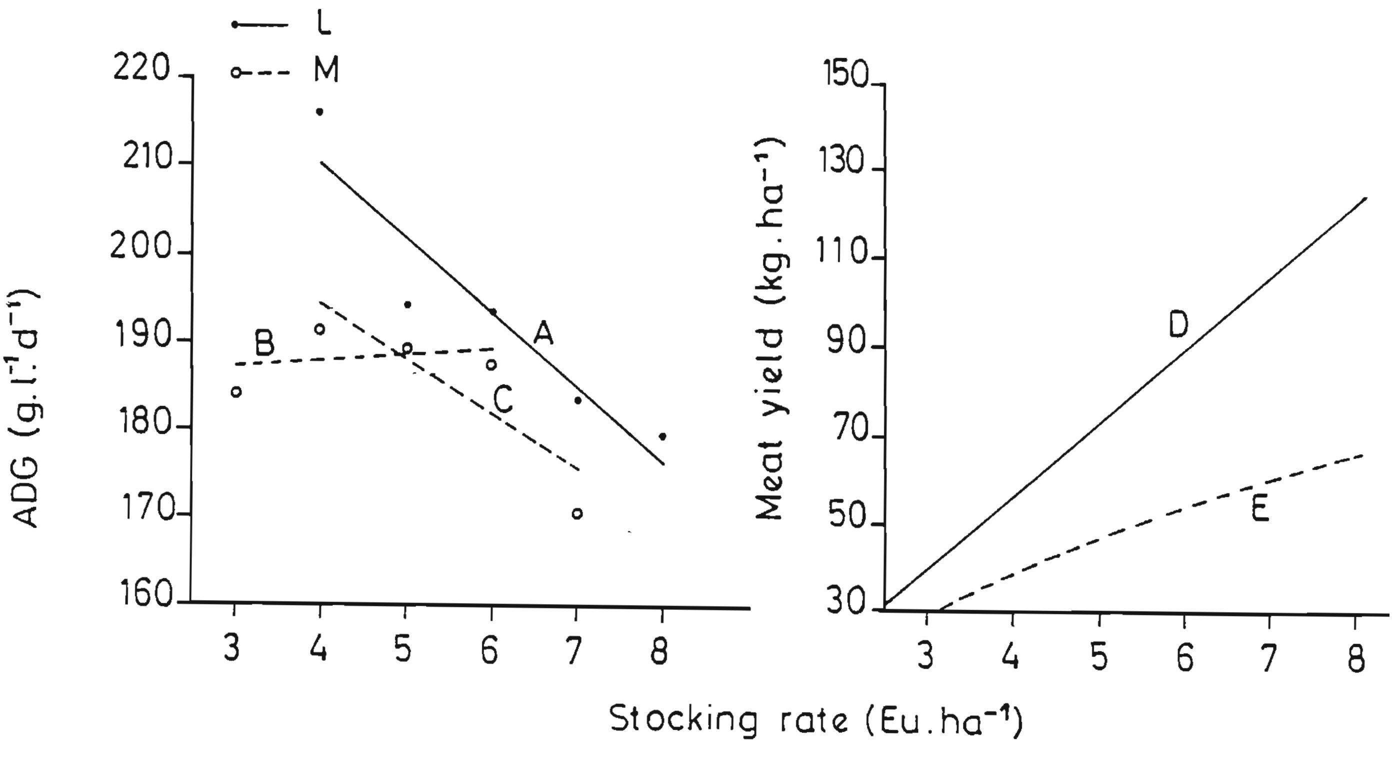


TABLE 4.10 FUNCTIONS DEPICTED IN FIGURE 4.14

Pasture type	Functions	R^2	P*
lucerne (L)	A: $y = 244 - 8,5x$	0,88	0,05
	D: $y = 244x - 8,5x^2$	-	-
medic (M)	B: $y = 185 + 0,7x$	0,09	NS
	C: $y = 220 - 6,5x$	0,76	NS
	E: $y = 220x - 6,5x^2$	-	-

* P indicates significance of regression

as the ADG clearly declined with increased stocking rate above a certain level (see figure 4.14). The quality of the available pasture material, as reflected by its legume content, however, did have a statistically significant influence and this relationship is depicted in figure 4.15. The ADG was significantly linearly and positively related to the legume content of the available green material.

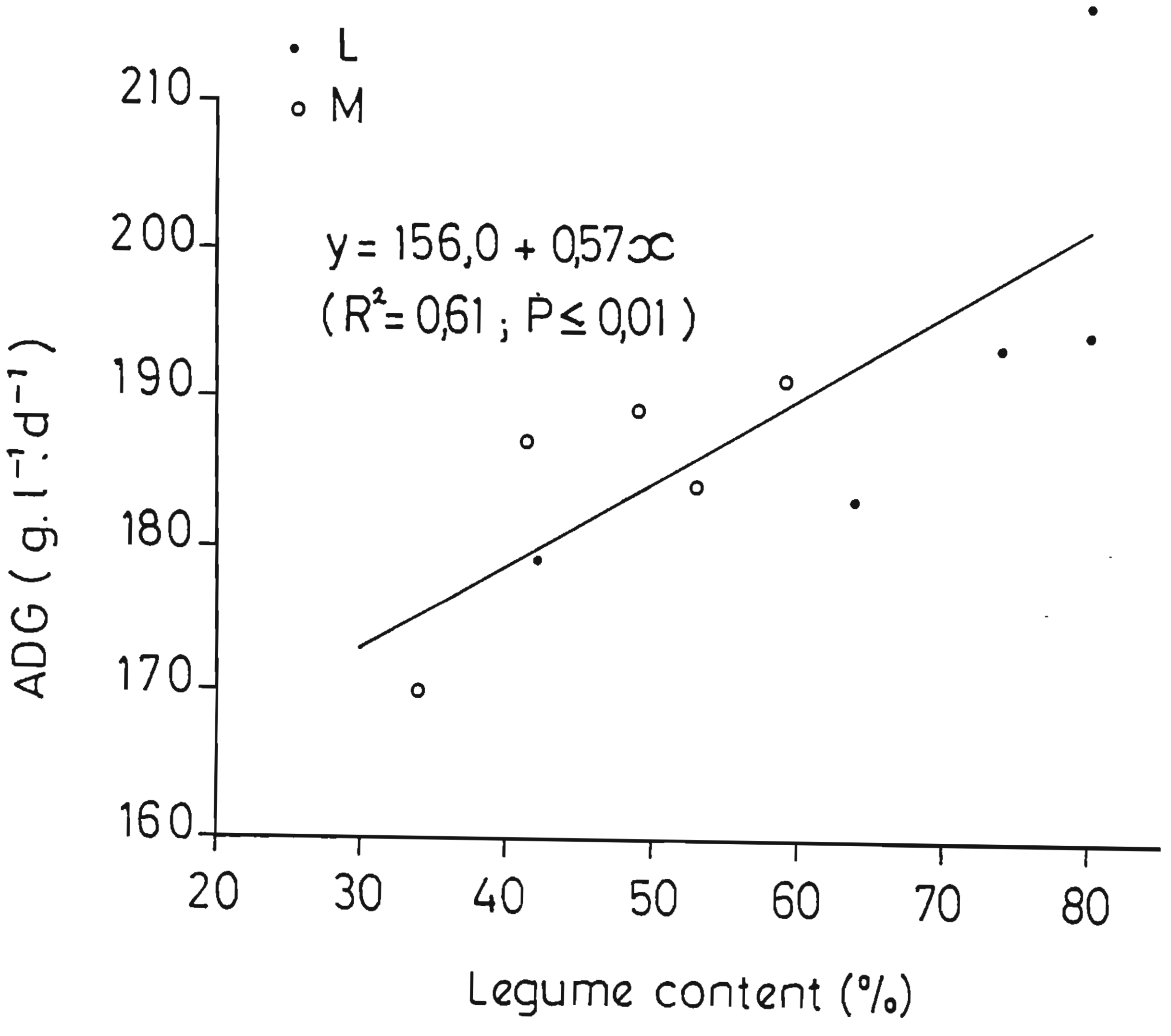
4.5.1.4 Discussion and conclusions

The fact that the trial had no replications largely prohibited the determination of statistical differences in available pasture material and botanical composition and quality of available material between the two pasture types. The general trends in available material have, however, been discussed and the effect of stocking rate on the available material, its botanical composition and the animal production have been determined statistically by regression techniques.

Although the seasonal trend in total available material was very similar on the medic and lucerne pastures, the higher yield of available green material during summer resulted in a higher quality pasture being available on the lucerne than on the medic pasture. This had important implications as far as the general ewe condition during summer was concerned and could have been one of the reasons for the higher animal production potential of lucerne as compared to the medic pastures.

The botanical composition of both pasture types changed with age and, although the grass content of the pastures was maintained reasonably constant by the application of grass killers, the broad leaved weed population increased with age of the pastures. This degeneration of the botanical composition of the pastures had important implications as

Figure 4.15 Relationship between the legume content (%) of the available green pasture material and the growth rate of the lambs (ADG) ($g.l^{-1}.d^{-1}$) on the lucerne (L) and medic (M) pastures, meaned over the whole trial period (P indicates significance of regression)



far as the pasture quality. As the degeneration of the legume component was much faster on the medic than on the lucerne pastures, the last mentioned pasture type had a greater botanical stability and therefore also a greater longivity, compared to the medic pastures.

The resultant higher legume content of the available green material on the lucerne pastures, compared to the medic pastures, was reflected in the higher crude protein content of the total available material during the active growing season on the lucerne pastures. This fact also had important implications on the relative animal production potential of the two pasture types. This was substantiated by the fact that a positive linear relationship was found to exist between the legume content of the pastures and the ADG and wool production per EU. This positive relationship between animal production and the legume content of pastures is also substantiated by research reported in the literature (Gibb & Treacher, 1983; Stewart, et al, 1983; Stewart & McCullough, 1985). It was also found that the wool production per EU and per hectare, as well as the ADG of the lambs and the meat production per hectare, were higher on the lucerne than on the medic pastures. This clearly indicated that dryland pasture mixtures in this area should be based on lucerne for maximum animal production.

The legume content and the available material per EU of both pasture types was, however, also influenced by stocking rate and decreased at very high stocking rates. A curvilinear relationship was found to exist between the stocking rate and these two parameters and it seemed as if the greatest levels of available material and highest legume content was maintained at stocking rates below 5 $EU.ha^{-1}$. This has important implications as far as the management of these two pastures is concerned and indicates that intermediate stocking rates, which do not necessarily result in the maximum animal production per hectare in the short term, would be more advantageous to the maintenance of maximum available pasture material per EU and the legume content of the pasture material. The calculated optimum stocking rates for maximum wool and meat production, based on the Jones & Sandland (1974) model, were therefore considered to be too high, as their application would not only create severe problems during summer and late pregnancy, but could also lead to undesirable changes in the botanical composition of the pastures.

The problem encountered with the application of the Jones & Sandland (1974) model could perhaps be attributed to the large variation in available material during the trial period. This suggests, however, that the results of this model cannot be extrapolated beyond the treatment levels. It seemed, therefore, as if stocking rates of 5 $EU.ha^{-1}$ on the medic and 6 $EU.ha^{-1}$ on the lucerne pastures would be most suitable and should result, not only in a high per animal production, but also a greater longevity of both pasture types.

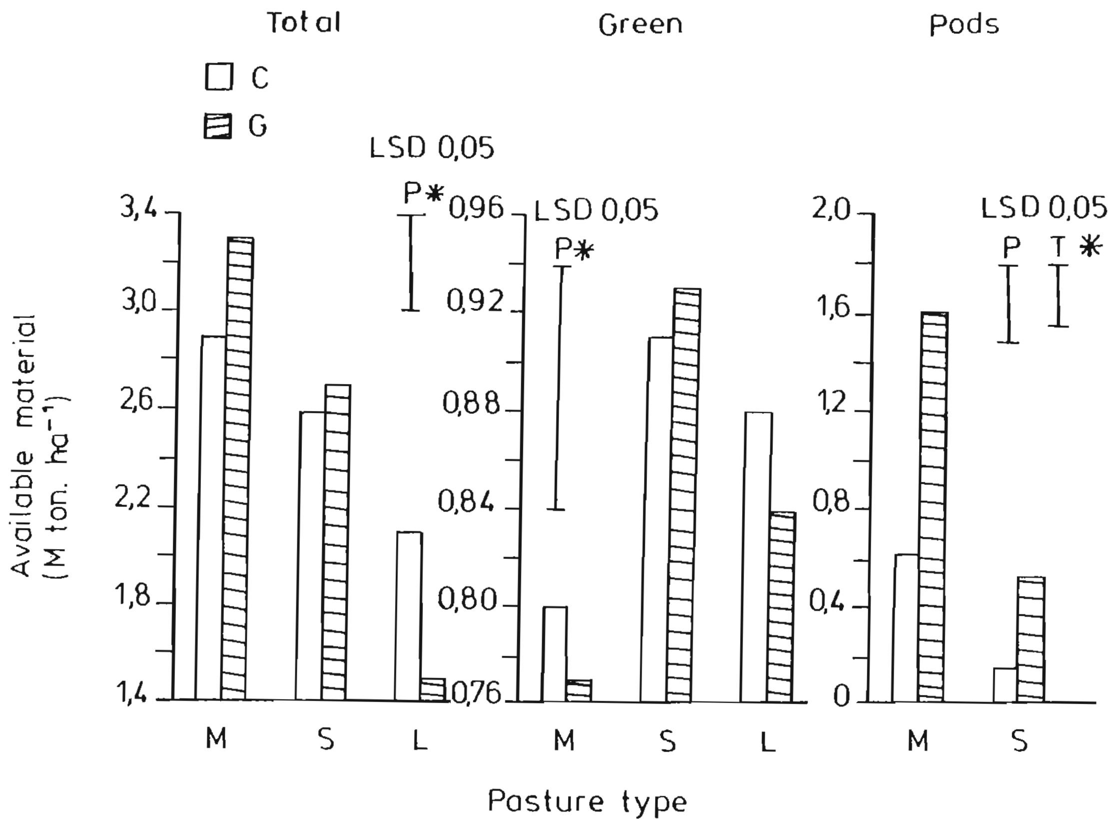
4.5.2 Trial 2: Determination of the influence of grass control measures on the animal production potential of dryland medic, lucerne and subterranean clover pastures at Tygerhoek

For details refer to tables 4.1 and 4.3.

4.5.2.1 Available pasture material

The mean total available pasture material and its two components, the available green material and the pods, calculated over two seasons (1983/84 and 1984/85) for all pasture types and treatments, are depicted in figure 4.16.

Figure 4.16 Total available pasture material, and two of its components, the available green material and pods, on the three pasture types (P), medic (M), subterranean clover (S) and lucerne (L), and two weed control practices (T), no control (C) and grass control (G), meaned over two seasons (1983/84 to 1984/85) and four stocking rates (* LSD's for individual treatment means)



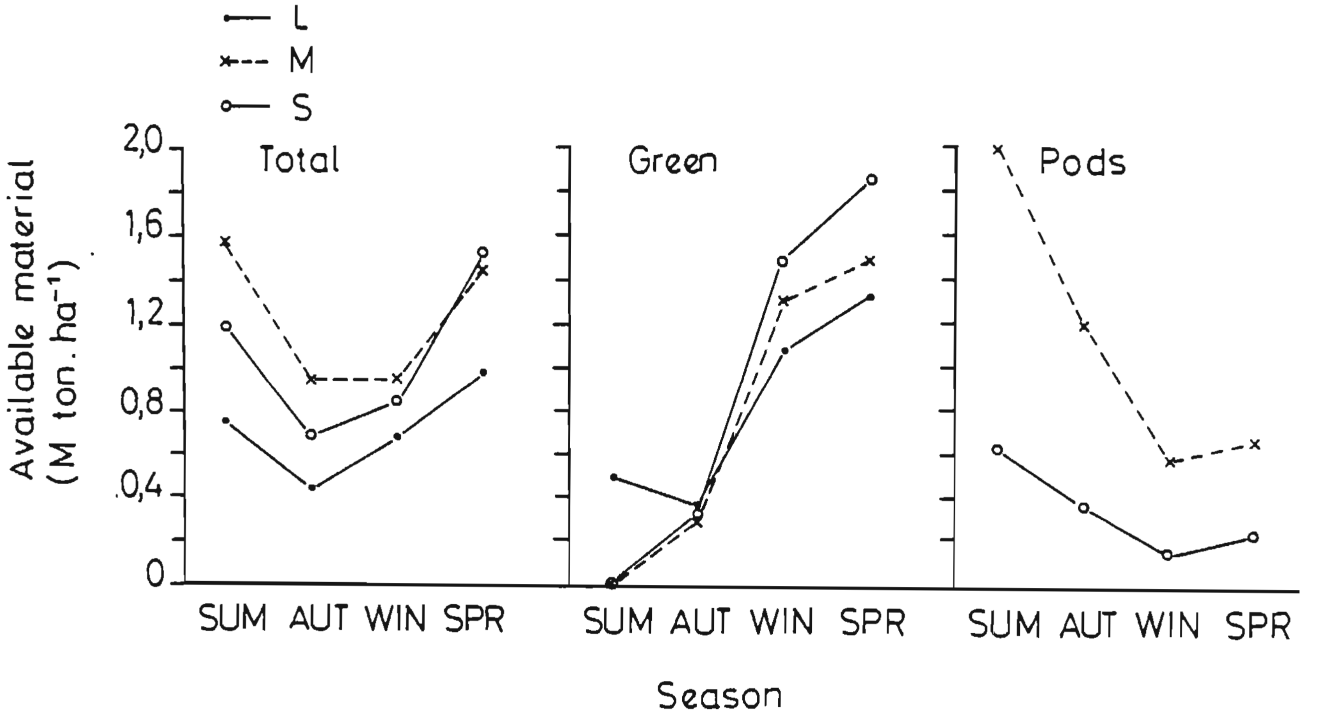
The interaction between pasture type (P) and weed control treatment (T) was not significant.

The weed control treatment had no significant influence on either the total available pasture material, or the available green material. The yield of available pods was, however, significantly higher on the sprayed than on the unsprayed plots on both the medic and subterranean clover pastures.

The three pasture types differed significantly in terms of total available material. The total available material was lowest on the lucerne and highest on the medic pastures. The medic pastures had significantly lower values of the available green material, than the other two pasture types. The lucerne and subterranean clover pastures did, however, not differ significantly, although the subterranean clover pasture did tend to carry a larger amount of green material than the medic pastures. In the case of the two annual pasture types, the medic pastures had more available pods than the subterranean clover pastures.

The mean seasonal variation in available pasture material on the three pasture types, calculated over two seasons and treatments, is indicated in figure 4.17. Significant differences could not be determined, but general trends will be discussed. The general trend in available matèrial on the pasture types was basically the same, although the actual values did differ. The total available material tended to be lowest during autumn and winter on all three pasture types. The available green material, however, seemed to be lowest during summer and autumn and highest during spring. The available green material on the lucerne pastures, however, remained relatively high during summer. The amount of available pods, on the medic and subterranean

Figure 4.17 Seasonal available total and green pasture material and pods on the lucerne (L), medic (M) and subterranean clover (S) pastures, during summer (SUM) (December to February), autumn (AUT) (March to May), winter (WIN) (June to August) and spring (SPR) (September to November), meaned over two seasons (1983/84 to 1984/85) and four stocking rates



clover pastures, tended to be lowest during winter and spring and highest during summer.

The mean botanical composition of the available green material meaned over the three pasture types and two treatments, and calculated over both seasons, is depicted in figure 4.18. Weed control treatments had a significantly positive influence on the legume content, while it decreased the grass content of the available green material significantly. No significant influence of this treatment on the broad leaved weed content was, however, found. The legume content of the green material of the lucerne pastures was significantly higher than that of the other two pasture types. The other two pasture types did, however, not differ significantly in this respect. There was little difference in the grass content of the three pasture types.

4.5.2.2 Wool production

The mean wool production per SU on each treatment and pasture type, is depicted in figure 4.19. Wool production was very sensitive to differences in pasture type and weed control treatments, and a significant response to pasture type and treatment was noted. The wool yields were significantly higher on the lucerne than on the subterranean clover pastures, on which the yields were again significantly higher than on the medic pastures. On all pasture types, wool production per SU was highest on the camps on which grass weeds were removed, but only in the case of the lucerne and subterranean clover pastures, significantly so.

Stocking rate influenced the relationship between weed control treatment and wool production per SU, on the three pasture types. These relationships are depicted in figure 4.20. However, the trends shown were, with the exception

Figure 4.18 Botanical composition (%) of the available green material on the medic (M), subterranean clover (S) and lucerne (L) pastures, at two weed control treatments, no control (C) and grass control (G), meaned over two seasons (1983/84 to 1984/85) and four stocking rates (LSD's for individual treatment means)

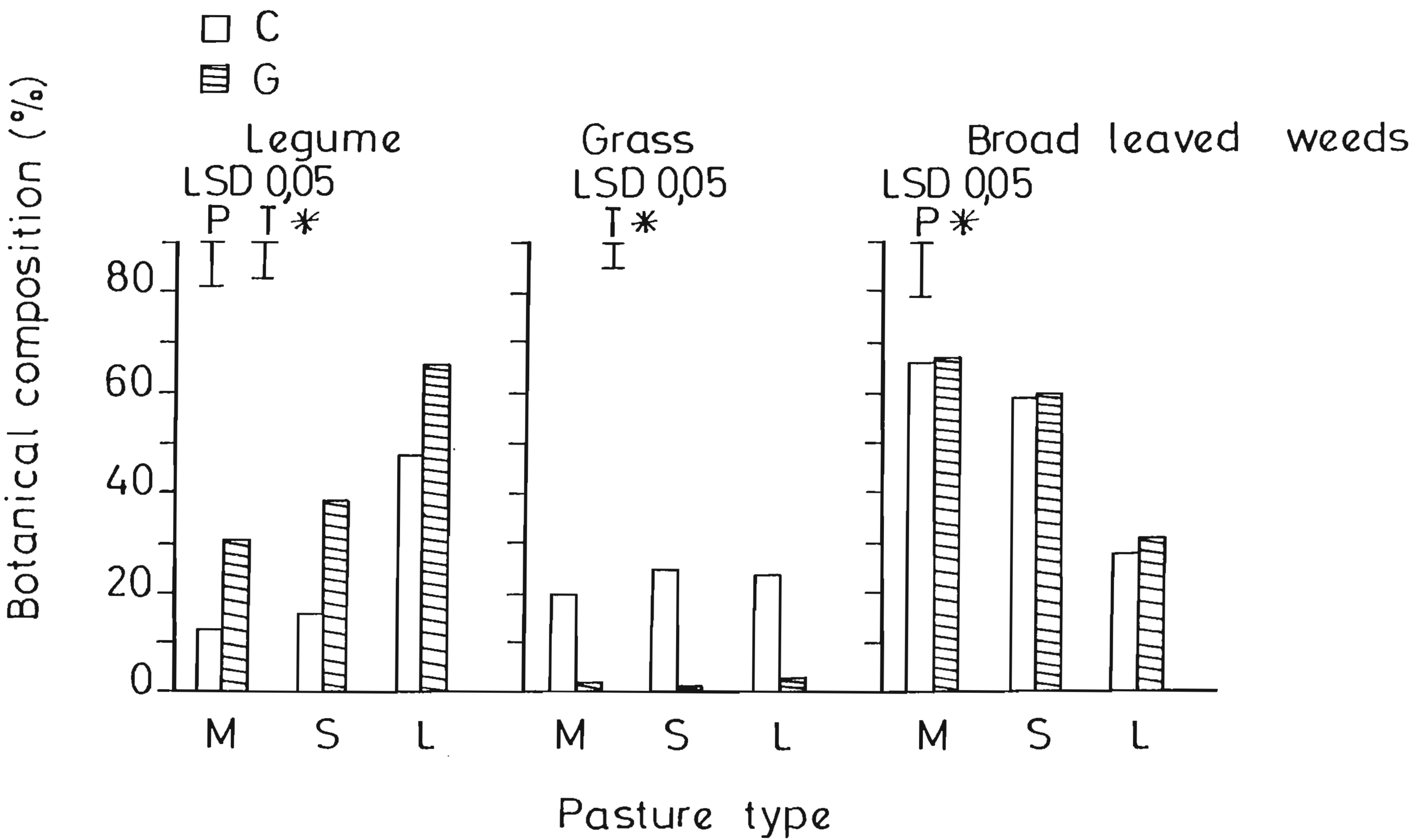


Figure 4.19 Annual wool production per sheep-unit (kg. SU^{-1}), on the three pasture types (P), medic (M), subterranean clover (S) and lucerne (L), and two weed control treatments (T), no control (C) and grass control (G), meaned over two seasons (1983/84 to 1984/85) and four stocking rates

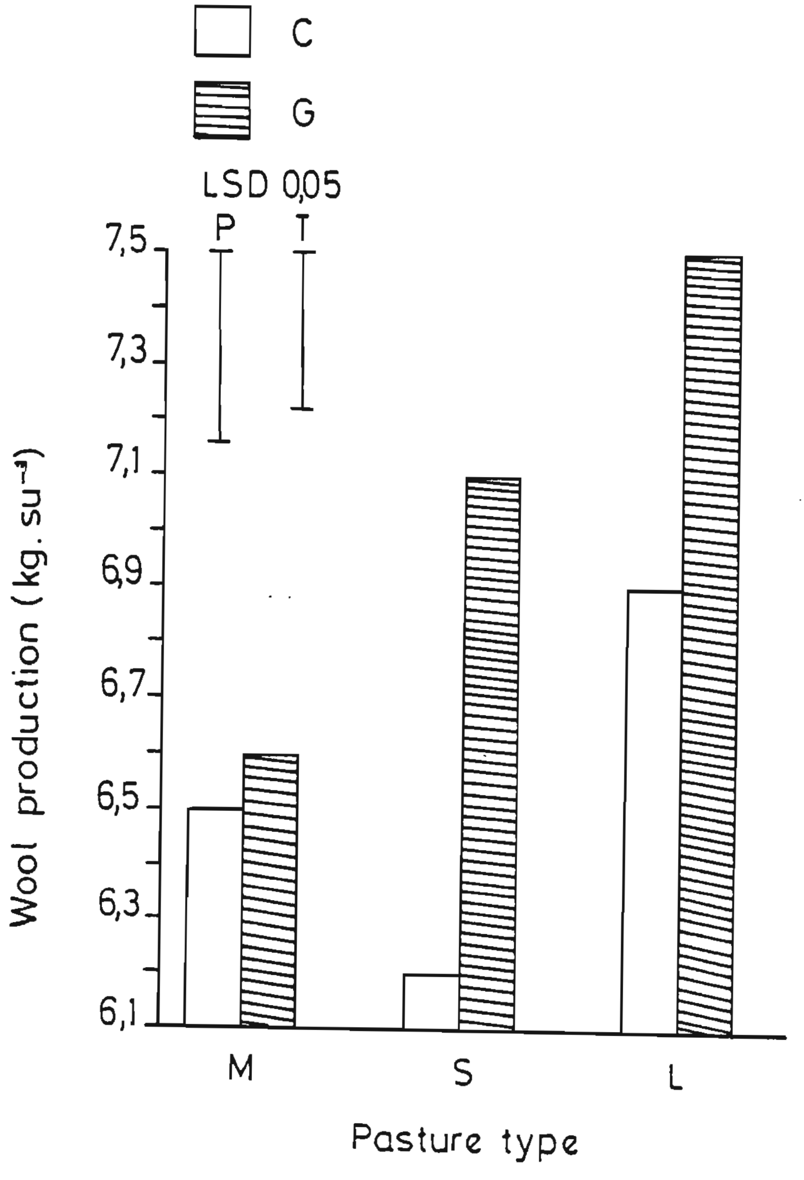
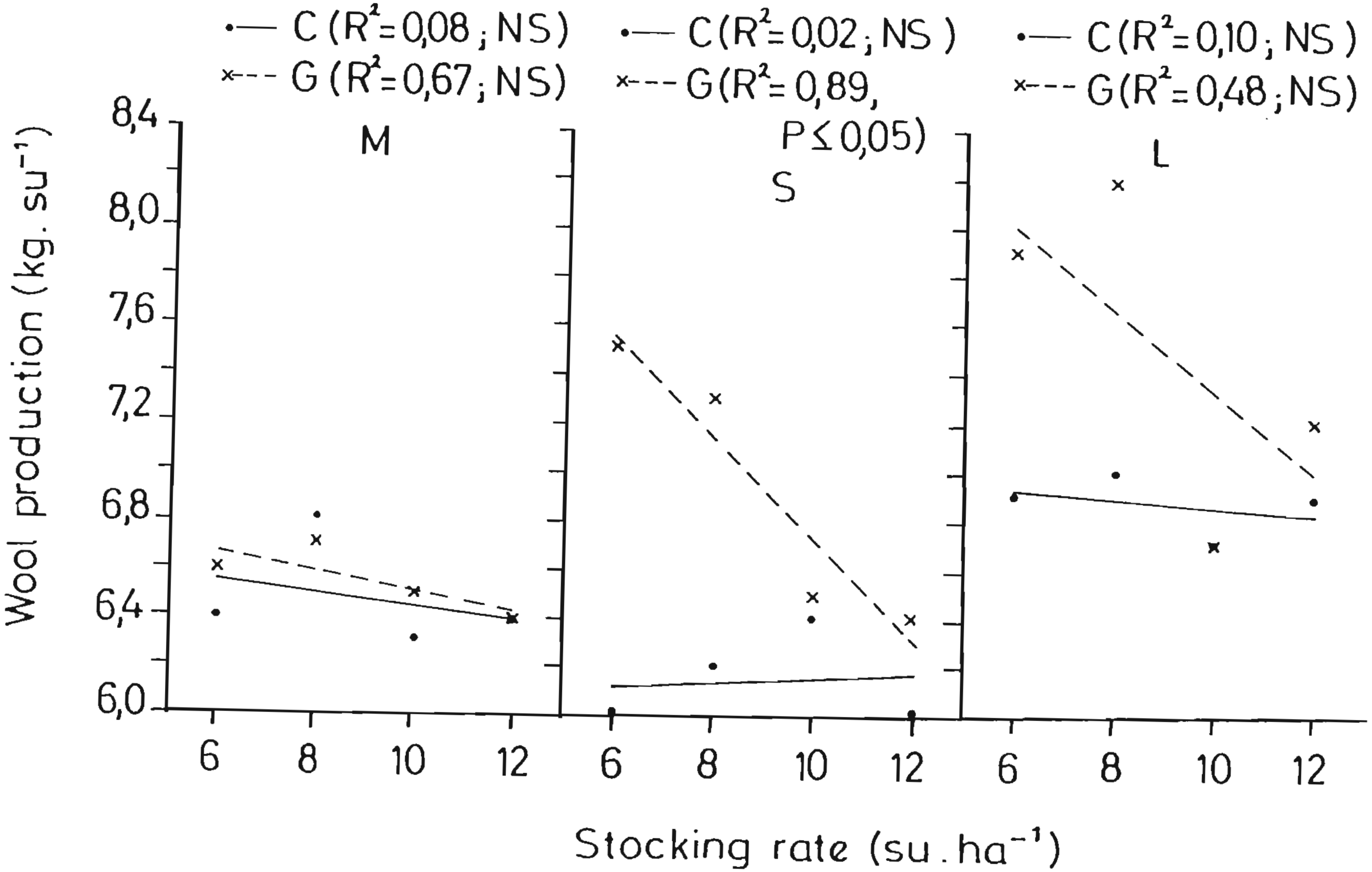


Figure 4.20 Influence of stocking rate on the annual wool production per sheep-unit ($kg.SU^{-1}$), on three pasture types, medic (M), subterranean clover (S) and lucerne (L), and two weed control treatments, no control (C) and grass control (G), meaned over two seasons (1983/84 to 1984/85) (P and NS indicates significance/not significance of regression)



of the weed control treatment on the subterranean clover pasture, not significant presumably due to the small number of degrees of freedom involved and also the large between camp variation. It was, however, very evident that stocking rate tended to have an influence on the response of wool production to treatment at least on the sprayed lucerne and subterranean clover pastures. On the medic pastures, however, a much smaller response was evident on the treated camps. Generally stocking rate had little or no effect on wool production in control plots. The net result was that wool production was not responsive to weed control treatments when stocking rates were too high.

An effort was made to determine the reasons for the difference in wool production on the various treatments. With this in mind the influence of three pasture parameters, (i.e. the total available pasture material, the available green material and the legume content of the available green material) on the wool production per SU was compared, using a stepwise regression approach. The resultant correlations were: R^2 = -0,37 for the total available material; R^2 = 0 for the available green material and R^2 = 0,72 for the legume content of the green material. Because of its importance the relationship between the wool production per SU and the legume content of the available green material was therefore determined and is depicted in figure 4.21. The highly significant and positive correlation between the legume content of the available green material and the wool production per SU, is evident.

4.5.2.3 Average daily gain (ADG)

The influence of pasture type and weed control treatment on the average daily gain (ADG) ($g.SU^{-1}.d^{-1}$), averaged over all stocking rates and seasons, is depicted in figure 4.22. The ADG of the two weed control treatments differed

Figure 4.21 Influence of legume content (%) of the available green pasture material on the wool production per sheep-unit ($kg.SU^{-1}$), meaned over two seasons (1983/84 to 1984/85), four stocking rates and three pasture types (P indicates significance of regression)

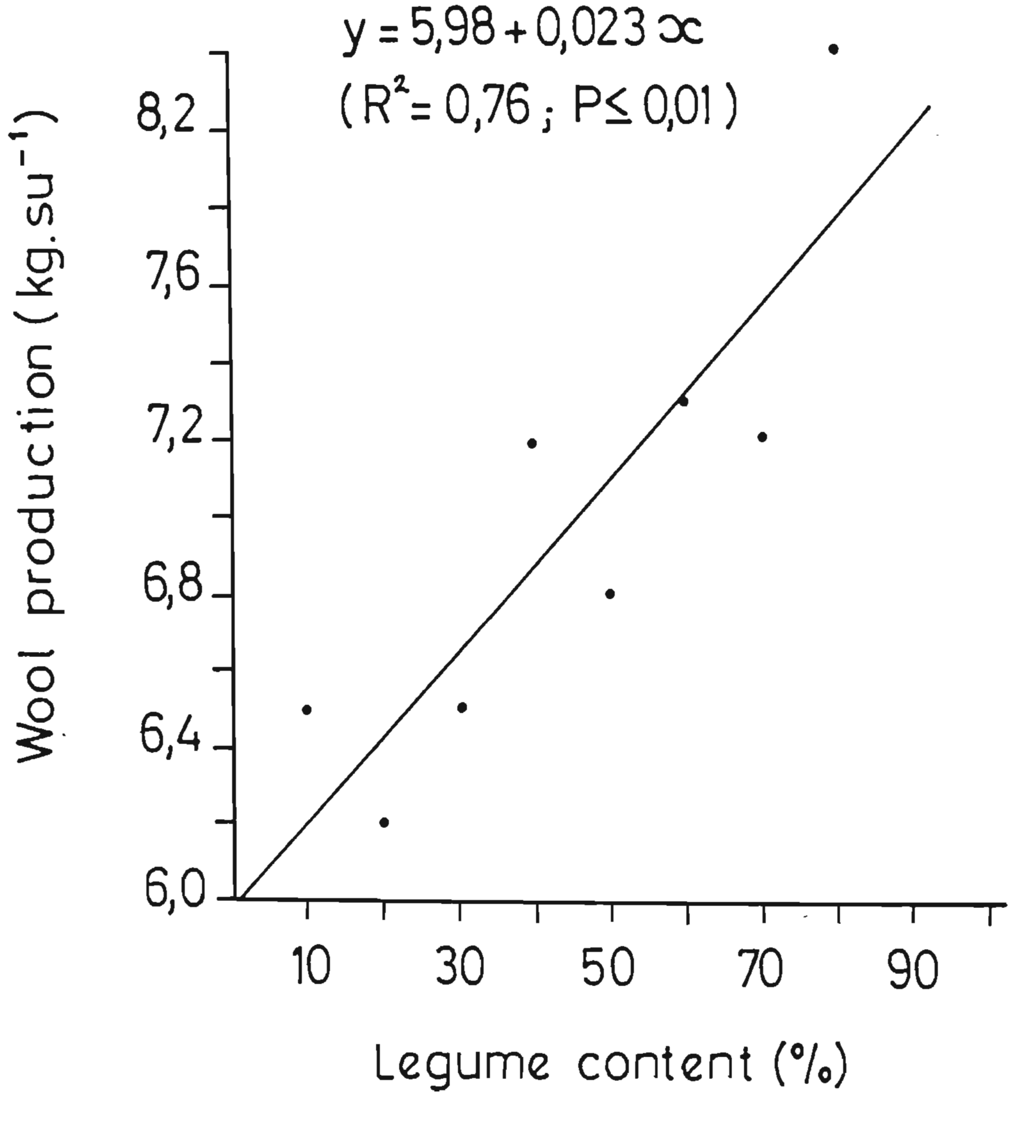
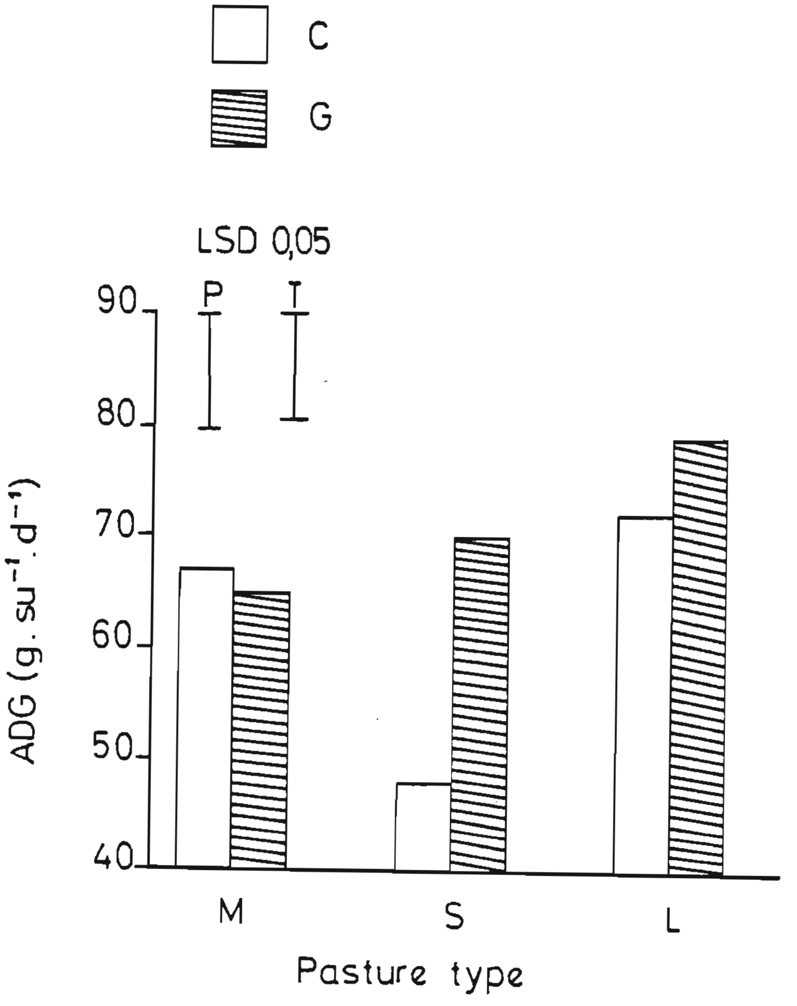


Figure 4.22 Average daily gain (ADG) per dry sheep-unit, on the three pasture types, medic (M), subterranean clover (S) and lucerne (L), and two weed control treatments, no control (C) and grass control (G), meaned over two seasons (1983/84 to 1984/85) and four stocking rates



significantly on only the subterranean clover pastures. The control treatment of this pasture type was also the only one on which the ADG was significantly different (i.e. lower) from the ADG on any of the other pasture types and treatments. It therefore seems that the ADG was not sensitive to differences in pasture type and treatment. Although not significantly so, the ADG was, however, clearly highest on the lucerne pastures.

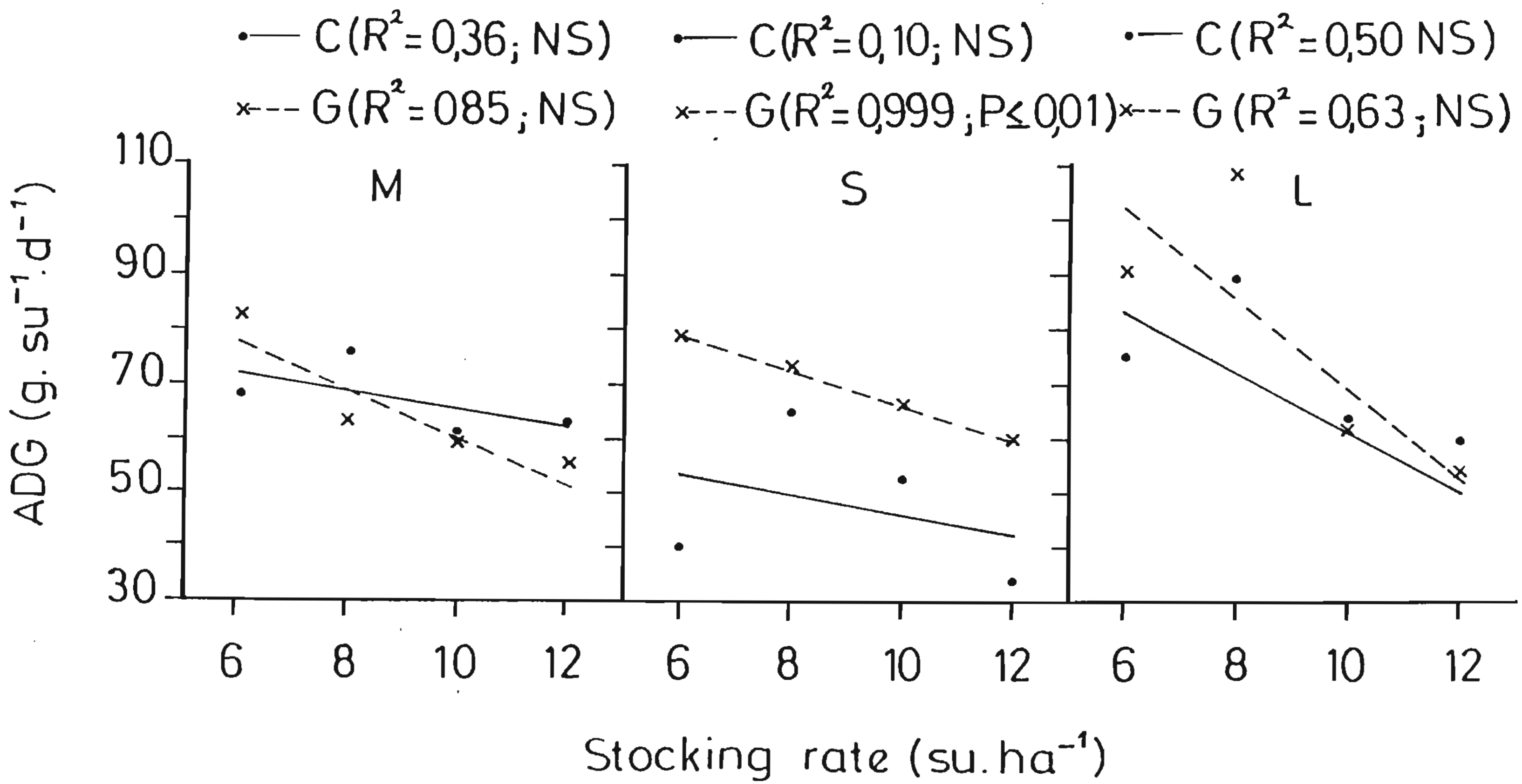
Stocking rate tended to influence the degree of the response to treatment on the three pasture types. These relationships are depicted in figure 4.23. A statistically significant linear relationship between stocking rate and ADG was apparent only on the treated subterranean clover pastures. Generally, however, it seems that the ADG of the control treatments was more responsive than wool production to stocking rate change. Although not significantly so, stocking rate seemed to influence the degree of response to weed control on the medic and lucerne pastures to a greater degree than on the subterranean clover pastures. It was also evident that an increase in stocking rate tended to reduce the positive effect of weed control.

The influence of the total available pasture material, the available green material and the legume content of the available green material on the ADG was evaluated, using a stepwise regression approach. It was found that none of these factors, i.e. the total available pasture material (R^2 = -0,07), the available green material (R^2 = 0,29) and the legume content of the available green material (R^2 = 0,42), had a significant influence.

4.5.2.4 <u>Discussion and conclusions</u>

As weed control treatment did not significantly influence the total available pasture material or the available green

Figure 4.23 Influence of stocking rate on the mean ADG per sheep-unit ($g.SU^{-1}.d^{-1}$) on the three pasture types, medic (M), subterranean clover (S) and lucerne (L) and two weed control treatments, no control (C) and grass control (G), meaned over two seasons (1983/84 to 1984/85) (P and NS indicates significance/not significance of regression)



material, this factor could not be related to differences in animal production on the different weed control treatments. The weed control treatments, however, had a very large positive influence on the mass of available pods on the medic and subterranean clover pastures. Since the importance of the production of adequate numbers of pods for re-establishment was clearly demonstrated by the research reported by Carter (1980; 1981) and Carter, et al (1982), it is clear that the removal of the volunteer grass component in the annual medic and subterranean clover pastures, by the application of chemical weed killers, would increase their life span.

Weed control measures, however, had a positive influence on the legume content of all three pasture types and an equally large negative influence on the grass component, while the broad leaved weed content did not react to the treatments. Spraying with a chemical grasskiller therefore could have had a positive influence on pasture quality, which should have reflected in animal performance (Gibb & Treacher, 1983; Stewart, et al, 1983; Freer & Jones, 1984; Stewart & McCullough, 1985). This important influence of the legume content of the available pasture material, was subsequently also confirmed by the highly significant correlation which was found to exist between the wool production per SU and the legume content of the available green material. No such relationship could, however, be established between the ADG and the legume content of the pasture material. Wool production was found to be higher on the treated than the untreated pastures, while weed control treatments had only a very small influence on the ADG which, however, also generally tended to be higher on the treated pastures.

The fact that the wool production per SU was highest on the lucerne and lowest on the medic pastures, can largely be attributed to the more regular availability of green material, but also to the higher legume content of the available green material on the lucerne pastures. The fact that the ADG was not influenced to the same extent by pasture type is, however, very difficult to explain.

Although not significantly so, the effects of grass control treatments decreased with increased stocking rate. Intuitively such a response would have been attributed to the effect of the weedicide on total forage availability, but no evidence for this was found.

The above mentioned results can be viewed as of preliminary nature only, as the trial has only completed two full seasons. The results were also very difficult to interpret, due to the large variations between camps and the small number of degrees of freedom. They did, however, indicate that grass control measures increase individual animal performance, but tend to decrease carrying capacity. The grass control treatments therefore seem to have had the greatest value when applied at low stocking rates, while higher stocking rates, which would have made it economically more viable, largely negated these effects. More results will, however, be necessary before any definate conclusions can be drawn.

4.5.3 **Trial 3:** Determination of the grazing capacity and animal production potential of a complex irrigated grass/legume pasture at Tygerhoek

4.5.3.1 Determination of the seasonal grazing capacity

In this part of the trial the seasonal grazing capacity of a complex grass/clover pasture was determined by the use of variable stocking rates or a put-and-take system with dry merino sheep-units (SU) as the animal factor (see tables 4.4 and 4.5. for more details).

4.5.3.1.1 Pasture production rate

The estimated mean monthly and mean annual pasture production rates (kg $DM.ha^{-1}.d^{-1}$), meaned over three seasons (1981/82 to 1983/84) for each of three grazing pressures, are depicted in figure 4.24. As the seasonal production rates could not be compared statistically, only the general trends will be discussed. The values depicted in figure 4.24 were low when compared with those derived in the plot trials and should be seen as relative values, which enable the comparison of the influence of the three grazing pressures on pasture production rate. The lowest monthly production rates tended to occur during winter (June/July) and the highest during spring (October/November). The mean annual production rates were lowest at the highest grazing pressure (1,5 kg DM. $SU^{-1}.d^{-1}$) and highest at the lowest grazing pressure (3,0 kg $DM.SU^{-1}.d^{-1}$).

4.5.3.1.2 **Botanical** composition **of** the **available** green pasture material

The mean botanical composition of the available green material, at the three grazing pressures over the three seasons, is indicated in figure 4.25. The clover and grass content of the available green material changed substantially with the age of the pasture. The clover content was much higher during the first (1981/82) season than the two subsequent seasons, but did not differ much between the latter two seasons. The grass content was, however, much higher during the last two seasons, but did also not differ much between these two seasons (1982/83 and 1983/84). The lucerne content, however, did not change much during the three seasons.

Figure 4.24 Monthly and annual production rate of the pasture grazed at three grazing pressures, meaned over three seasons (1983/84 to 1984/85) (P indicates significance of regression and SD the standard deviation)

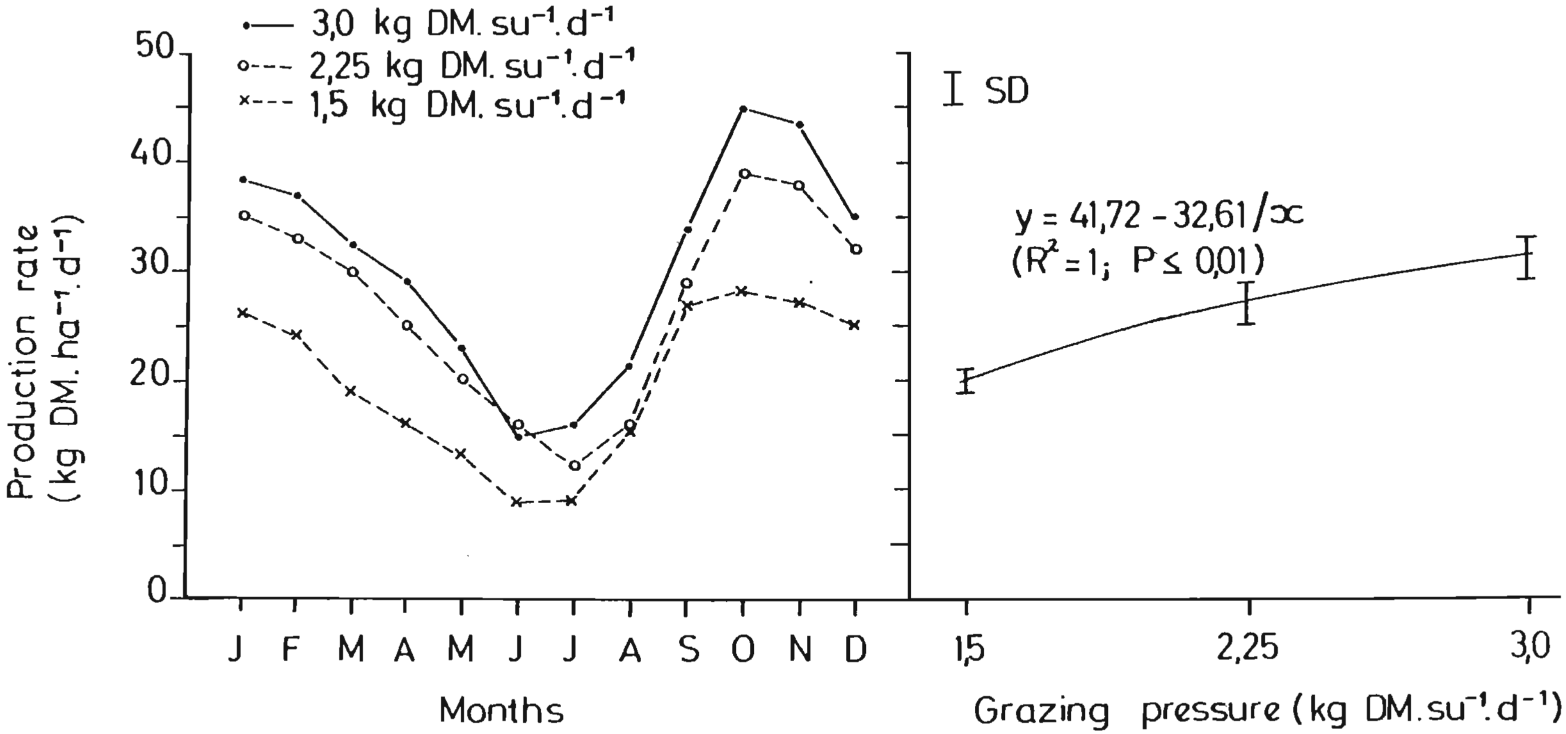
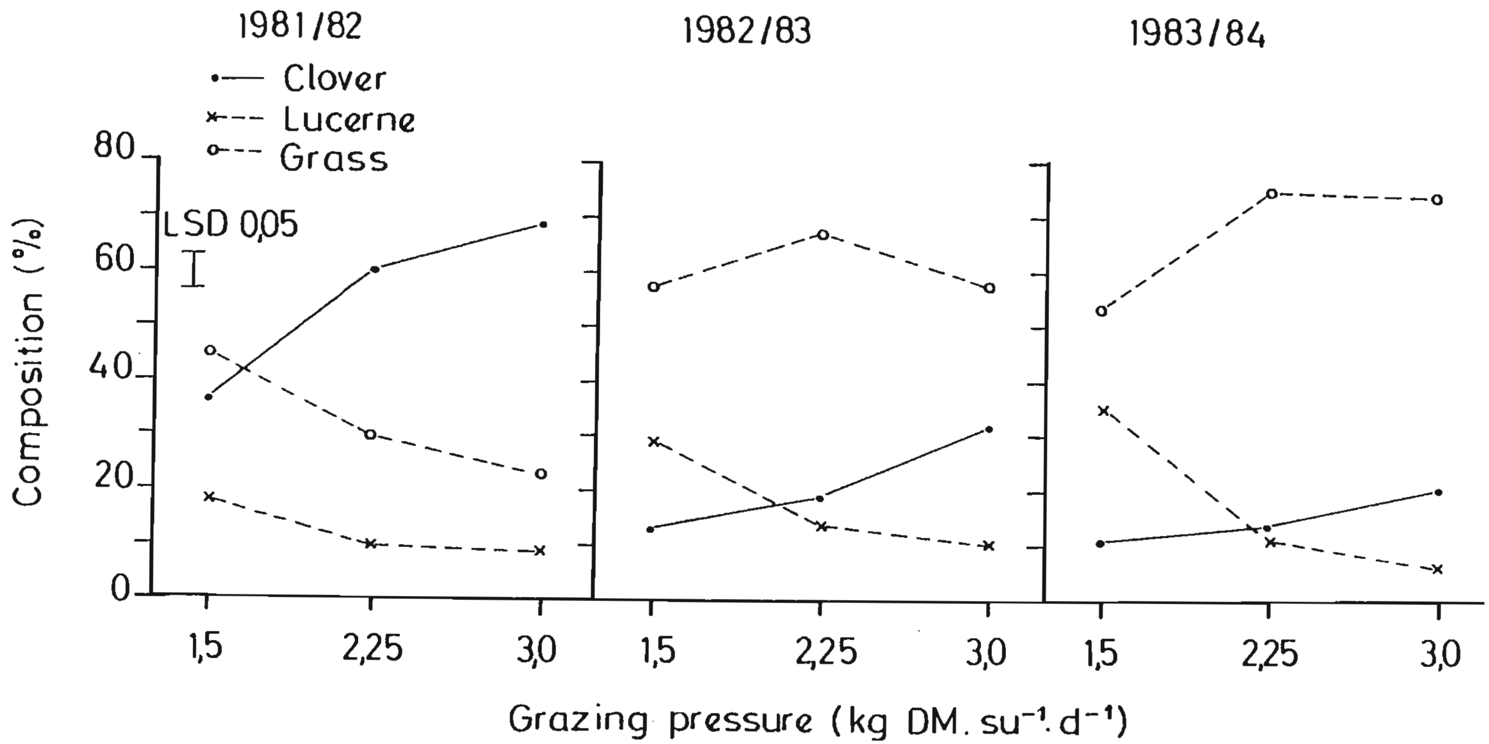


Figure 4.25 Influence of grazing pressure and pasture age on the botanical composition (%) of the available green pasture material, during three successive seasons



Grazing pressure did not have the same effect on the three components of the available green material. This treatment also did not have the same effect on the grass content during the three seasons and its effect is difficult to interpret. Grazing pressure did, however, have very definite but opposite effects on the clover and lucerne contents of the available green material. While the lucerne content tended to increase with increased grazing pressure, the clover content was depressed by high grazing pressures.

4.5.3.1.3 Intake of pasture material

The estimated mean monthly and annual intake of pasture material by the grazing animals (kg $DM.SU\text{-}1.d^{-1}$) at the three grazing pressures, are indicated in figure 4.26. As in the case of the pasture production rates, the data on the monthly mean intakes could not be compared statistically and will only be discussed in general. The estimated intake values were much lower than those reported in literature (Arnold, 1975; Rattray, 1978). The reasons for this are very difficult to identify, but could possibly have resulted from the high grazing pressures used in these trials. The highest intake tended to occur during late spring, summer and early autumn (October to April) and the lowest during late autumn, winter and early spring (May to September). Increased grazing pressure clearly seemed to depress the estimated intake to a very great extent.

4.5.3.1.4 Grazing capacity and wool production

The mean monthly stocking rate, calculated over three seasons (1981/82 to 1983/84) at each of the three grazing pressures, is depicted in figure 4.27. Again, these data could not be compared statistically, but will be discussed in general. The seasonal trend in stocking rate was very similar to that of the pasture production rate. The lowest

Figure 4.26 Monthly and annual intake of pasture material per sheep-unit (kg $DM.SU^{-1}.d^{-1}$), when grazed at three grazing pressures, meaned over three seasons (1981/82 to 1983/84) (P indicates significance of regression and SD the standard deviation)

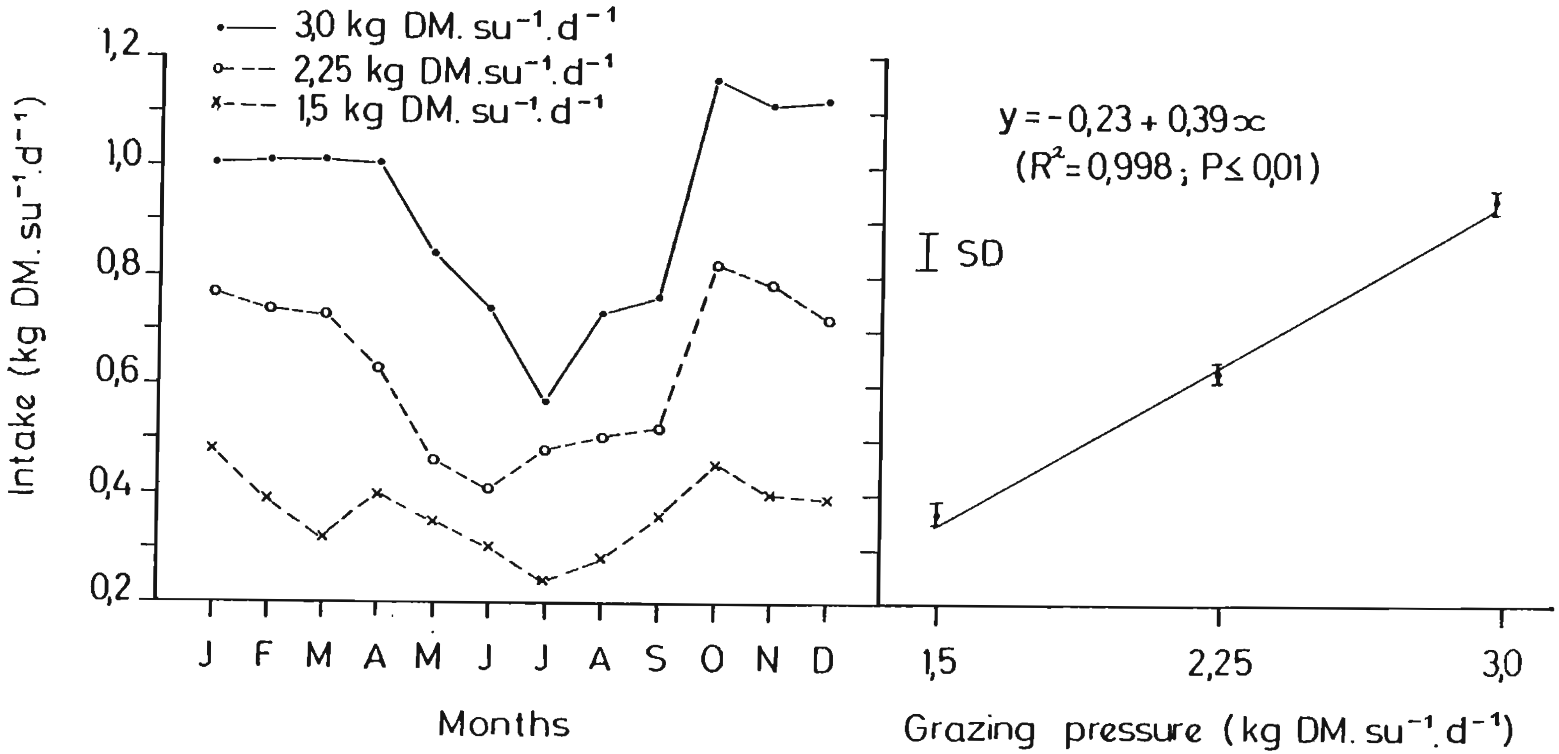
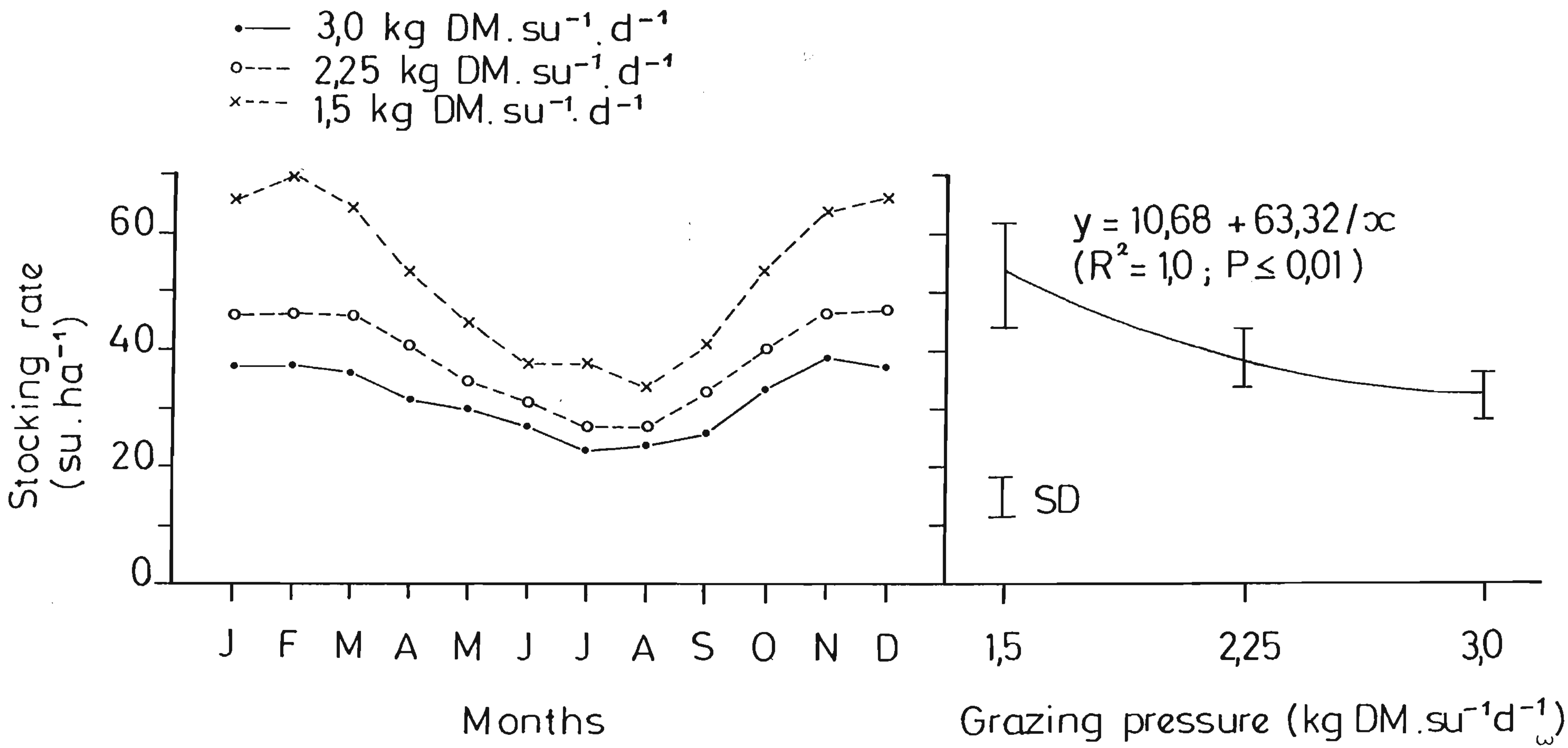


Figure 4.27 Monthly and annual stocking rates ($SU.ha^{-1}$) of the pasture grazed at three grazing pres-sures, meaned over three seasons (1981/82 to 1983/84) (P indicates significance of regression and SD the standard deviation)



values tended to occur during May to August and the highest during the period November to February. The selected grazing pressure seemed to have a large influence on the stocking rate and a sharp increase occurred when the grazing pressure was increased.

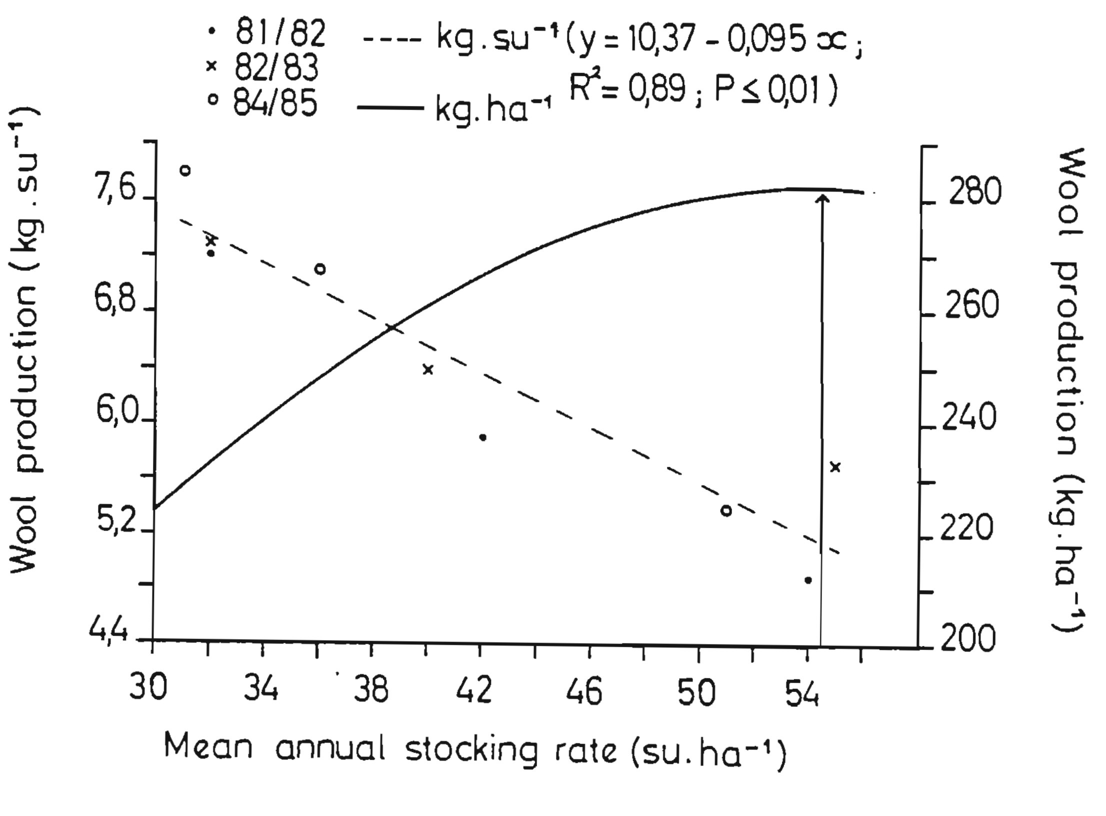
The determination of an optimum grazing pressure for maximum animal production per hectare was very difficult, as the same animals were used as the permanent (tester) group for the duration of the trial. The only measure of the influence of grazing pressure on the production per SU, was therefore the wool production. The relationship between the wool production per SU and the grazing pressure, is depicted in figure 4.28. The wool production per SU declined linearly with increased stocking rate, but the response was not large enough to enable the estimation of a realistic optimum mean annual stocking rate for maximum wool yield per hectare. The estimated value of 54,4 SU per hectare, based on the technique of Jones & Sandland (1974), is clearly too high to be realistic.

4.5.3.1.5 Discussion and conclusions

As a definite seasonal pasture production pattern was evident, with the minimum occurring during winter (June/July) and the maximum during spring (October/November), it is clear that the rate of dry matter production would be most limiting during winter. Any animal production system utilising this type of pasture should therefore be manipulated to ensure that the period of highest dry matter requirement coincides with the spring and summer flush.

The applied grazing pressures had a substantial influence on the pasture production rate which was severely reduced by increased grazing pressure over the whole range. This

Figure 4.28 Relationships between the mean annual stocking rate and the wool production per sheep-unit (kg.SU^{-1}) and per hectare (kg. ha^{-1}), during three seasons (1981/82 to 1983/84) (P indicates significance of regression)



indicated that the grazing pressure treatments were effective in evaluating the response of the pasture to increased levels of utilisation and also for the possible determination of a grazing capacity for maximum animal production per hectare.

While increased pasture age generally led to an increased grass and a decreased clover content of the pasture material, the sensitivity of the clover component to intensity of utilization was illustrated by the extent to which this component declined as grazing pressure increased. In contrast, the lucerne component was not sensitive to the level of utilisation and was influenced much less by pasture age.

Pasture age and grazing pressure seem to be the main determinants of the longevity of this type of pasture, at least in the sense of longevity being judged by the clover content of the pasture. The results, however, clearly demonstrated that the rate of decline in clover content with age could be reduced by the correct level of pasture utilisation.

As in the case of the production rate, the rate of the estimated intake of pasture material by the grazing animals seemed to fluctuate to a very great extent during the season, with the lowest values occurring during winter. The estimated intake values, however, tended to be lower than those reported by Arnold (1975) and Rattray (1978). This can be attributed to a number of factors, notably the grazing method, which could have resulted in extreme levels of utilisation (Allden, 1962; Rattray & Jagusch, 1978; Pownall, <u>et al</u>, 1984), the low dry matter content of the grazing material (Lloyd Davies, 1962), the low clover content of the grazing material at high grazing pressures (Milne, <u>et al</u>, 1982) and structural differences in the grazing material, resulting from the differences in botanical composition brought about by increased grazing pressure (Kenney & Black, 1984).

As in the case of the previously mentioned two parameters, the stocking rate seemed to vary during the year, as well as with grazing pressure and it was clear that, in a fat lamb production system, one would have to limit the main lambing season to spring (September). However, the fact that the stocking rate during winter was more than half of that of the summer indicated that a secondary lambing period during autumn (April) may be advisable.

An attempt was made to determine the optimum mean annual stocking rate by using data on the wool production per SU, but this resulted in an unrealisticly high optimum value (54,4 $SU.ha^{-1}$), for maximum wool production per hectare because of the general insensitivity of wool production to grazing pressure. Observations on the level of available grazing material and changes in the botanical composition of the available green material, however, indicated that the medium grazing pressure (2,25 kg $DM.SU^{-1}.d^{-1}$), which resulted in a mean stocking rate of 40 $SU.ha^{-1}$, was about the most effective and least damaging to the pasture. The lower levels (3,00 kg $DM.SU^{-1}.d^{-1}$) seemed to result in the grass component becoming unpalatable, while the highest level (1,5 kg $DM.SU^{-1}.d^{-1}$) lead to severe overgrazing and seemed to be very damaging to the clover component of the pasture.

4.5.3.2 Influence of grazing management on the animal production potential

In this part of the trial the mean annual grazing capacity and animal production potential of the pasture was determined in two grazing management regimes, using reproducing merino ewes at three set stocking rates (see tables 4.4 and 4.5 for more details).

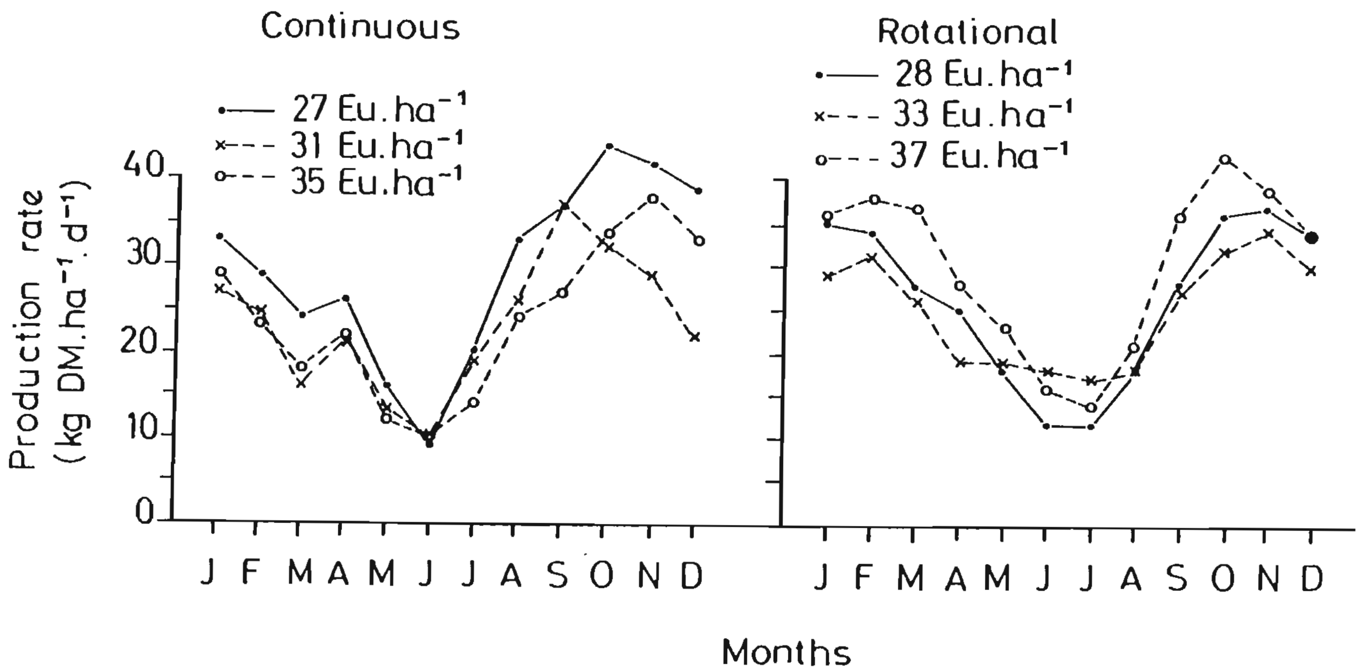
4.5.3.2.1 Pasture production rate

The estimated mean monthly production rates (kg $DM.ha^{-1}.d^{-1}$) of the pasture, at three stocking rates (means of three seasons) and two grazing management systems and calculated over three seasons (1981/82 to 1983/84), are depicted in figure 4.29. Unfortunately the mean monthly production rates could not be compared statistically, but general trends will be discussed. The estimated production rates were lower than those which had been derived in the plot trials. The results should therefore be seen as relative values only, but could none-the-less be used to compare the different treatments. The seasonal production pattern seemed to be very similar in the two management systems and over the three stocking rates.

Under continuous grazing the lowest production rates seemed to occur during May to July, while the lowest values occurred during June to August on the rotationally grazed system. The highest values also generally seemed to occur earlier on the continuously grazed system, i.e. September/ October, than on the rotationally grazed system, i.e. October/November. It was, however, not possible to determine a general influence of stocking rate and treatment, using the data as such. To facilitate this comparison the mean annual production rates were determined for each treatment.

The stocking rates applied during the 1981/82 and 1982/83 seasons differed from those applied during the 1983/84 season. In order to make a comparison of the mean annual growth rates in the different treatments possible, the mean stocking rates were calculated and used as basis. These

Figure 4.29 Production rate (kg DM.ha^{-1}.d^{-1}) of the pasture at two grazing management systems and three stocking rates, meaned over three seasons (1981/82 to 1983/84)



results are depicted in figure 4.30. The production rates tended to be highest on the continuously grazed camps at the low stocking rate. As stocking rate increased, the rate of production declined to values much lower than in the rotationally grazed system. On the rotationally grazed pasture the estimated growth rates tended to be highest at the medium stocking rate, and were lowest at the highest stocking rate.

4.5.3.2.2 Botanical composition of the available green pasture material

The mean botanical composition of the available green material during each of the three seasons at the three stocking rates, is depicted in figures 4.31 to 4.33. On both management systems the stocking rates had to be adjusted during the third (1983/84) season because the highest rate (36 $EU.ha^{-1}$) was too high for the continuously grazed system, while the lower rates were too low for the rotationally grazed system. Due to these changes the only method by which the different treatments could be compared statistically, was by fitting nonlinear multiple regression functions to the data. This approach enabled the determination of trends in treatment and seasonal effects on the botanical composition and, by using all the data, a large enough number of degrees of freedom were available. The coefficients and levels of significance of the curves fitted to the data on the three components of the available green material, clover, grass and lucerne, are presented in table 4.11.

The clover content (figure 4.31) was highest on the continuously grazed pastures, but responded more to stocking rate and decreased more with age on this system than on the rotationally grazed system, on which no significant responses were evident. On both management systems,

Figure 4.30 Production rate of the pasture (kg DM.ha^{-1}.d^{-1}) at three stocking rates and two grazing management systems, continuous (C) and rotational (R) grazing, meaned over three seasons (1981/82 to 1983/84) (SD indicates standard deviation)

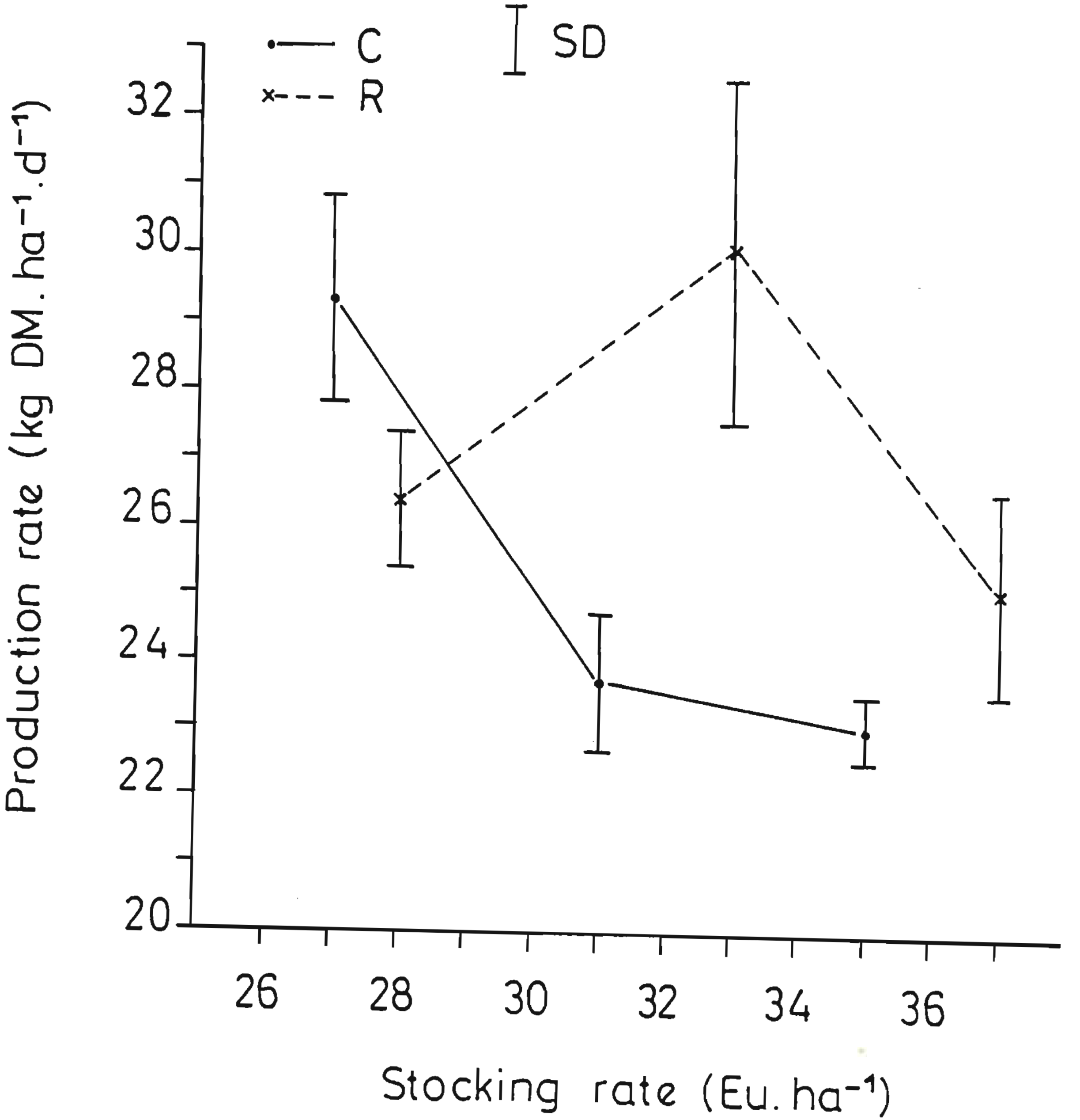


Figure 4.31 Influence of stocking rate, age of pasture and pasture management system on the clover content (%) of the available green pasture material

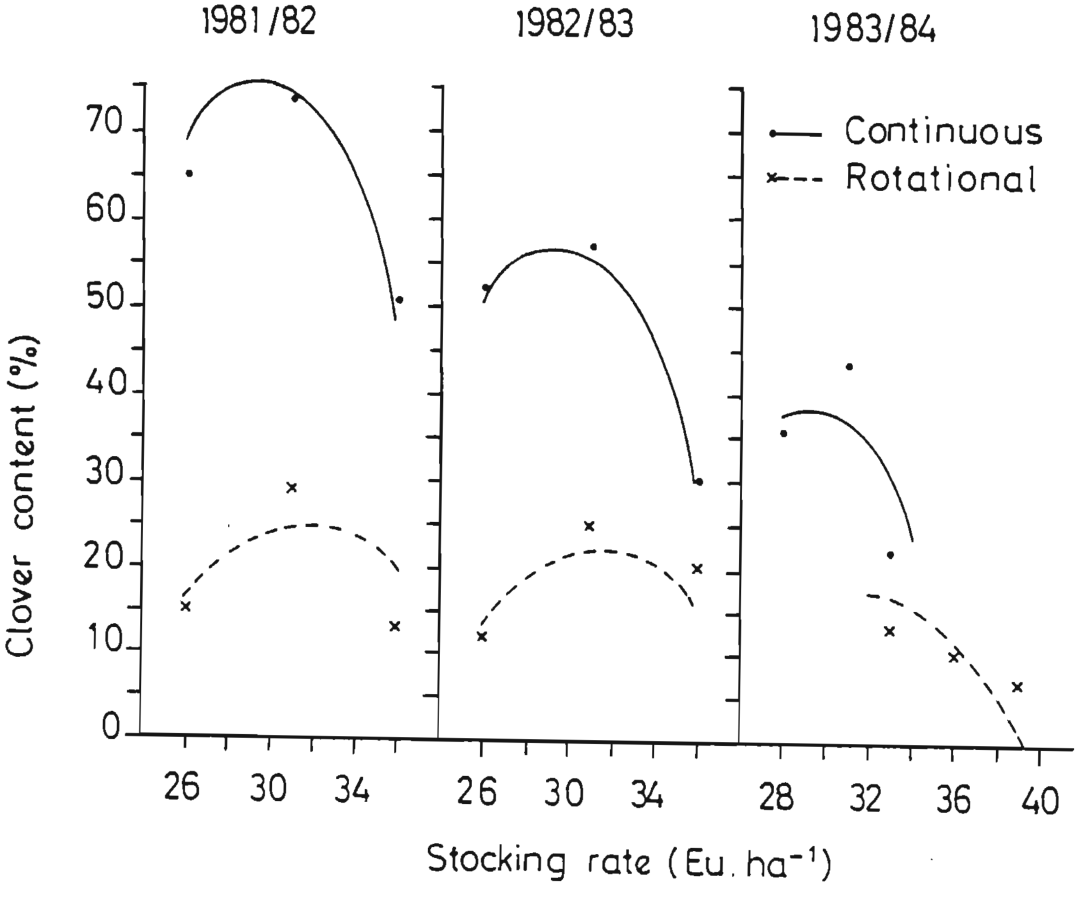


Figure 4.32 Influence of stocking rate, age of pasture and pasture management system on the lucerne content (%) of the available green pasture material

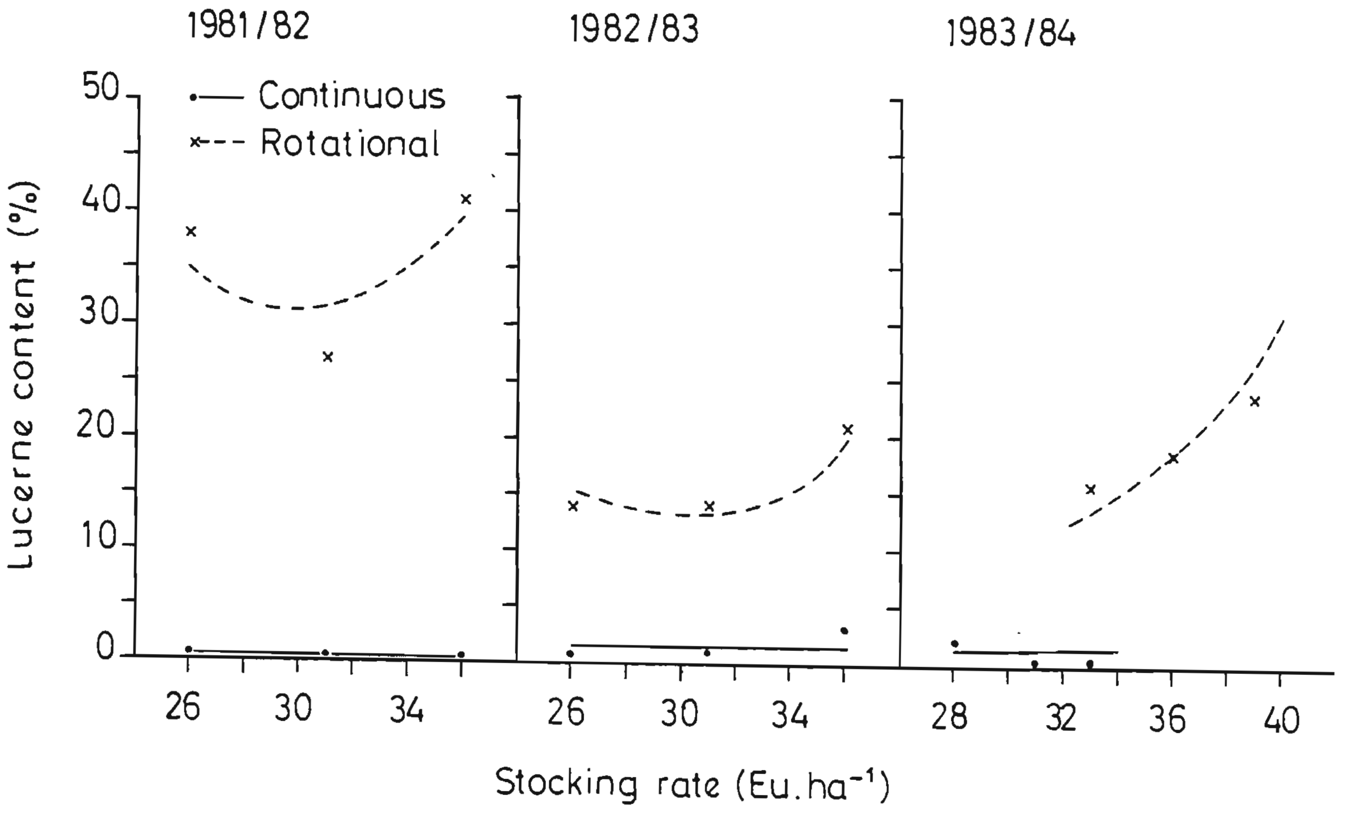


Figure 4.33 Influence of stocking rate, age of pasture and pasture management system on the grass content (%) of the available green pasture material (see Table 4.11 for functions)

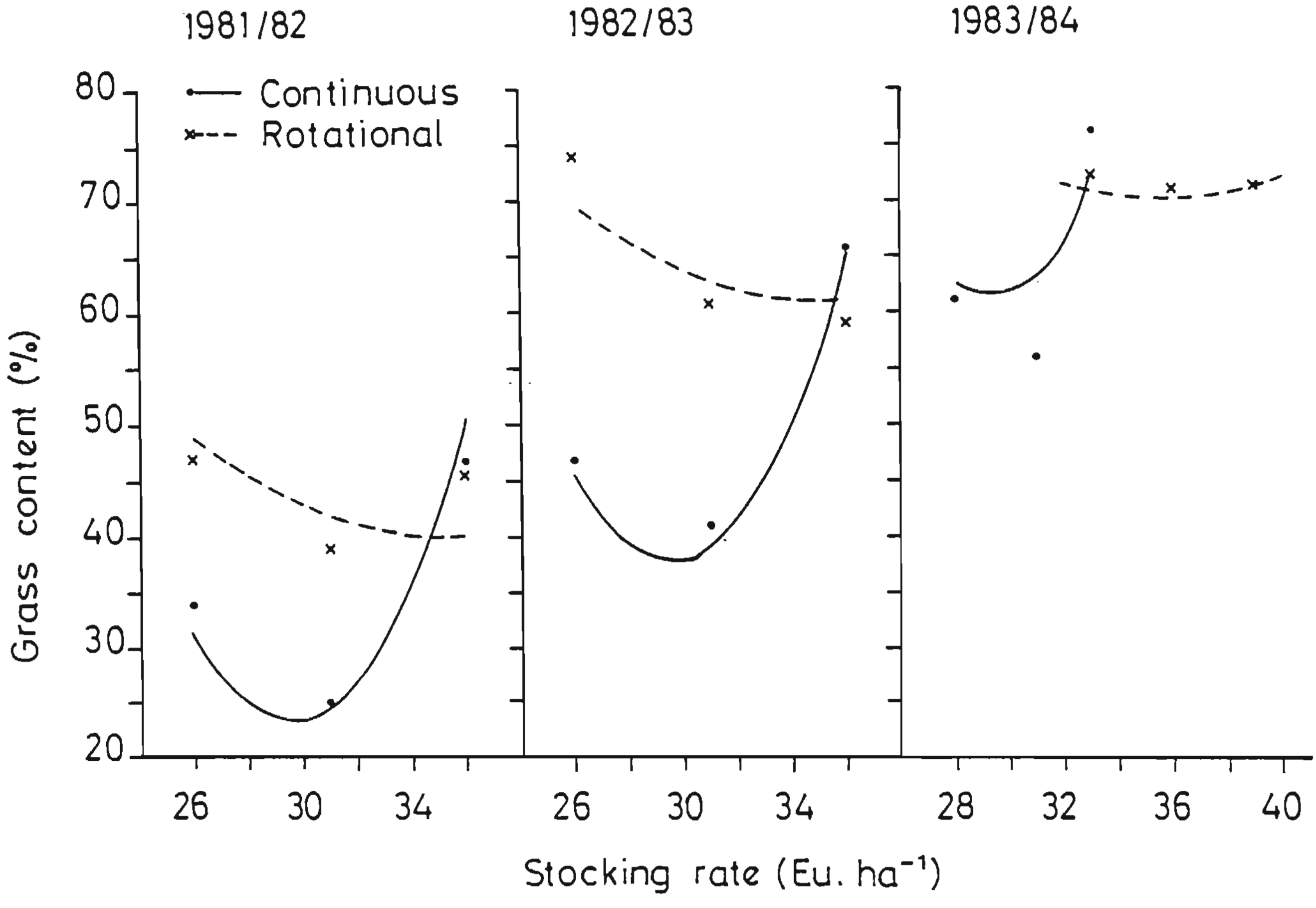


TABLE 4.11 COEFFICIENTS OF CURVES FITTED TO DATA ON THE RELATIONSHIPS BETWEEN THE BOTANICAL COMPOSITION OF THE AVAILABLE GREEN MATERIAL AND PASTURE AGE (SEASON = X_1) AND STOCKING RATE (X_2)

Component (%)	Management system	Parameters								
		Abscissa	X_1	X_2	X_3 (X_1^2)	X_4 (X_2^2)	F	Df	P*	R^2
Clover	Continuous	-449,23	-18,88	37,07	-	-0,63	30,5	3 and 5	0,01	0,95
	Rotational	-247,54	-	17,36	-0,96	-0,28	4,9	3 and 5	NS	0,74
Lucerne	Continuous	- 4,33	5,67	-	-1,33	-	2,4	2 and 6	NS	0,44
	Rotational	234,72	-45,79	-11,14	8,93	0,19	14,0	4 and 4	0,01	0,93
Grass	Continuous	582,43	-	-38,17	4,66	0,65	37,3	3 and 5	0,01	0,96
	Rotational	133,00	38,29	-7,09	-5,87	0,10	19,2	4 and 4	0,01	0,94

* P indicates significance of regression

however, the clover content tended to be highest at the intermediate stocking rates and to decrease with age of the pasture.

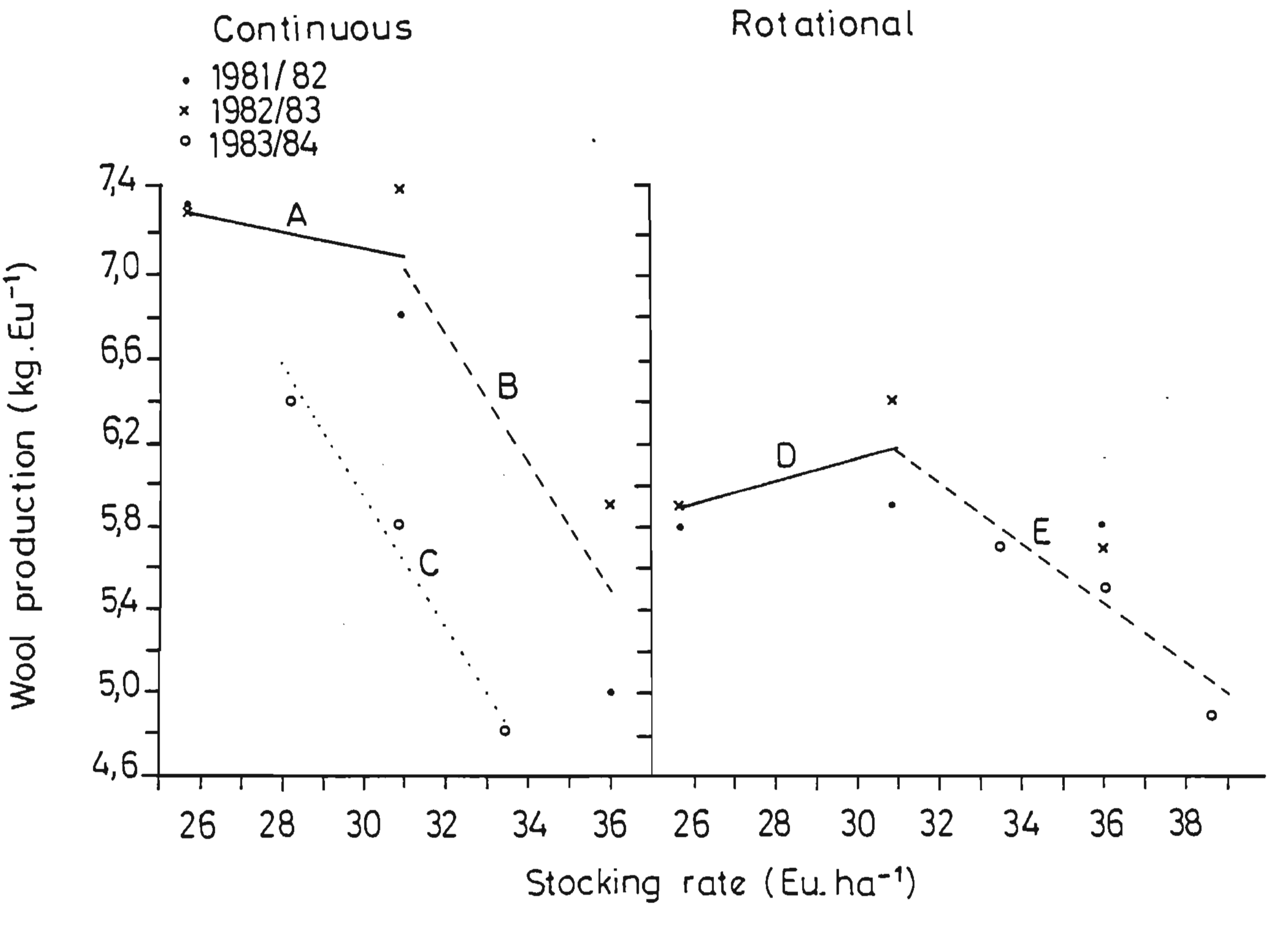
In contrast to the clovers, there was no lucerne in the available green material on the continuously grazed pastures even during the first season and it did not respond to further treatments or to seasons (figure 4.32). The lucerne content of the rotationally grazed camps was, however, quite substantial and tended to decrease with age between the first and second seasons, but not between the second and third. The effect of stocking rate on this last mentioned component of the green material was not very clear on the rotationally grazed treatment. It did, however, seem as if increased stocking rate tended to increase the relative lucerne content during the last two seasons.

The grass content (figure 4.33) showed a response opposite to that of the clover content and tended to increase with pasture age. Also, this fraction was lowest on the continuously grazed system at the two lowest stocking rates, with the minimum values occurring at the medium rates. The effect of stocking rate on the grass content of the rotationally grazed pastures was, however, not clear, as the response differed during different seasons. It did, however, seem to decrease with increasing stocking rate during the first two seasons.

4.5.3.2.3 Wool production of ewes

The relationship between wool production per EU and stocking rate, calculated over three seasons and two pasture management systems, are depicted in figure 4.34. Linear regression functions were fitted to the data over the range of stocking rates where a linear decline in wool production per EU was evident. For this purpose, the data derived on

Figure 4.34 Influence of stocking rate and grazing management system on the annual wool production per ewe-unit (kg.EU^{-1}), over three successive seasons (1981/82 to 1983/84) (see Table 4.12 for functions)



the continuously grazed system were grouped together over the stocking rate range 31 to 36 $EU.ha^{-1}$ in the first two seasons and for all seasons over the range 31 to 39 $EU.ha^{-1}$ on the rotationally grazed system. During the 1983/84 season the data of all three stocking rates were used to fit a separate function for the continuously grazed system. The functions fitted to the data and their correlations and levels of significance, are depicted in table 4.12.

On the continuously grazed system, during the first two seasons, and on the rotationally grazed system during all three seasons, the response to stocking rate was not significant over the range 26 to 31 $EU.ha^{-1}$. The wool production per EU, however, tended to be much much higher on the continuously, than on the rotationally grazed system. A linear decline in wool production per EU was evident over the range 31 to 36 $EU.ha^{-1}$ during the first two seasons on the continuously grazed system and over the range 31 to 39 $EU.ha^{-1}$ during all three seasons on the rotationally grazed system. This linear decline was, however, only significant at the 10% level over the first two seasons (1981 to 1983: function B) on the continuously grazed system, but more highly significant on the rotationally grazed system over all three seasons. On the continuously grazed system a significantly linear decline, however, occurred over all three stocking rates during the third season (1983/84), when the wool production per EU was also much lower.

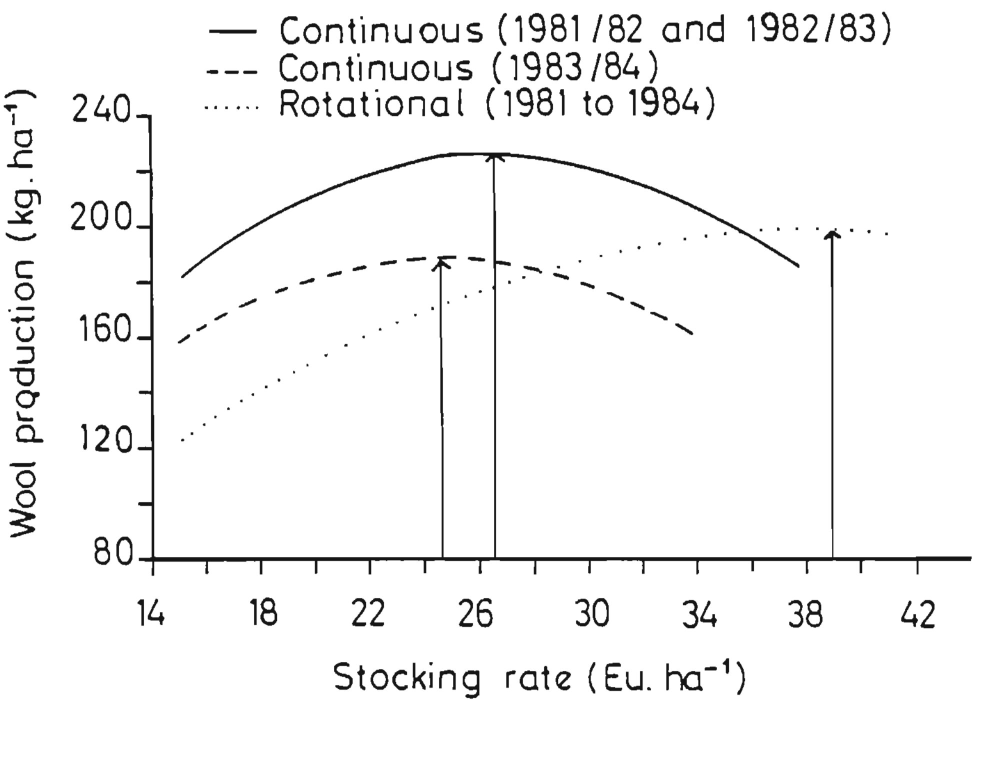
Using these functions and applying the Jones & Sandland (1974) approach, the wool production per hectare and the optimum stocking rate for maximum wool production per hectare were calculated. These relationships are depicted in figure 4.35. The mean optimum stocking rates for maximum wool production per hectare, for both periods, were lowest on the continuously grazed system, i.e. 26,55 $EU.ha^{-1}$ for the 1981/82 and 1982/83 and 24,55 $EU.ha^{-1}$ for the

TABLE 4.12 FUNCTIONS DEPICTED IN FIGURE 4.34

Management system	Functions	R^2	P*
Continuous	A: y = 8,30 - 0,039x	0,18	NS
	B: y = 16,99 - 0,32x	0,82	0,10
	C: y = 15,26 - 0,311x	0,98	0,05
Rotational	D: y = 4,35 + 0,058x	0,41	NS
	E: y = 10,22 - 0,131x	0,72	0,05

* P indicates significance of regression

Figure 4.35 Relationships between stocking rate ($EU.ha^{-1}$) and grazing management system and the annual wool production per hectare ($kg.ha^{-1}$), over three seasons (1981/82 to 1983/84)



1983/84 seasons, respectively. On the rotationally grazed system the mean optimum stocking rate for maximum wool production per hectare, calculated over all three seasons, was 39,04 $EU.ha^{-1}$.

The calculated wool production per EU, corresponding with these three stocking rates, was 8,5; 7,6 and 5,1 $kg.EU^{-1}$, respectively and the wool production per hectare 225; 187 and 200 $kg.ha^{-1}$, respectively. The optimum stocking rate for maximum wool yield per hectare was therefore highest on the rotationally grazed system, but as the wool production per EU was much higher on the continuously grazed system during the first two seasons, the wool production per hectare was also highest on the latter system during these two seasons. During the 1983/84 season, however, the optimum stocking rate for maximum wool yield per hectare, as well as the wool production per EU, were lower on the continuously grazed system, resulting in a lower wool production per hectare at this rate than in the rotational grazing system.

An attempt was made to relate the observed differences in wool production per EU, derived from data from the different systems and during different seasons and at the three stocking rates, to differences in available green material and the legume content of the available green material. These relationships are depicted in figures 4.36 and 4.37. Wool yield was positively correlated with available green material in both systems, but the legume content of the green material had a significantly positive influence only on the continuously grazed system.

Figure 4.36 Relationships between the wool production per ewe-unit ($kg.EU^{-1}$) and the available green pasture material per ewe-unit ($kg.EU^{-1}$) on two grazing management systems, meaned over three seasons (1981/82 to 1983/84) (P indicates significance of regression)

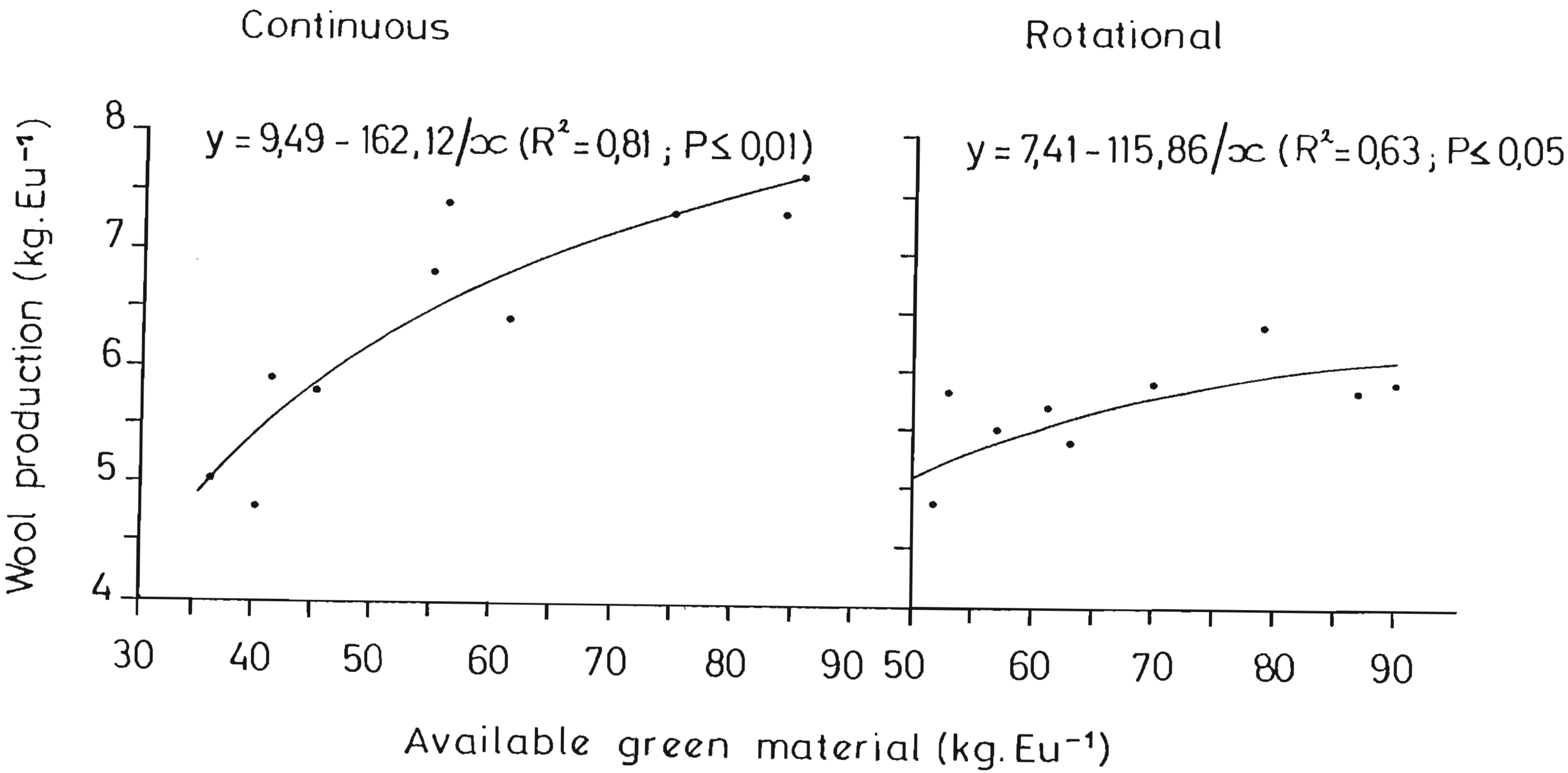
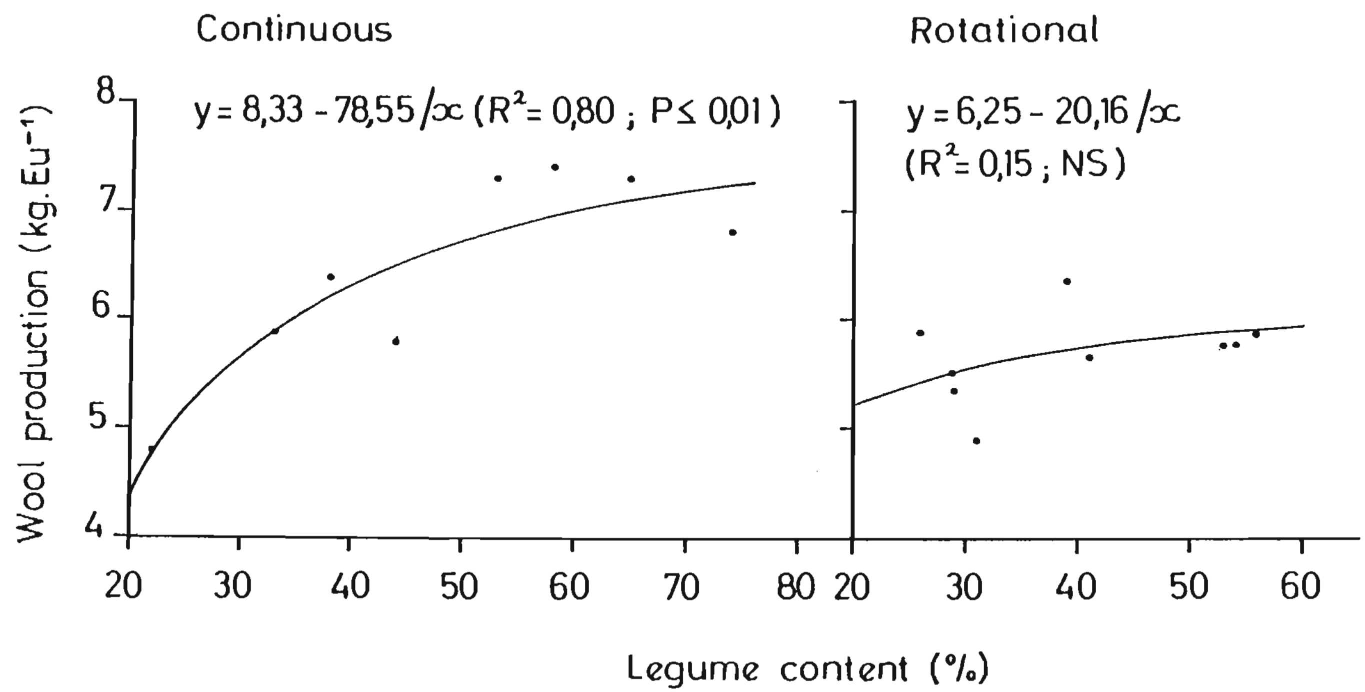


Figure 4.37 Relationships between the legume content (%) of the available green pasture material and the wool production per ewe-unit ($kg.EU^{-1}$) on two grazing management systems, meaned over three seasons (1981/82 to 1983/84) (P indicates significance of regression)



4.5.3.2.4 **Average daily gain (ADG) of lambs and the meat production per hectare**

The relationship between the mean average daily gain (ADG) of the lambs ($g.l^{-1}.d^{-1}$) and the stocking rate on the two pasture management systems, calculated over three seasons, is depicted in figure 4.38. Linear regression functions were subsequently fitted to the range of data over which a linear response to stocking rate tended to occur. For this purpose the data of the first two seasons were grouped together, while separate functions were fitted to the data of the third season, in both management systems. The functions fitted to the data and their correlations and levels of significance, are depicted in table 4.13.

The ADG tended to be higher on the continuously than the rotationally grazed system at the two lower stocking rates during all three seasons. On both management systems the ADG, however, tended to be much higher during the first two seasons (1981/82 and 1982/83) than during the third season (1983/84). A linear decrease in ADG tended to occur beyond 31 $EU.ha^{-1}$ on both management systems, although only significantly so on the continuously grazed system. During the third season, however, the ADG decreased linearly with increased stocking rate over all three stocking rates on the two grazing management systems although, once again, only significantly so on the continuously grazed system.

Applying the Jones & Sandland (1974) approach to these functions, which are depicted in figure 4.38, the optimum stocking rates for maximum meat production per hectare and the meat production per hectare at these rates, were calculated for both management systems. These results are depicted in figure 4.39. The calculated optimum stocking rates for maximum meat yield per hectare on the continuously grazed system were 20,8 and 18,7 $EU.ha^{-1}$, respectively, for

Figure 4.38 Influence of stocking rate and grazing management system on the average daily gain per lamb (ADG) $(g.l^{-1}.d^{-1})$, over three successive seasons (1981/82 to 1983/84) (see Table 4.13 for functions)

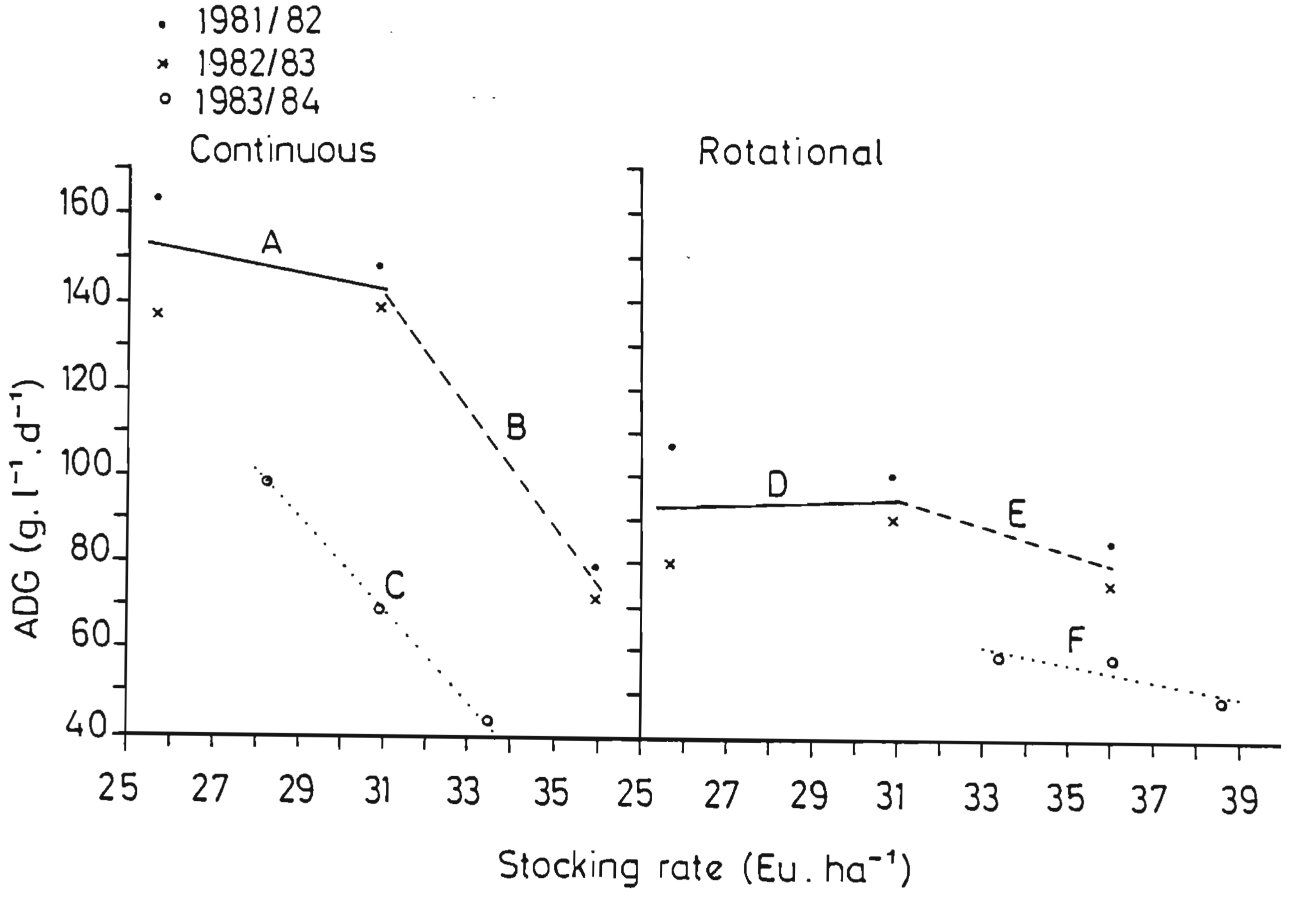
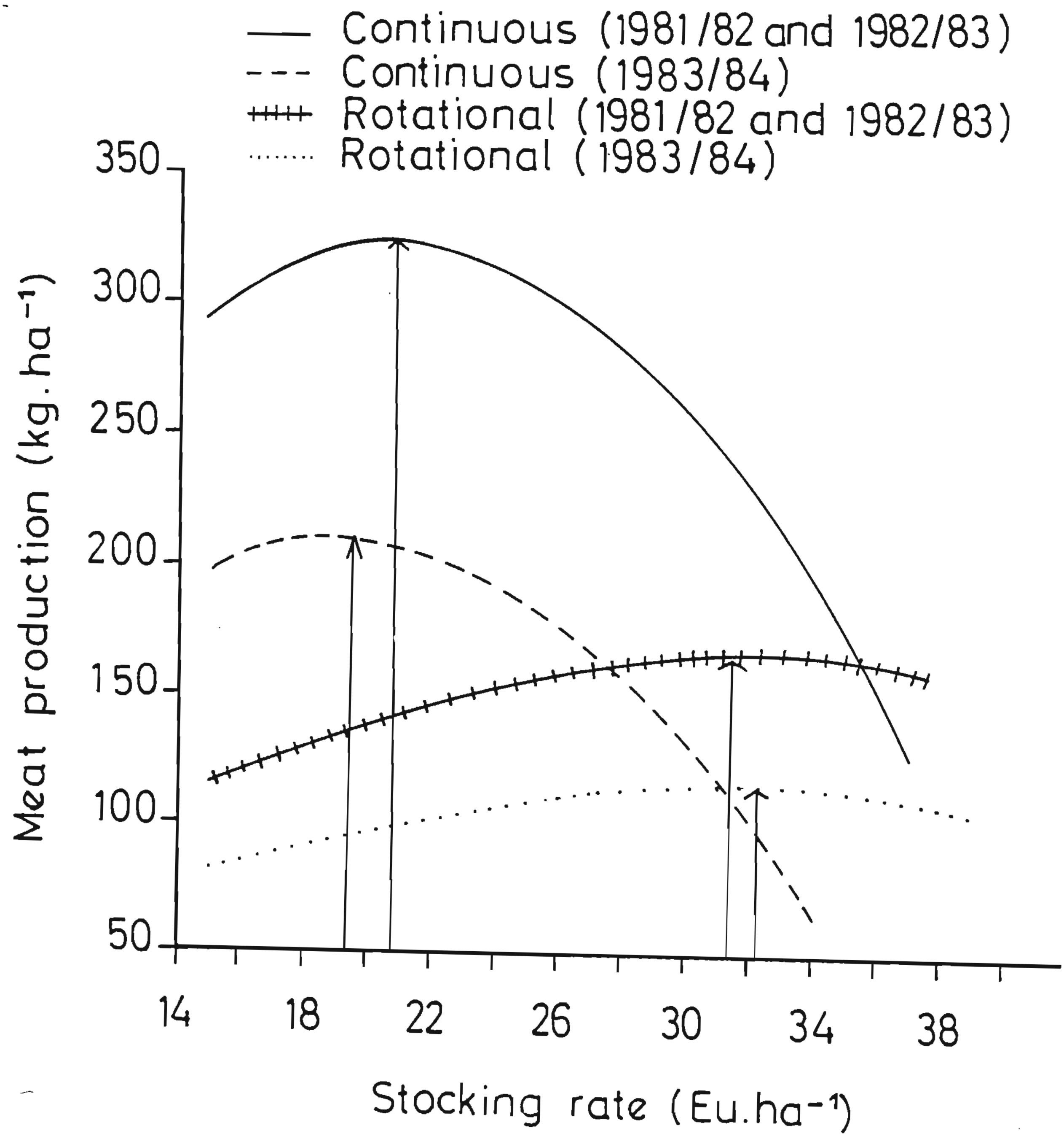


TABLE 4.13 FUNCTIONS DEPICTED IN FIGURE 4.38

Management system	Functions	R^2	P*
Continuous	A: 185,03 - 1,36x	0,11	NS
	B: 550,47 - 13,20x	0,98	0,01
	C: 399,60 - 10,67x	0,999	0,01
Rotational	D: 85,99 + 0,29x	0,005	NS
	E: 184,88 - 2,91x	0,69	NS
	F: 125,39 - 1,95x	0,82	NS

* P indicates significance of regression

Figure 4.39 Relationships between stocking rate ($EU.ha^{-1}$) and grazing management system and the annual meat production per hectare ($kg.ha^{-1}$), over three successive seasons (1981/82 to 1983/84)



the two periods (1981 to 1983 and 1983/84) and were much lower than the 31,7 and 32,2 $EU.ha^{-1}$, respectively, calculated for the rotationally grazed system. The calculated meat production at these stocking rates, however, was 244 and 158 $kg.ha^{-1}$, respectively, for the continuously grazed system and much higher than the 124 and 86 $kg.ha^{-1}$ for the rotationally grazed system.

An attempt was once again made to relate the differences in ADG found on the different treatments (i.e. stocking rates and management systems) and during different seasons, to differences in available green material per EU and the legume content of the available green material. The relationship between the ADG and the available green material was not significant, but a significantly positive relationship was found to exist between the legume content and the ADG. The latter mentioned relationships, derived for each of the management systems, are depicted in figure 4.40.

4.5.3.2.5 Relationship between the total digestible nutrient (TDN) and crude protein (CP) content of the pasture material and its legume content

The relationships between the total digestible nutrient (TDN) and crude protein (CP) content of the total available pasture material and the legume content of the available green material, are depicted in figures 4.41 and 4.42. Both relationships were significant and seem to provide an explanation for the positive relationships which were found between the legume content of the available green material and production per animal.

Figure 4.40 Relationships between the legume content (%) of the available green pasture material and the average daily gain of lambs (ADG) (g. $l^{-1}.d^{-1}$) on two management systems, over three seasons (1981/82 to 1983/84) (P indicates significance of regression)

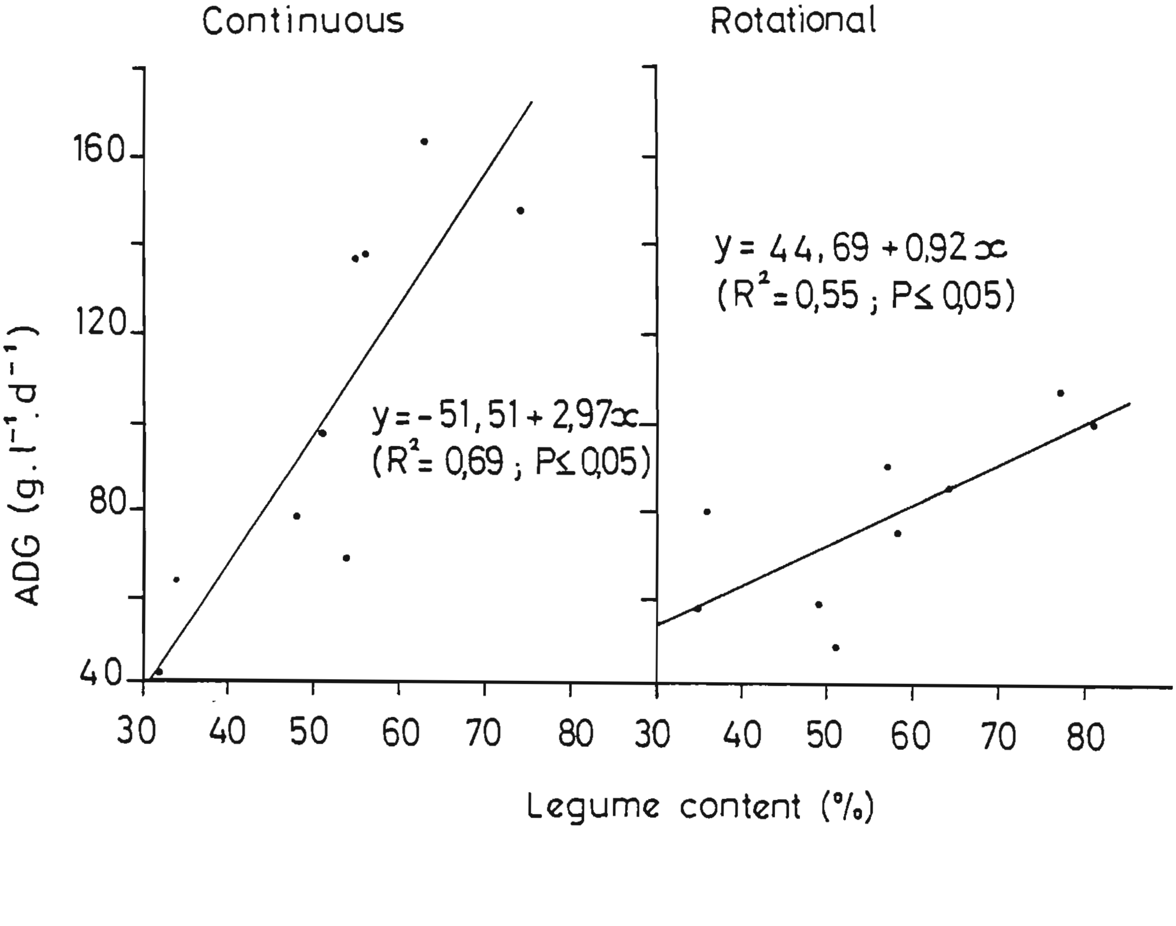


Figure 4.41 Relationship between the mean legume content (%) of the green material and the crude protein (CP) content (%) of the total available pasture material on two management systems and over three seasons (1981/82 to 1983/84) (P indicates significance of regression)

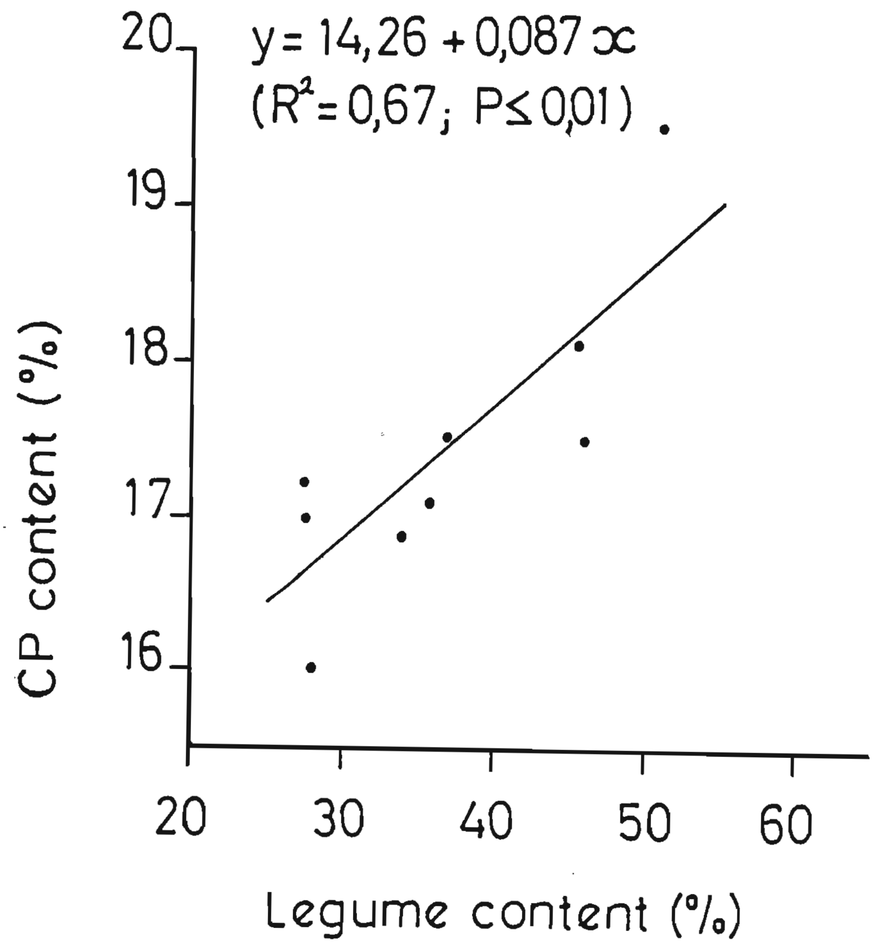
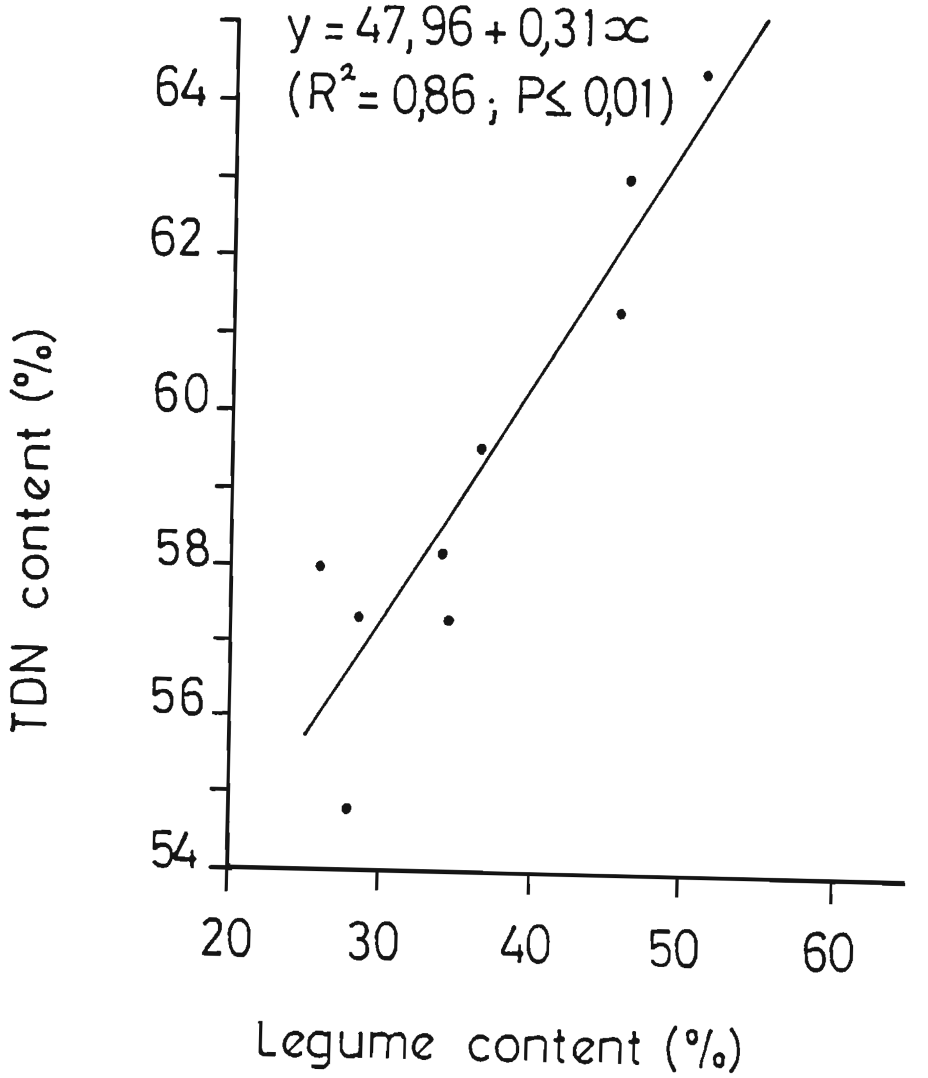


Figure 4.42 Relationship between the legume content (%) of the green material and the total digestable nutrient (TDN) (%) content of the total available pasture material on two management systems and over three seasons (1981/82 to 1983/84) (P indicates significance of regression)



4.5.3.2.6 Discussion and conclusions

Although the estimated mean monthly pasture production rates had basically the same pattern in the continuously and rotationally grazed systems, as well as at the three stocking rates, the production rates decreased faster with increased stocking rate on the continuously grazed, than the rotationally grazed system. This was the first indication that the application of a system of rotational grazing might result in the pasture having a higher potential grazing capacity.

Determinations of the botanical composition of the available green material, however, indicated that not only pasture production, but also its botanical composition, are influenced by pasture management and stocking rate. These results indicated that lucerne was the least sensitive of the three components of the available green material (i.e. grass, lucerne and clover) to changes in stocking rate and therefore intensity of utilisation. Lucerne, however, seemed to be very sensitive to grazing management and was completely irradicated from the pasture by continuous grazing. This is in keeping with the results of McKinney (1974) who found lucerne to be extremely sensitive to length of rotation. The results, however, also seem to indicate that lucerne could perhaps be more sensitive to grazing management under irrigation than under dryland, as observations has indicated it to be more resistant to continuous grazing management under dryland conditions in the same area.

In contrast to lucerne, the clover content was decreased by rotational grazing, very low stocking rates and ageing of the pasture. The results seem to indicate that the lucerne and clover components have completely different management requirements, with intensity of grazing, i.e. stocking rate, having a more important influence on the clover component than length of rotation. With these differences in mind, it is therefore clear that lucerne and clover should not be included in the same pasture mixture.

The fact that the clover content of the continuously grazed pastures was, at least initially, higher than that of the rotationally grazed pastures, resulted in animal production being much higher on the first mentioned system during the first two seasons. It was also found that wool production per EU and per hectare were highest on the continuously grazed system during these two seasons. For the same reason, the ADG and maximum potential meat production per hectare were also highest during all three seasons on the continuously grazed system.

The estimated stocking rate for maximum meat and wool production per hectare, calculated using the Jones & Sandland (1974) model tended, however, to be higher on the rotationally grazed than on the continuously grazed system. This can be attributed to the lower pasture production rate at very high stocking rates under continuous grazing, resulting in a sharp decline in the estimated stocking rate for maximum wool yield per hectare on the continuously grazed system during the last season and in a higher wool production per hectare being recorded on the rotationally grazed system. The decline in wool yield at the high stocking rate under continuous grazing can, however, also be attributed to a very drastic decrease in the clover content of the continuously grazed pastures during the same period.

The above-mentioned assumptions were substantiated by the fact that the differences in animal production (wool production per EU and ADG), on the different management systems and on the same management system at different stocking rates and during different seasons, was found to be positively related to available green material per EU and its legume content. This confirms the general belief that management system, as well as pasture age, influence the animal production potential through their influence on the available pasture material and the botanical composition of that material. The results on the influence of the legume content of the pasture on animal production is also substantiated by results reported in literature (Gibb & Treacher, 1983; 1984; Stewart, et al, 1983; Kenny, 1984; Kenny & Reed, 1984; Freer & Jones, 1984; Stewart & McCullough, 1985). It was further substantiated by the fact that the legume content of the available green material was found to be linearly and positively related to the TDN and CP content of the total available pasture material.

It is therefore clear that a continuously grazed system of pasture management can be acceptable on condition that the stocking rate is not too high. The results, however, seem to indicate that it should be possible to develop a system of pasture management which combines the positive aspects of both continuous and rotational grazing and will ensure higher carrying capacities, without the resultant degeneration of the botanical composition of the pasture.

4.5.4 **Trial 4:** Determination of the grazing capacity and animal production potential of a number of irrigated pure grass and grass/legume pasture mixtures at Outeniqua

For details see tables 4.6 and 4.7.

4.5.4.1 Pasture production rate

The estimated mean production rates (kg DM.$ha^{-1}.d^{-1}$) of each of the seven pasture mixtures which were evaluated over two seasons (1983/84 and 1984/85) and under two pasture management regimes, are depicted in figure 4.43. These results could not be compared statistically, but the general trends will be discussed. With the exception of the pure ryegrass pasture, the minimum production rates of all the pasture mixtures tended to occur during the period June/July and the maximum rates during the period September/October to December/January. A sharp decrease in production rate occurred on these pastures during the period January to May/June and an equally sharp increase during July to September/October. In the case of the pure ryegrass pasture the production rates were, however, very low during the whole of the period from January to June.

The highest production rates were generally associated with the pasture mixtures with fescue or cocksfoot as the grass component, while those with ryegrass as a component, were lowest producing. The winter production rates of the pastures with fescue as grass component were also higher than those with cocksfoot and compared favourably with ryegrass. The pastures with white clover and lucerne, as legume components had basically the same trend in seasonal production.

In order to facilitate the statistical comparison of the different pasture mixtures and the two grazing management systems, the production rates were measured over both seasons. These results are depicted in figure 4.44. The response of the pasture mixtures to grazing management differed. The white clover based pastures and the pure ryegrass pasture had significantly higher mean production rates on the seven camp compared with the five camp system. The pure fescue pasture, however, had the highest mean rate on the five camp system, while the lucerne based pasture did not respond significantly to treatment.

Figure 4.43 Production rates (kg DM.$ha^{-1}.d^{-1}$) of seven pasture mixtures, meaned over two management systems and two seasons (1983/84 to 1984/85) (W = white clover, L = lucerne, R = ryegrass, F = fescue and C = cocksfoot)

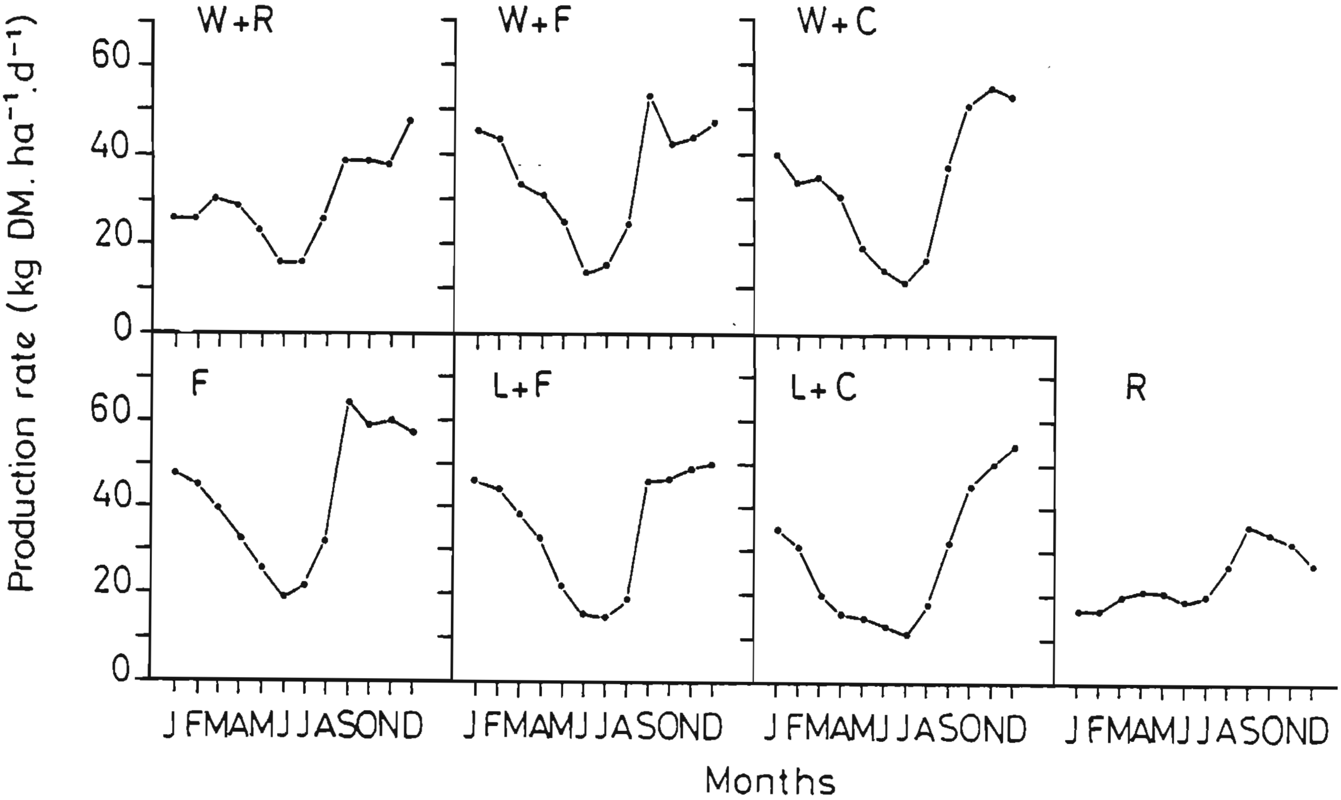
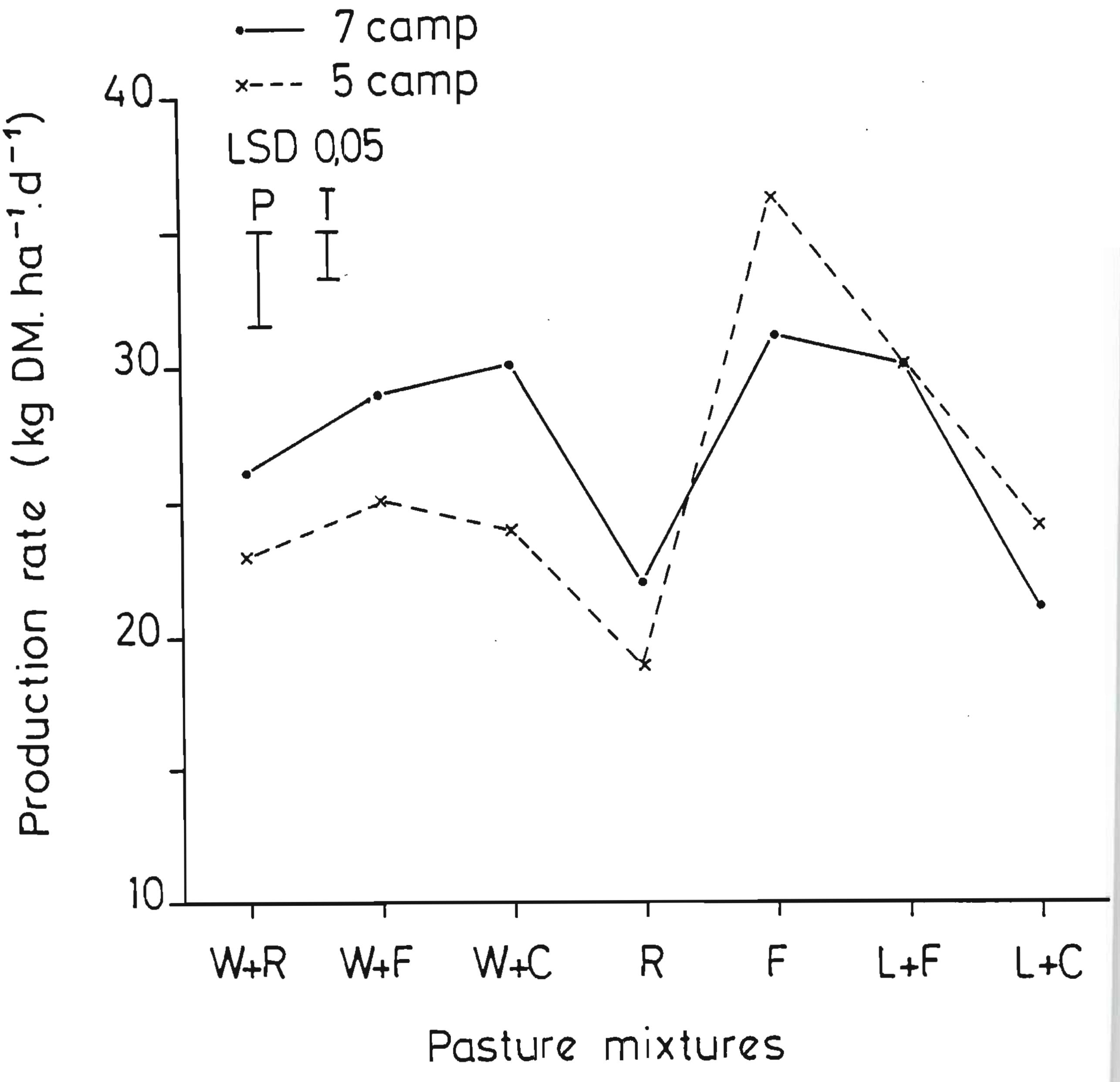


Figure 4.44 Production rates (kg $DM.ha^{-1}.d^{-1}$) of seven pasture mixtures (P) grazed under two management systems (T), i.e. a seven and a five camp system, meaned over two seasons (1983/84 to 1984/85) (W = white clover, L = lucerne, R = ryegrass, F = fescue and C = cocksfoot)



The differences between pasture mixtures were larger on the five than the seven camp system. On the seven camp system the production rates of the white clover plus fescue, white clover plus cocksfoot, pure fescue and lucerne plus fescue pastures were significantly higher than those of the pure ryegrass and lucerne plus cocksfoot pastures.

On the five camp system, the mean production rate of the pure fescue pasture was significantly higher and that of the pure ryegrass pasture, significantly lower than that of other pastures. The lucerne plus fescue pasture also had a significantly higher production rate than the other pastures in this system. The white clover based pastures and the lucerne plus cocksfoot pasture mixture produced much the same in the five camp system.

4.5.4.2 Legume content of the available green material

The mean legume content (%) of the five grass/legume mixtures in the two grazing management systems, meaned over two seasons, are depicted in figure 4.45. The legume content of all the mixtures, was significantly higher on the seven than on the five camp system. It was also clear that the legume content of the pastures with fescue as the grass component was significantly lower than in those with the same legume component, but with cocksfoot or ryegrass as the grass component.

4.5.4.3 Grazing capacity

The estimated mean monthly grazing capacities ($SU.ha^{-1}$) of each pasture mixture, meaned over two seasons and the two grazing management systems, are depicted in figure 4.46. As in the case of the production rates, these results could not be compared statistically, but the general trends will be discussed. The minimum monthly grazing capacities of all

Figure 4.45 Legume content (%) of five grass/legume pasture mixtures (P) grazed under two management systems (T), i.e. a seven and a five camp system, meaned over two seasons (1983/84 to 1984/85) (W = white clover, L = lucerne, R = ryegrass, F = fescue and C = cocksfoot)

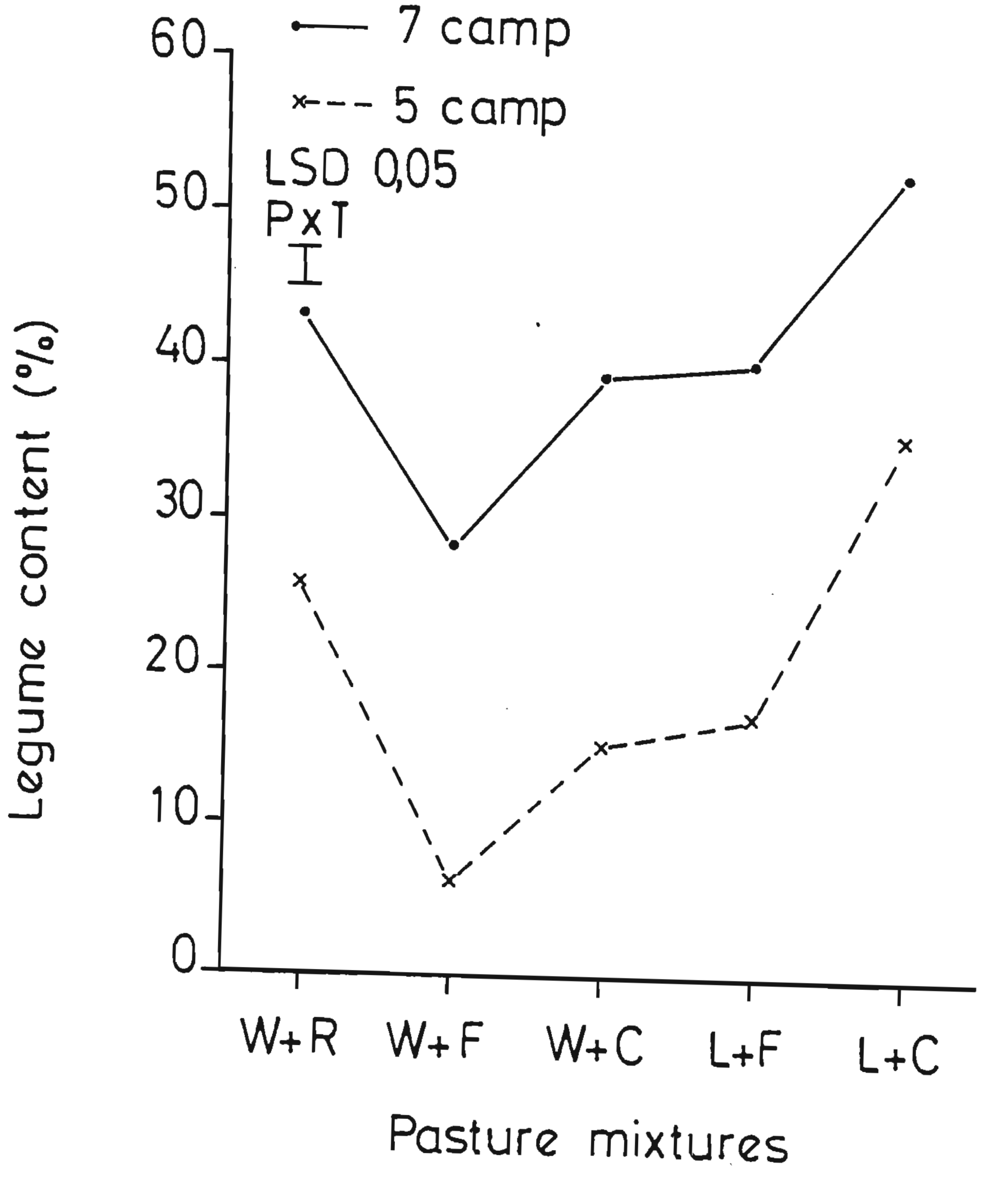
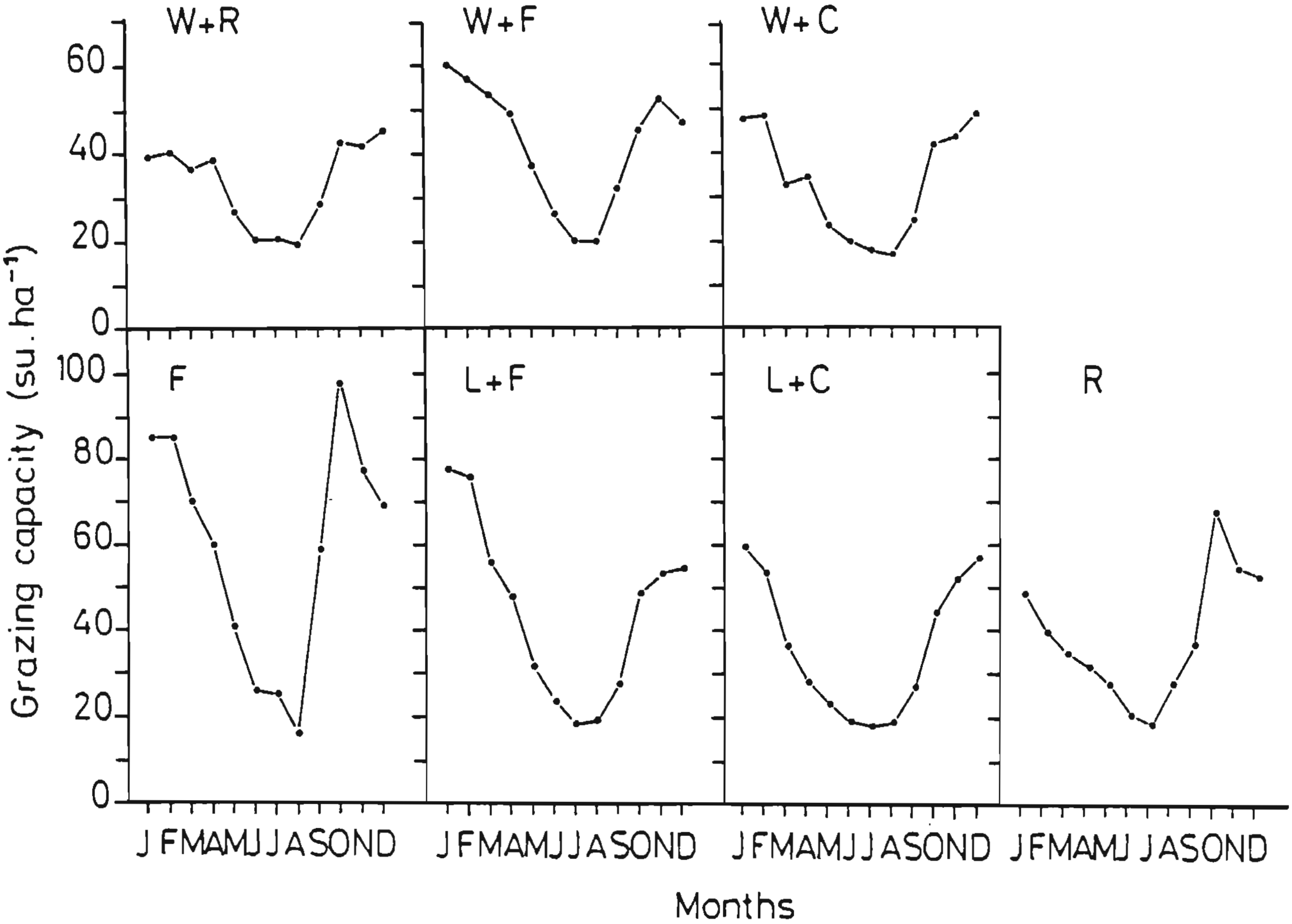


Figure 4.46 Grazing capacities (SU.ha^{-1}) of seven pasture mixtures grazed under two management systems, i.e. a five and a seven camp system, meaned over two seasons (1983/84 to 1984/85) (W = white clover, L = lucerne, R = ryegrass, F = fescue and C = cocksfoot)



seven pasture mixtures tended to occur during the period June to August, while the highest capacities occurred during the period October to February. A sharp decrease in grazing capacity seemed to occur on all the pasture mixtures during the period February to May/June and a sharp increase during August/September to October/November. During winter the grazing capacities of the different pasture mixtures seemed not to differ much, but during summer the pastures with fescue as grass component seemed to have had the highest and those with ryegrass, the lowest grazing capacity.

The mean annual grazing capacities ($SU.ha^{-1}$) of the seven pasture mixtures and two grazing management systems, meaned over two seasons, are depicted in figure 4.47. With the exception of the pasture mixtures with lucerne as the legume component, which did not respond to grazing management system, all the pasture mixtures had significantly higher grazing capacities under the seven camp than the five camp system. The pure fescue pasture had a significantly higher grazing capacity under both management systems than all the other pastures, and the two grass/ legume mixtures with fescue as grass component, the second highest. These two mixtures also had a significantly higher grazing capacity than the remaining pastures.

4.5.4.4 Wool production

The mean annual wool production per tester animal ($kg.SU^{-1}$), on the seven pasture mixtures and two management systems meaned over two seasons, is depicted in figure 4.48. Wool production per tester animal was significantly affected by grazing management on only the two lucerne based pasture mixtures, and was higher on the five than the seven camp system. Wool production was significantly higher on the white clover based and lucerne plus cocksfoot pasture mixtures than on the pure ryegrass and fescue pastures, on

Figure 4.47 Grazing capacities ($SU.ha^{-1}$) of seven pasture mixtures (P) grazed under two management systems (T), i.e. a five and a seven camp system, meaned over two seasons (1983/84 to 1984/85) (W = white clover, L = lucerne, R = ryegrass, F = fescue and C = cocksfoot)

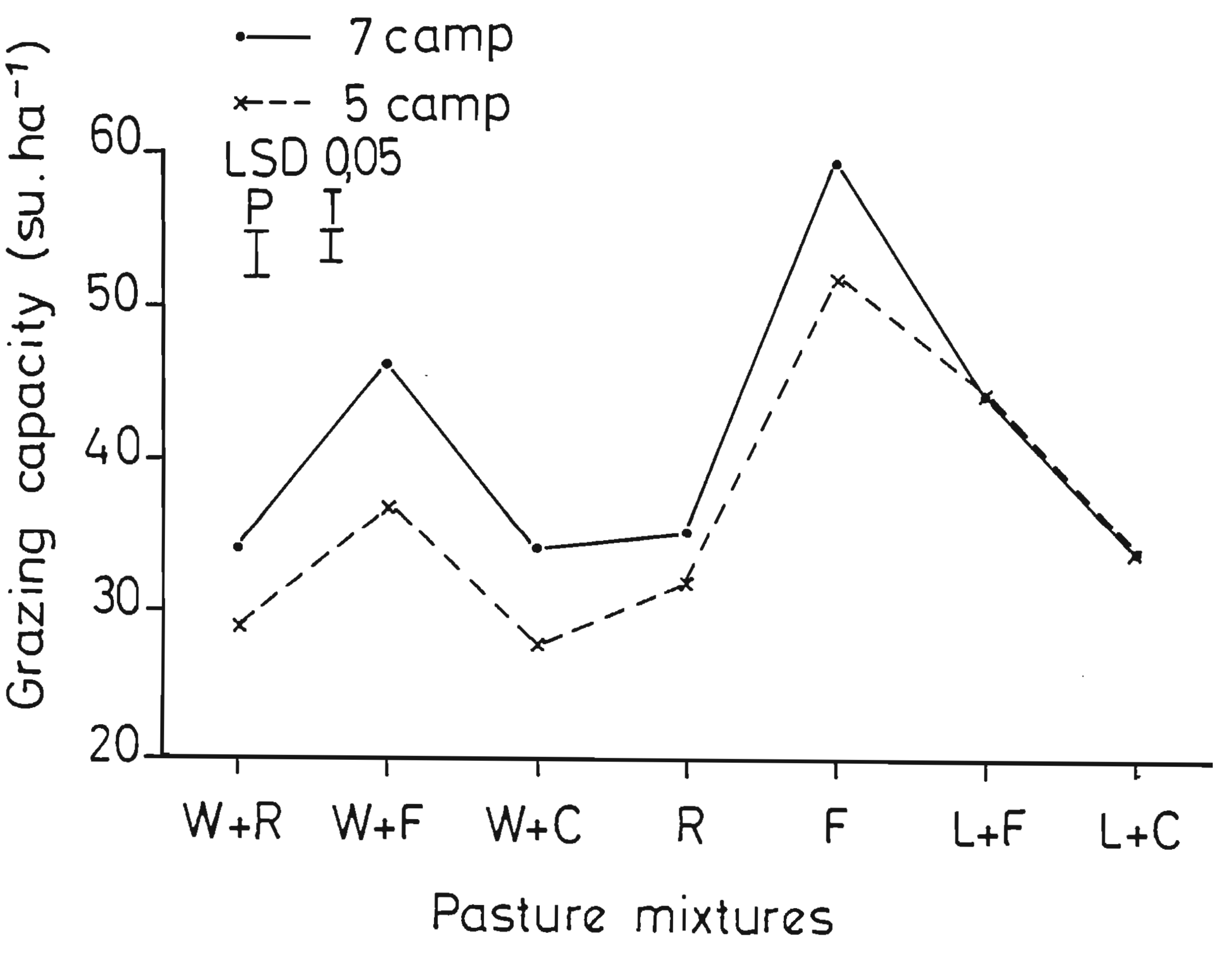
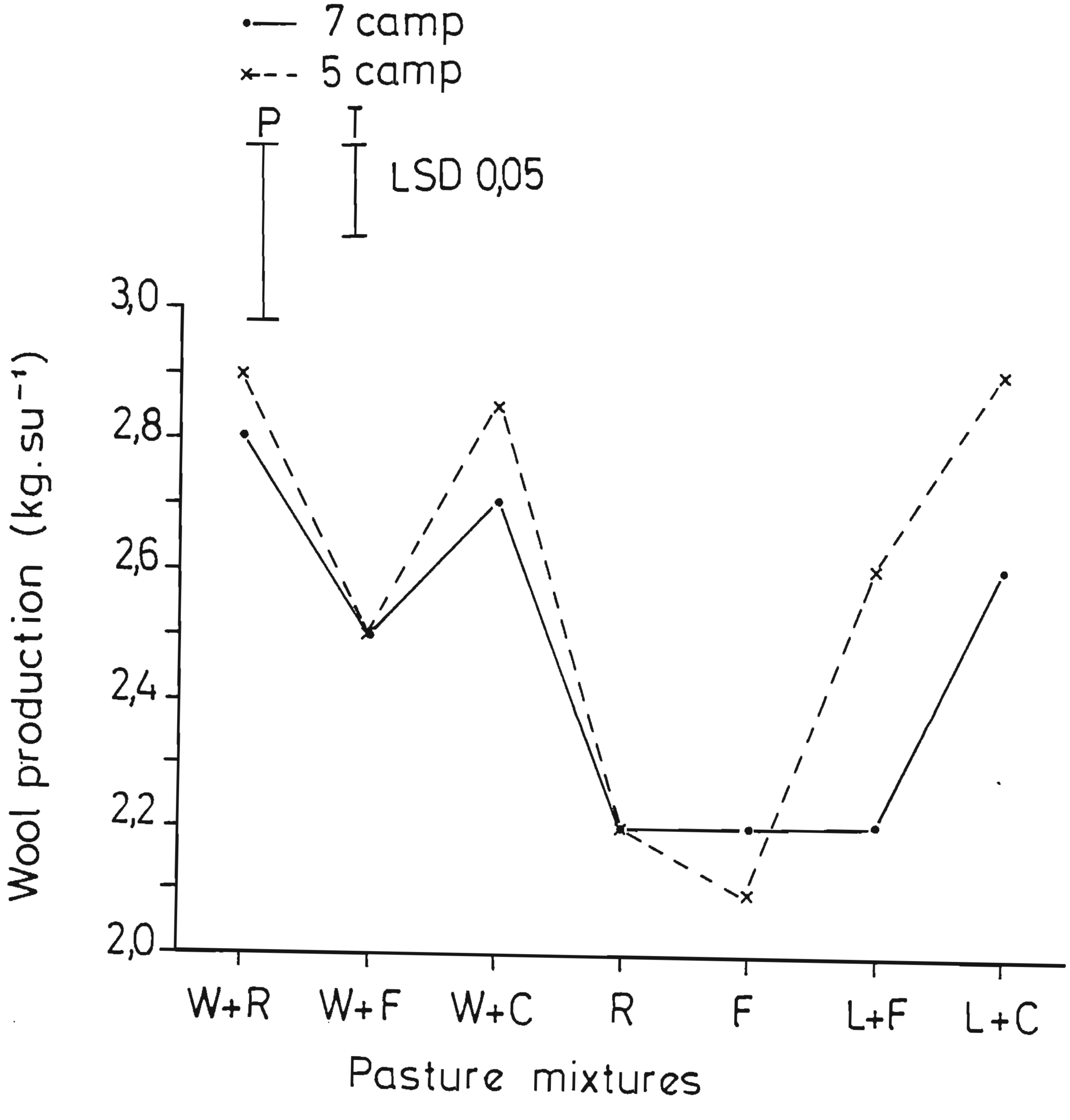


Figure 4.48 Wool production per tester animal ($kg.SU^{-1}$) on the seven pasture mixtures (P) and under two management systems (T), i.e. a five and a seven camp system, meaned over two seasons (1983/84 to 1984/85) (W = white clover, L = lucerne, R = ryegrass, F = fescue and C = cocksfoot)



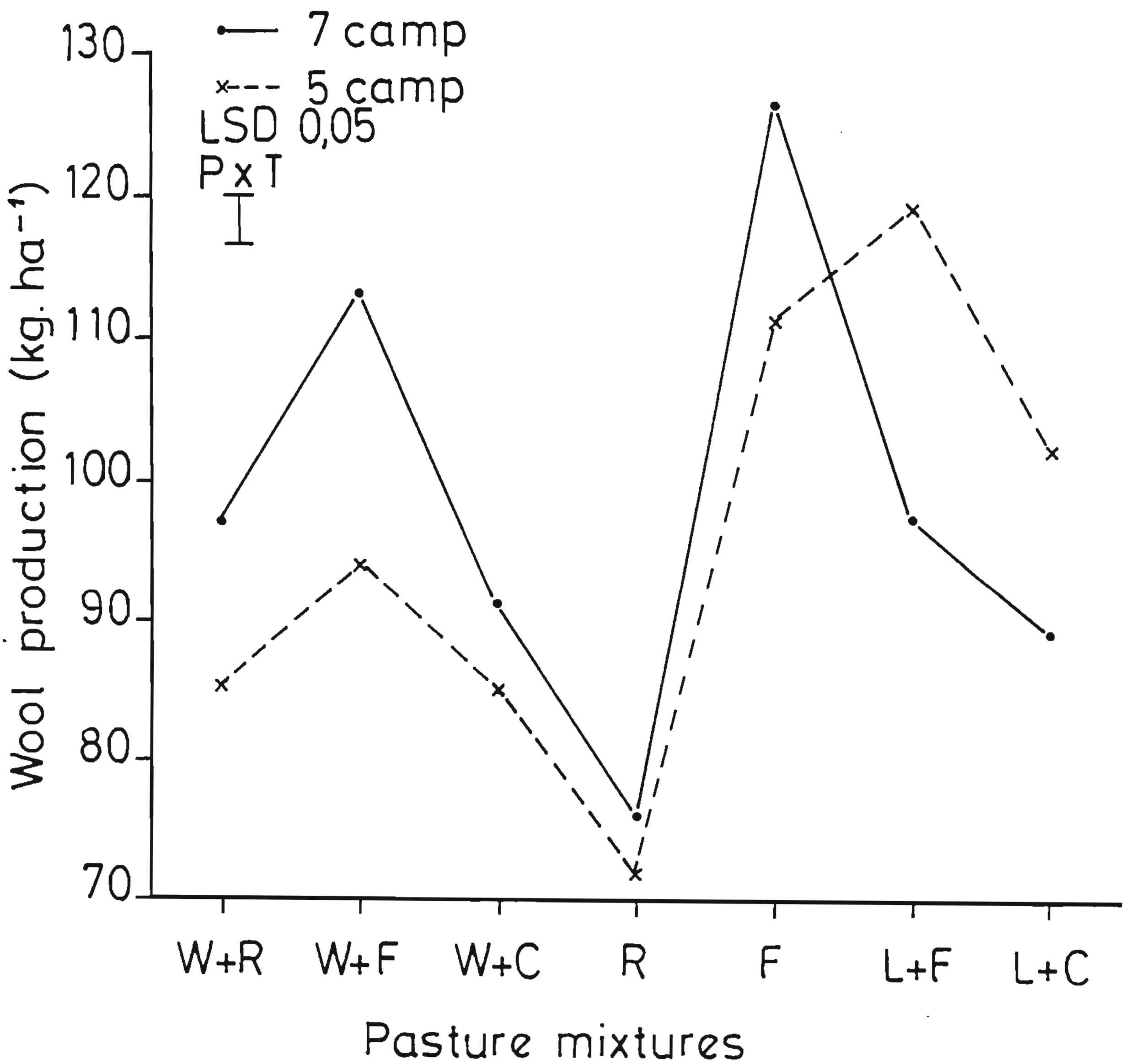
both management systems. On the lucerne plus fescue pasture, the wool production per tester was significantly higher than on the white clover plus fescue pasture on the five camp system, while the yield on the seven camp system was equal to that of the pure grass pastures.

The mean annual wool production per hectare ($kg.ha^{-1}$), calculated as the product of the number of $SU.ha^{-1}$ and the wool $production.SU^{-1}$, on the seven pasture mixtures and two management systems over two seasons, is depicted in figure 4.49. On the lucerne based pasture mixtures, wool production per hectare was significantly highest on the five camp system, but on the other five pasture mixtures, the production tended to be highest on the seven camp system, although it was not significantly so on the pure ryegrass pasture.

On the seven camp system, the wool production per hectare was highest on the pure fescue and lowest on the pure ryegrass pasture, and significantly so. In the case of the five camp system, wool production per hectare was, however, significantly highest on the lucerne plus fescue and significantly lowest on the pure ryegrass pasture.

On the grass/legume pastures, the wool production generally tended to be higher on those mixtures with fescue as grass component, than those with the same legume, but ryegrass or cocksfoot as grass component. The relative influence of legume component was, however, determined by grazing management. The wool production was significantly higher on the white clover than the lucerne based pastures on the seven camp system, but on the five camp system the opposite result was found.

Figure 4.49 Total wool production per hectare ($kg.ha^{-1}$) on the seven pasture mixtures (P) and under two management systems (T), i.e. a seven and a five camp system, meaned over two seasons (1983/84 to 1984/85) (W = white clover, L = lucerne, R = ryegrass, F = fescue and C = cocksfoot)



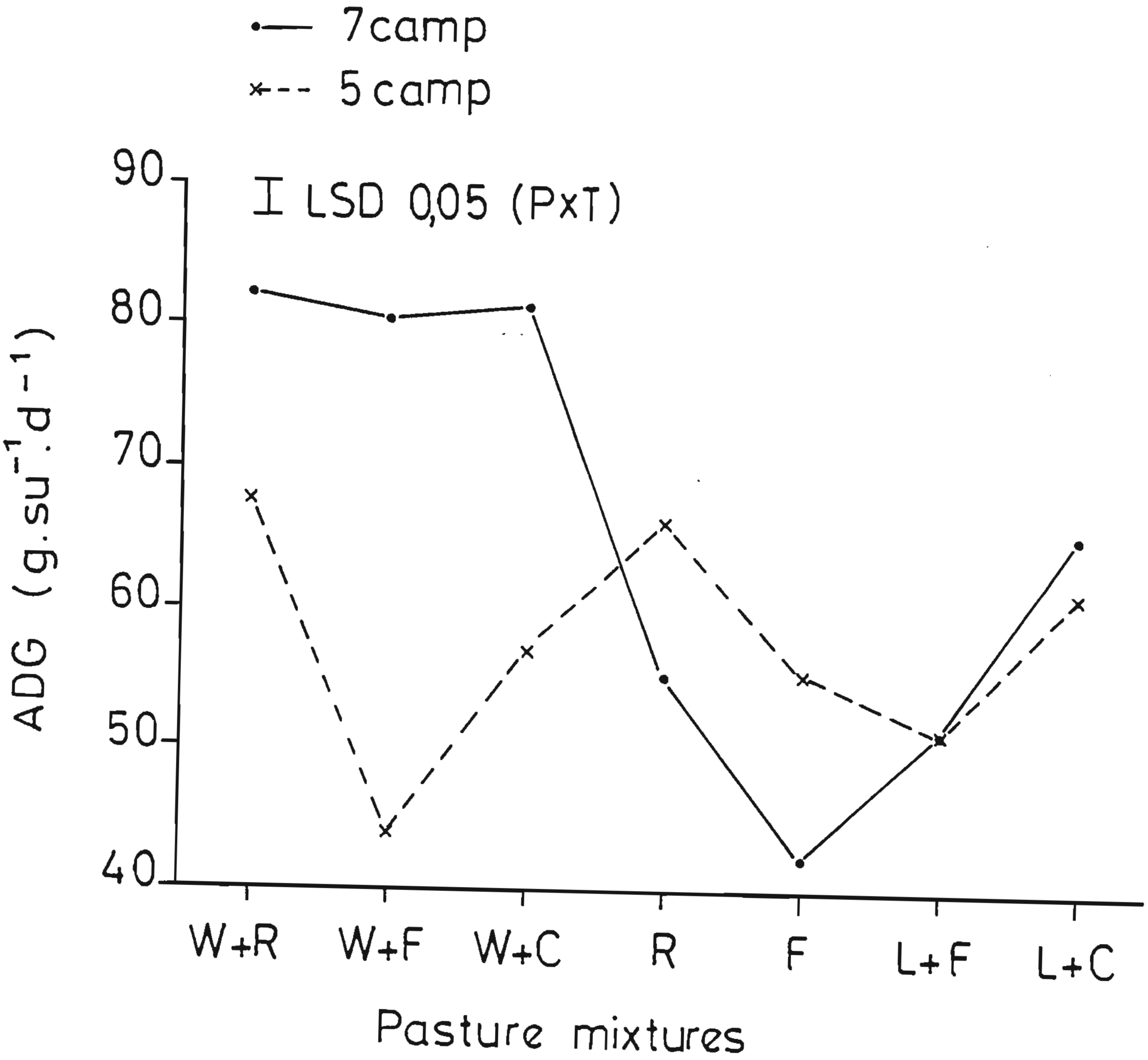
4.5.4.5 Average daily gain (ADG) and meat production

The mean annual average daily gain (ADG) per tester animal ($g.SU^{-1}.d^{-1}$) on the seven pasture mixtures and two grazing management practices, calculated over two seasons, is depicted in figure 4.50. Grazing management had no significant influence on the ADG of the tester animals on the lucerne based mixtures. On the white clover based mixtures, however, the ADG was significantly highest on the seven camp system, while the ADG was significantly lower on the latter mentioned system on the two pure grass pastures.

On the seven camp system the ADG was significantly higher on the white clover based pastures than the lucerne based pastures and generally significantly lowest on the pure fescue pasture. On the five camp system, however, the ADG was significantly highest on the ryegrass and cocksfoot based pastures and significantly lowest on the fescue based grass/legume pastures. In contrast to this, however, the ADG on the pure fescue pasture was about equal to that derived on the white clover plus cocksfoot pasture, when grazed at this system.

The mean annual meat production per hectare (i.e. total weight increase per ha x 0,47) on the different pasture mixtures and management systems, calculated over the two seasons, is depicted in figure 4.51. The response of the meat production per hectare to grazing management on the seven pasture mixtures differed quite considerably. The mean annual meat production on the white clover based pastures was significantly higher on the seven than the five camp system. On the pure fescue and lucerne plus fescue pastures, however, it was significantly higher on the five than the seven camp system, while no significant response to management system was apparent on the pure ryegrass and the lucerne plus cocksfoot pastures.

Figure 4.50 Average daily gain per tester animal ($g.SU^{-1}.d^{-1}$) on the seven pasture mixtures (P) and under two management systems (T), i.e. a seven and a five camp system, meaned over two seasons (1983/84 to 1984/85) (W = white clover, L = lucerne, R = ryegrass, F = fescue and C = cocksfoot)



The relative meat production on the different pasture mixtures differed on the two grazing management systems. On the seven camp system, the meat production was significantly highest on the white clover based pastures. On the five camp system, however, the meat production was significantly highest on the pure fescue pasture, with the values attained on the lucerne based pastures also being significantly higher than those on the pure ryegrass and white clover based pasture.

4.5.4.6 Discussion and conclusions

The seasonal production rates of the majority of the pastures tended to be lowest during winter and highest during spring and summer. This was largely reflected in the estimated grazing capacities, resulting in equally low capacities being derived during this time of the year. This finding was somewhat disappointing as none of the pastures seemed to solve the problem of the generally low winter grazing capacity of irrigated pastures. The high winter grazing capacity of fescue based pastures, as compared to pastures based on cocksfoot and even ryegrass, was, however, very heartening and indicated that pastures based on this grass should go a long way in solving this problem.

Another important finding was that the grass component of the pastures seemed to have a far greater influence on the seasonal pasture production and grazing capacity than the legume component. It was for instance found that pastures based on lucerne and white clover, with the same grass component, had basically the same production rates and grazing capacity. The fescue based pastures were subsequently found to have the highest production rates and grazing capacity during the greater part of the year.

The response of the different pasture mixtures to grazing management differed quite significantly and the results did not in all cases agree with those of the plot trials. It was for instance found that the white clover based pastures seemed to be more sensitive to grazing management than the lucerne based pastures. The legume content of all the grass/legume pastures was found to be higher on the seven camp than on the five camp system. It was also found that all the pastures, with the exception of the lucerne based pastures, had the highest production rates and grazing capacities on the seven camp system. This was clearly contrary to the results of the plot trials, which indicated that white clover would be promoted by a shorter rotation, while lucerne was not only more sensitive to length of rotation, but was also promoted by a longer period between defoliation.

The animal production response to grazing management differed on the different pasture mixtures and this resulted in a difference in the relative animal production potential of the different pasture mixtures in the five and seven camp systems. Generally the animal production potential of the white clover based pasture mixtures was found to be highest on the seven camp system, while that of the lucerne based pasture was either highest on the five camp system or did not differ between the two systems. Variable results were obtained with the pure grass pastures where wool production tended to be highest on the seven camp system, while the meat production was highest on the five camp system.

This was also contrary to the plot trial results. Based on the results of the latter mentioned trials it would have been expected that the lucerne based and pure fescue pastures would have been highest yielding in a seven camp system, and the white clover and ryegrass based pastures in a five camp system. On the contrary the results seem to indicate that a white clover based pasture in this area should be grazed only every six weeks (i.e. a seven camp system), while such a period between grazings was clearly to long for the lucerne based and in some cases also for the pure grass pastures.

The results found can perhaps be attributed to the fact that the quality of the available forage on the lucerne and grass pastures decreased more with age than that of white clover. This may subsequently have led to a lower quality pasture being produced on the first mentioned two pasture types in the seven camp system. The fact that the wool production was promoted most by a seven camp system on the pure grass pastures, can possibly be attributed to the lower sensitivity of this parameter to pasture quality, than for instance the ADG.

The results of this trial are, however, of preliminary nature only, as they were the product of only two seasons work. Problems with the application of the grazing pressures may also have had an influence on the results. As the pasture types differed quite largely in palatability, and therefore in level of utilisation at the same grazing pressure, this factor could very well have influenced the results. It was for instance very evident that the fescue based pastures were extremely unpalatable and they were therefore generally under-utilised in the longer rotations, resulting in a lower quality pasture developing with each successive grazing.

Generally, however, the results seemed to indicate that white clover based pastures with fescue as main grass component, and preferably grazed every six weeks (i.e. a seven camp system), would be the highest producing pasture under irrigation in this area. Observations during the trial, however, indicated that a cutting treatment after the spring and summer flush period and preferably just before winter would have to be introduced. This is necessary, as levels of utilisation which would be optimal for the clover component would lead to severe under-utilisation of the fescue component and lead to a very low quality pasture developing, unless it were completely defoliated at least once every year.

4.5.5 Development of a general relationship between stocking rate and animal production

4.5.5.1 Introduction

One of the very first, and also one of the best known, mathematical representations of the general relationship between stocking rate and animal production is that of Mott (1960). This model postulated a modified exponential relationship between production per animal unit and stocking rate. Subsequent workers, such as Owen & Ridgman (1968); Cowlishaw (1969) and Conniffe, et al. (1970), however, found that a linear relationship existed between stocking rate and production per animal unit, at stocking rates beyond a certain maximum value. None of these models, however, found wide application. Jones & Sandland (1974) subsequently developed a similar relationship, which is at present widely used to describe animal production:stocking rate relationships on natural grasslands (Edwards, 1980; Danckwerts & King, 1984), as well as on established pastures (Bransby, 1984) in South Africa.

The results found in trials 1 and 3, however, indicated some degree of non-linearity in the response of per animal production, to change in stocking rate. It was therefore possible that the Jones & Sandland (1974) model was not directly applicable to the complex grass/legume mixtures which had been evaluated. The wool production and ADG statistics derived in trials 1 and 3 were therefore pooled and used to evaluate the latter mentioned model.

4.5.5.2 Results

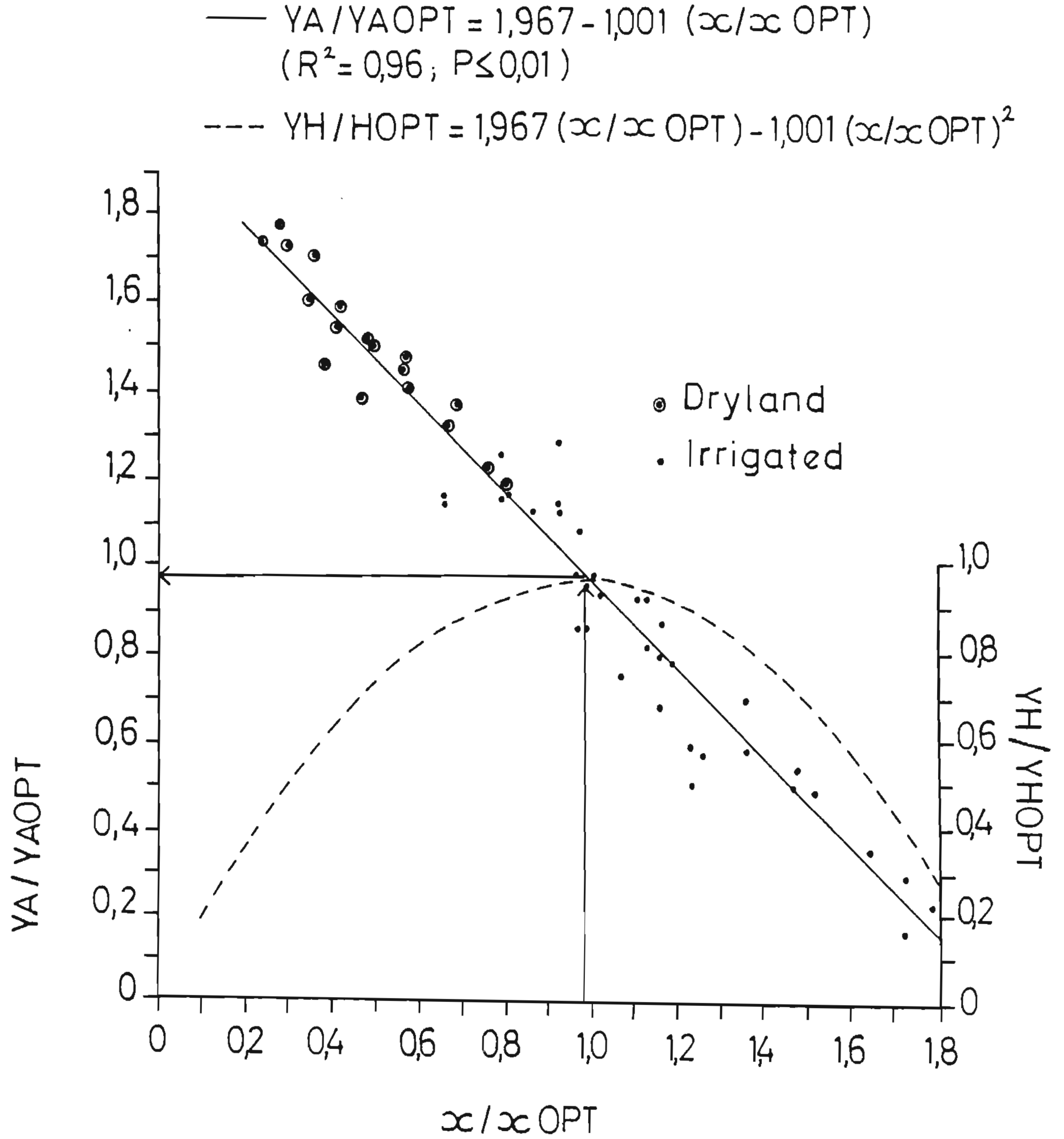
The relationship between the production per animal (wool and ADG) divided by the per animal production at the calculated optimum stocking rate ($Y_A.Y_{AOPT}^{-1}$), was subsequently plotted against the stocking rate divided by the optimum stocking rate ($X.X_{OPT}^{-1}$), for the results derived in trials 1 and 3. This relationship is depicted in figure 4.52.

It is clear from figure 4.52 that a highly significant negatively linear relationship exists between the two parameters. The linear model describing this relationship, i.e. $Y_A.Y_{AOPT}^{-1} = 1{,}967 - 1{,}001(X.X_{OPT}^{-1})$, was almost identical to the general relationship found by Jones & Sandland (1974), i.e. $Y_A.Y_{AOPT}^{-1} = 1{,}999 - 0{,}999(X.X_{OPT})$. The relationship between the production per unit area divided by the production at the optimum stocking rate ($Y_H.Y_{HOPT}^{-1}$) and the stocking rate divided by the optimum stocking rate ($X.X_{OPT}^{-1}$), is also depicted in figure 4.52 and also agrees very well with the corresponding model derived by Jones & Sandland (1974).

4.5.5.3 Conclusions

From the results it was clear that the Jones & Sandland (1974) model was indeed applicable to the results of trials 1 and 3, in so far a similar linear relationship was derived. However, it is clear that the data derived under irrigation (trial 3), generally fall beyond the optimum value of $X.X_{OPT}$, while data derived under dryland (trial 1), fall below this value. This seems to indicate that the stocking rate for maximum animal production per hectare derived under dryland, was to high. This substantiates the

Figure 4.52 Relationships between the ratio: stocking rate (X)/optimum stocking rate (X_{OPT}) for maximum animal production per hectare, and the ratios: production per animal (Y_A)/production per animal at X_{OPT} (Y_{AOPT}) and production per hectare (Y_H)/production per hectare at X_{OPT} (Y_{HOPT})



conclusions arrived at when the results of this trial were discussed (trial 1; section 4.5.1.4).

The afforementioned, therefore, seem to indicate that the Jones & Sandland (1974) method is not foolproof and will overestimate the optimum stocking rate for maximum animal production per hectare under certain conditions. This seems to be the case under conditions of low sensitivity of animal production to stocking rate such as; in some long-term trials and under dryland conditions. In both these situations, the availability and quality of available grazing material fluctuates quite widely (trial 1; sections 4.5.1.2 and 4.5.1.3). Under conditions such as these this method could lead to the overestimation of the optimum stocking rate for maximum animal production per hectare. In short term trials, as well as under conditions of reasonably uniform forage supply and quality, such as encountered under irrigation (trial 3; sections 4.5.3.2.3 and 4.5.3.2.4), however, this method is very successful, but also only in cases where the grazing animals are responsive enough to changes in stocking rate.

5 PRELIMINARY SIMULATION OF THE GRAZING CAPACITY AND ANIMAL PRODUCTION POTENTIAL OF PASTURES CONSISTING OF PURE STANDS AND TWO-SPECIES MIXTURES OF THE SPECIES EVALUATED

5.1 Introduction

The objective of this part of the study was the integration of the climate:pasture production models based on the results of the plot trials (discussed in chapter 3) with the pasture:sheep production relationships, derived in the four grazing trials (discussed in chapter 4). Initially an attempt was made to use linear programming techniques for the integration of the pasture production curves with the dry matter requirements of different sheep production systems at a number of sites. The results of the grazing trials, however, not only clearly indicated that the pasture species evaluated differ in dry matter production potential, and therefore in grazing capacity, but also that legumes and grasses differ in their animal production potential per unit dry matter, i.e. quality. As the data of the grazing trials dit not provide an adequate basis for the quantification of these quality differences, the application of linear programming tecniques was not possible. The only other solution was to attempt to develop a climate:pasture:animal production model.

The model which was eventually developed not only incorporated the derived climate:pasture production models, but also functions depicting the relationship between the legume content of the pastures and their wool and meat production potential (discussed in chapter 4). It also makes provision for the integration of anything from a minimum of one to a maximum of 15 possible pasture mixtures on a single farm.

The choice of possible species is made by the model, based on climatic and other input data such as soil potential (high or low potential soils under irrigation and wet or well drained soils under dryland or in low potential irrigated soils) and the availability or non availability of adequate irrigation water. These data are either read from a file or supplied interactively. The model subsequently provides a list of possible species for each situation, from which combinations of species can be chosen and pasture mixtures compiled. The pasture production potential of a specific mixture is subsequently calculated as the mean of its component species. The contribution of a specific species is calculated as proportional to its contribution to the mixture as a whole. The legume content of the monthly production of each pasture, which has to be known to enable the calculation of its animal production potential, is therefore calculated as the sum of the percentage contribution of its component legumes.

The model also provides for the manipulation of certain animal management factors, such as the lambing time (during six different months), and the lambing and weaning percentages. By making use of data derived from literature (Rattray & Jagusch, 1978) on the dry matter requirements of grazing sheep during different gestation stages, as well as making assumptions on the efficiency of pasture utilisation by grazing sheep, the model estimates the mean grazing capacity and wool and meat production for different pastures, as well as on a whole farm basis. The model presently only provides for the use of an all wool or Merino type of sheep. The reason for this is that the majority of the results of the grazing trials were derived, using Merino's and that the results on this type of sheep would therefore be more reliable.

The mean annual grazing capacity of the whole farm is calculated on the basis of the annual mean monthly dry matter production of all the pastures. The animals are then allocated to each pasture on a monthly basis in numbers proportional to the contribution of each pasture to the whole farm's mean monthly grazing capacity. The animal production on each pasture is calculated as a function of the number of animals grazing it, the legume content of the pasture and a factor indicating the over or under availability of dry matter (dry matter stress) on the particular pasture. The animal production potential of the whole farm is then calculated as the sum of the per annum grazing capacity and animal production potential of all the pastures on the farm.

By incorporating data on the mean fertiliser requirements of the pastures, based on the actual values derived from soil analysis statistics supplied by the soil science section of the Winter Rainfall Region (Beyers, pers com), the fertiliser cost of pastures consisting of varying proportions of legumes and grasses, is also calculated. The establishment cost, i.e. seed, cultivation and sowing costs, of the different pasture types were accepted as similar, and these costs were also incorporated. By further introducing a price per kg for the meat and wool produced, the derivation of a gross margin per unit area is possible. It must, however, be kept in mind that the cost and income factors can be manipulated and should therefore not be seen as constant, but variable and dependent on current price structures.

5.2 <u>Model structure</u>

The model consists of six subroutines, i.e. CLIMAT, SOIL, POTEN, CHOICE, COMBS and ANIMAL. The subdivision of the model into subroutines increased its memory and computer time efficiency considerably. The functions for each of the six subroutines are as follows:

(i) CLIMAT

This subroutine reads climatic data from a file and recalculates some of the data to a form more acceptable to the climate:pasture models. The climatic input consists of the following mean monthly values: total rainfall, daily pan evaporation (converted by the program to total monthly values), mean temperature and daily sunshine hours. The mean daily sunshine hours has to be recalculated to total daily radiation (Q_{TOT}) values, using the function discussed in chapter 3. For this purpose the values depicted in table 3.1 are supplied as a data listing within the program.

(ii) SOIL

This subroutine prompts the user for details on the utilisation of the soil for the different pasture types. It makes provision for five different situations which are, as has already been indicated, based on soil potential and whether it is dryland or irrigated, as well as on the amount of available irrigation water. It makes provision for the following aspects:

- size of the farm;
- dryland, with a poorly drained or wet soil;
- dryland, with a well drained soil;
- irrigated, with a high potential soil;
- irrigated, with a low potential and poorly drained soil;
- irrigated, with a low potential, well drained soil;
- available irrigation water in $mm.week^{-1}$.

It further calculates the total area of the farm as the sum of its components and checks it against the area which had been supplied at the first prompt.

(iii) POTEN

This subroutine calculates the mean monthly production potential, as kg $DM.ha^{-1}.M^{-1}$, of each of the five legumes, lucerne, medics and subterranean, white and red clover, as well as the six grasses, fescue, cocksfoot, kikuyu, Phalaris and annual and perennial ryegrass for each of three situations, i.e. a dryland and a high and a low potential irrigated situation. The models discussed in chapter 3 are generally applied as such, with the output of CLIMAT as input. In chapter 3, however, it was noted that the production potential of annual species, such as subterranean clover, medics and annual ryegrass, was generally overestimated during summer, i.e. the period December to February, and it was therefore decided to assume that the production rates of these three species is zero during this period.

(iv) CHOICE

This subroutine supplies the user with a list of possible species based on climatic and soil input data supplied by CLIMAT and SOIL. Under each of the five headings indicated under SOIL, a list of species, out of which one to three pasture mixtures can be compiled, is provided. Resulting therefore in a total of from one to 15 possible combinations of soil potential, dryland and irrigated situations which can be specified on any single farm. The list of possible species is based on the following: under dryland and irrigation, the soil potential specified in SOIL; under dryland, the length of the effective growing season, as calculated by subroutine INDEX; and, under irrigation, the amount of irrigation water available. The possible choices under dryland are indicated in table 5.1

(v) INDEX

This subroutine calculates the indices used in CHOICE and depicted in table 5.1. They are calculated as $R.(E.F)^{-1}$, where R = total monthly rainfall(mm), E = total monthly pan evaporation(mm) and F = a constant, having values as indicated in table 5.1.

(vi) COMBS

This subroutine calculates the monthly production of each pasture mixture in Kg $DM.ha^{-1}.M^{-1}$, using the output of POTEN. As has already been indicated, the production of each combination of species, i.e. pasture, is calculated as the mean of its component species. In order to make provision for the efficiency of pasture utilisation two factors, one for irrigated (0,9) and one for dryland (0,6) situations, are employed. These factors are used as multipliers to reduce the total monthly pasture production and calculate the effective pasture production. The two factors differ from the 0,85 proposed by Rattray & Jagusch (1978).

(vii) ANIMAL

This subroutine uses the output of COMBS and calculates the grazing capacities, the wool and meat production on each pasture, as well as for the whole farm, and calculates the gross margin for the whole farm. It reads a file of data on the seasonal dry matter requirements of ewes and lambs at different stages of gestation. Data on six possible lambing seasons (March, April, May, August, September and October), as well as on lambing times and weaning percentages, are

TABLE 5.1 INDICES USED BY CHOICE FOR THE SELECTION OF POSSIBLE DRYLAND SPECIES

LOOPS	**INDEX	F	PERIOD	SPECIES*
IF	> 0,40	1	JAN TO DEC	LUC, SUB, WHI, RED, FESC, COCK, PHAL, PRYE, ARYE, KIK
ELSE IF	> 0,30	1	JAN TO DEC	LUC, SUB, RED, FESC, COCK, PHAL, PRYE, ARYE, KIK
ELSE IF	> 0,14	0,5	NOV TO FEB	LUC, MED, SUB, FESC, COCK, PHAL, ARYE
IF	> 0,30	0,5	APR TO OCT	LUC, MED, SUB, FESC, COCK, PHAL, ARYE
ELSE IF	> 0,22	0,5	MAY TO SEPT	LUC, MED, FESC, COCK, PHAL, ARYE
ELSE	≤ 0,22	0,5	-	LUC, FESC, COCK, PHAL
ELSE IF	> 0,11	0,5	NOV TO FEB	
ELSE IF	> 0,30	0,5	APR TO OCT	LUC, SUB, MED, PHAL, ARYE
ELSE IF	> 0,22	0,5	MAY TO SEPT	LUC, MED, ARYE
ELSE	≤ 0,22	0,5	-	NONE
ELSE	> 0,30	0,5	APR TO OCT	MED, SUB, ARYE
ELSE IF	> 0,22	0,5	MAY TO SEPT	MED, ARYE
ELSE	≤ 0,22	0,5	-	NONE

* LUC = Lucerne
SUB = Subterranean clover
MED = Medics
RED = Red clover
WHI = White clover
FESC = Fescue
COCK = Cocksfoot
PHAL = Phalaris
PRYE = Perennial ryegrass
ARYE = Annual ryegrass
KIK = Kikuyu

**INDEX = $R.(E.F)^{-1}$ where R = total monthly rainfall (mm), E = total monthly pan evaporation (mm) and F = as indicated in table.

supplied interactively. By combining these data with those on the dry matter requirements, the monthly dry matter requirements of a mean sheep unit is calculated and used to calculate the mean annual grazing capacity of the farm. The data on the monthly dry matter requirements of ewes and lambs used by the model are depicted in table 5.2.

The number of mean annual ewe-units (EU) per hectare of the farm are allocated to all the pastures in numbers proportional to the contribution of each pasture to the total dry matter production of the whole farm. This subroutine also calculates the legume content of each pasture mixture as well as the proportional dry matter availability. The latter factor is calculated as the ratio of the total available dry matter on the pasture to the dry matter requirement of the animals allocated to it. To be effective the factor is dimensionless with values between 0 and 1 and all values greater than 1 are therefore taken as being equal to 1. The relationships between the monthly wool and meat production of merino sheep and the legume content of the pastures, are depicted in figure 5.1.

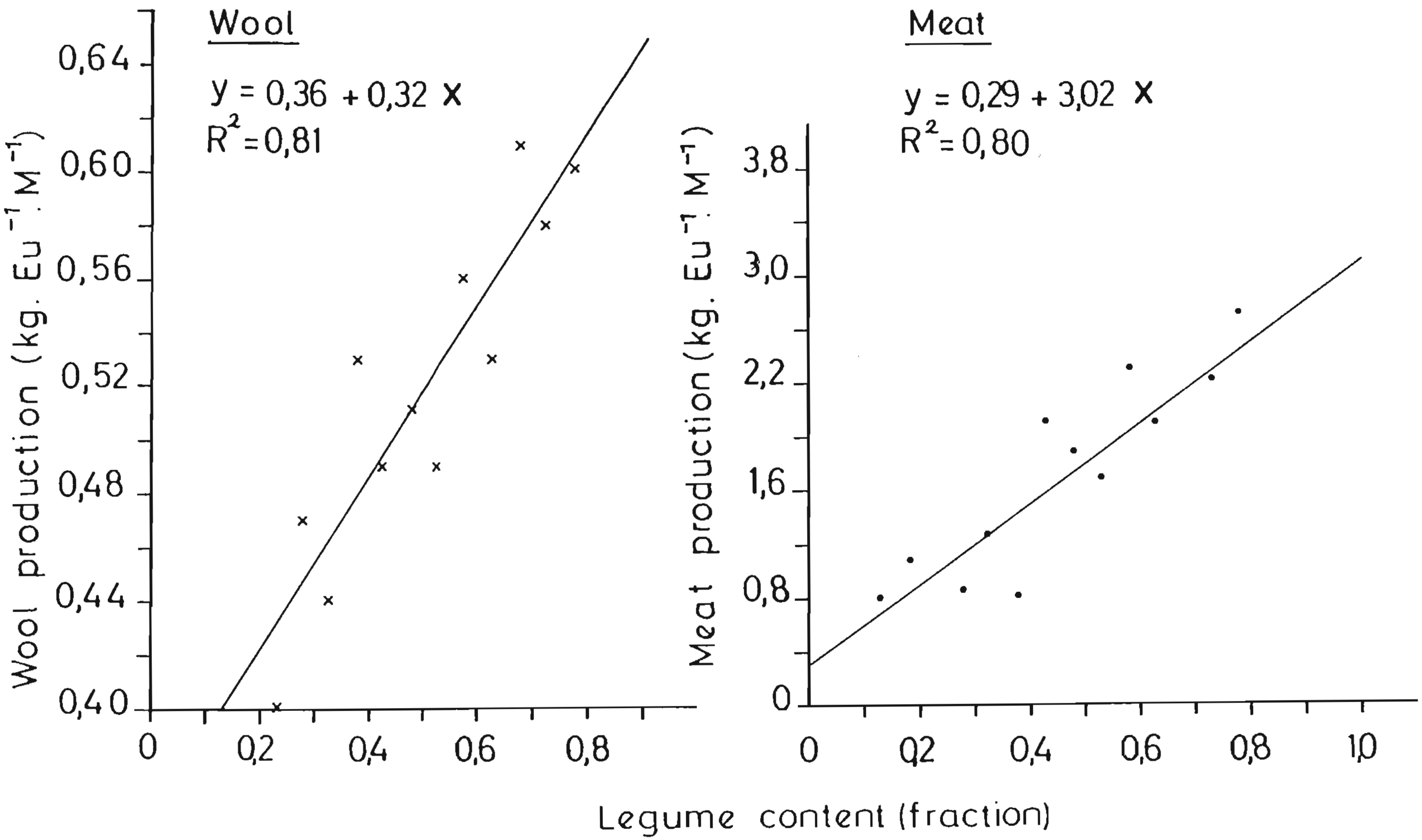
These two functions were derived from the data of trials 1 and 3. The mean monthly wool and meat production on a specific pasture is subsequently calculated as a function of the grazing capacity, the legume content and the dry matter stress. The total annual animal production on all the pastures is further calculated as the sum of the monthly production of all the component pastures.

The relative gross margin per hectare is subsequently calculated, using the present mean wool (R4-40.kg^{-1}) and meat (R3-00.kg^{-1}) prices, as well as fertiliser and establishment (R200.ha^{-1}) costs. The cost of irrigation is, however, not taken into consideration and therefore the relative gross income has to be adjusted by this figure

TABLE 5.2 THE SEASONAL DRY MATTER REQUIREMENT (KG.EU.$^{-1}$M^{-1}) OF MERINO EWES AND LAMBS FOR SIX DIFFERENT LAMBING SEASONS

Month	Ewe Requirement	Lamb requirement (for each lambing season)					
		March	April	May	September	October	November
January	38	8	0	0	0	38	32
February	38	11	8	0	0	0	38
March	38	16	11	8	0	0	0
April	38	21	16	11	0	0	0
May	38	27	21	16	0	0	0
June	38	32	27	21	8	0	0
July	38	38	32	27	11	8	0
August	38	0	38	32	16	11	8
September	38	0	0	38	21	16	11
October	38	0	0	0	27	21	16
November	38	0	0	0	32	27	21
December	38	0	0	0	38	32	27

Figure 5.1 General relationships between the legume content (e.g. 0,1 = 10%) of the pasture material and the wool and meat production per ewe-unit (EU) used in the model



depending on the type of irrigation system used. The fertiliser cost of each pasture also varies according to the mean annual legume content (MLEG) thereof. The cost of N fertilisation (NCOST, units = $R.ha^{-1}$) is calculated by the following functions:

NCOST(dryland) = 220 - 1100MLEG and
NCOST(irrigated) = 420 - 2100MLEG for values of MLEG $\leq$ 0,20.

The total cost of fertilisation ($R.ha^{-1}$), incorporating P, K and lime, is subsequently calculated as:

- dryland situations;
  - (a) where MLEG $\leq$ 0
    - SAND(on sandy soils) = NCOST + 68
    - SHALE(on shale soils) = NCOST + 55
  - (b) where MLEG > 0
    - SAND = NCOST + 120
    - SHALE = NCOST + 95

- irrigated situations;
  - (a) where MLEG $\leq$ 0
    - SAND = NCOST + 90
    - SHALE = NCOST + 65
  - (b) where MLEG > 0
    - SAND = NCOST + 155
    - SHALE = NCOST + 105

A factor for cost per animal (R8) was also added and used to calculate the animal cost per unit area (ACOST, units = $R.ha^{-1}$) as ACOST = CARRY * 8, where CARRY = mean grazing capacity of the whole farm.

5.3 Validation

The model was validated by comparing its results with those of trials 1; 3 and 4. The actual data used for validation however, had certain limitations, which will be briefly discussed. Firstly, while both trials 3 and 4 supplied data representing irrigated situations, only trial 1 supplied usefull data representing a dryland situation. It was therefore not possible to test the model under more dryland situations. Under irrigation only the data of trial 3 could be used for validation. The reason for this is that the model presently makes provision for the analysis of different ewe plus lamb (EU) systems only and does not take the ADG of the ewe into consideration. In spite of this shortcoming, the grazing capacity in terms of dry $EU.ha^{-1}$, i.e. $SU.ha^{-1}$ can, however, be calculated. The data of the first part of trial 3 and also that of trial 4, were therefore used for the determination of the accuracy by which the model predicts the grazing capacity in terms of $SU.ha^{-1}$ under irrigation.

A further problem is the fact that, as has already been discussed in chapter 4, the data supplied by trial 1 does not allow the determination of a realistic grazing capacity under dryland. By applying the Jones & Sandland (1974) model to these data the grazing capacities were greatly overestimated. This can largely be attributed to the large seasonal variation in available grazing material and also the fact that the mean annual grazing capacity was estimated, rather than that for shorter periods. A different approach was therefore adopted, by which it was possible to estimate more realistic grazing capacities under dryland.

A third problem, is the fact that the model makes certain assumptions as far as the botanical composition is concerned. It was therefore very difficult to simulate the animal production potential of a pasture accurately for situations where;

- pasture mixtures consisted of more than two species, and

- uncontrolled changes occurred in the botanical composition, e.g. under dryland due to the increase of volunteer grass and broad leaved weeds and under irrigation due to the gradual decrease in legume content with age of the pasture.

The final limitation is that the model makes provision for the limitations imposed on animal production by a limited supply in available grazing material during certain times of the year, but does, however, not make provision for the incorporation of some measure of the degree of annual variation in available dry matter or a risk factor during certain times of the year. The selection of a certain lambing season(/s) is based on only the mean annual dry matter availability, and the model does not take possible limitations, due to unreliable rainfall patterns, into consideration.

5.3.1 Dryland

The data of trial 1 was compared with the values predicted by the model, the results of which are depicted in tables 4.8 and 4.10 and figures 4.11 and 4.14. The results are presented in tables 5.3 and 5.4.

In this comparison, two major problems came to the fore. Firstly, making the correct assumptions on the botanical composition of the pastures included in the model was difficult. As indicated in previous sections, the botanical

TABLE 5.3 COMPARISON OF PREDICTED AND ACTUAL VALUES OF GRAZING CAPACITY ($EU.HA^{-1}$) UNDER DRYLAND AT TYGERHOEK, USING DATA DERIVED IN TRIAL 1 AND CLIMATIC DATA DERIVED DURING THIS TRIAL (1979-1984)

Pasture type	Predicted	Actual			
		*Based on wool yield		*Based on meat yield	
		Jones & Sandland	Maximum per animal	Jones & Sandland	Maximum per animal
Lucerne	7,1	10,5	5,5	14,4	6,0
Lucerne plus ann. ryegrass	7,9	-	-	-	-
Medic	4,7	8,5	5,4	16,9	4,9
Medic plus ann. ryegrass	4,6	-	-	-	-

* Optimum calculated on basis of wool and meat yields by applying either the Jones & Sandland (1974) concept or taking the optimum as being equal to the highest stocking rate at which the production (meat or wool) per EU is still at a maximum.

TABLE 5.4 COMPARISON OF ACTUAL AND PREDICTED VALUES OF WOOL AND MEAT YIELD PER HECTARE UNDER DRYLAND CONDITIONS AT TYGERHOEK, USING DATA DERIVED IN TRIAL 1 AND CLIMATIC DATA DERIVED DURING THIS TRIAL (1979 TO 1984)

Pasture type	Wool yield ($kg.ha^{-1}$)			Meat yield ($kg.ha^{-1}$)		
	Predicted	*Actual		Predicted	*Actual	
		Jones & Sandland	Maximum per animal		Jones & Sandland	Maximum per animal
Lucerne	42	51	39	60	1051	57
Lucerne plus ann. ryegrass	44	-	-	37	-	-
Medic	24	38	32	76	1862	45
Medic plus ann. ryegrass	20	-	-	42	-	-

* Optimum calculated on basis of grazing capacities in table 5.

composition of dryland pastures is very labile and the pastures mostly contained large proportions of volunteer grass and broad leaved weed species. In an attempt to solve this problem, pure lucerne and medic pastures, as well as mixtures of the two legumes with annual ryegrass were used in the simulation.

Secondly, the problem existed of calculating the correct values for actual grazing capacity from the trial data. The actual grazing capacities (table 5.4) were, therefore, calculated in four different ways, i.e. based on wool, as well as meat yield and, within each, by either using the Jones & Sandland (1974) method or a method based on the maximum production per animal. This latter approach entailed the fitting of two curves to the data representing the relationship between the stocking rate and the production per animal. The first (A) comprised the horizontal line representing the animal response to stocking rate at low rates, i.e. those levels at which the slope of the relationship was either zero, positive or only slightly negative (lines A and C in figure 4.11 and line B in figure 4.14). The second line (B) represented the relationship between the production per animal and the stocking rate over the range of stocking rates at which a clear response was evident (lines B and D in figure 4.11 and lines A and C in figure 4.14). The highest stocking rate at which the production per animal was still maximal, was then derived as the rate at which function A and function B intercept. This method was used to calculate the corresponding wool and meat yields by applying the Jones & Sandland (1974) model to function B (lines B and D in figure 4.11 and lines A and C in figure 4.14). The main problem was that the functions depicting the relationship between stocking rate and meat production on the lucerne pastures (line A in figure 4.14) did not indicate a horisontal line over the lowest stocking rates, when the lowest rate was taken into consideration.

The lowest rate was therefore eliminated and a line fitted between the second and third lowest rates for the purpose of deriving function A.

The results in tables 5.3 and 5.4 clearly indicated that the capacities based on the Jones & Sandland (1974) method were much higher than those predicted by the model. The data of the model, however, agreed much more closely with those of the capacities based on the maximum production per animal, particularly when using the meat production as indicator of animal response. The inclusion of annual ryegrass with either medics or lucerne had very little influence on the predicted wool yield, but decreased the meat yield. The wool yield was sligthly underestimated on the lucerne, but overestimated on the medic pastures.

5.3.2 Irrigated

The seasonal grazing capacities determined in trials 3 and 4 were compared to the values estimated by the model, using the climatic data derived during the trials, as input. These results are depicted in figures 5.2 to 5.6. In all cases the seasonal trends of the two sets of data were significantly correlated. The main difference between the two sets of data, was in the absolute values at any time. This can be attributed to the fact that both the predicted and the so called actual values were in fact estimated values, which could be manipulated by varying the grazing pressures (in the grazing trials) or by changing the assumptions on the dry matter requirements and/or efficiency of pasture utilisation (in the model).

The second difference was due to a time lag effect. This can be attributed to the fact that the estimated grazing capacity during a specific month was mostly the result of the growth which had taken place during the previous month.

Figure 5.2 Comparison of the actual (A) and predicted (P) monthly grazing capacity ($SU.ha^{-1}$) of an irrigated grass/legume pasture at Tygerhoek (actual values are those derived at a grazing pressure of 2,25 kg $DM.SU^{-1}.d^{-1}$)

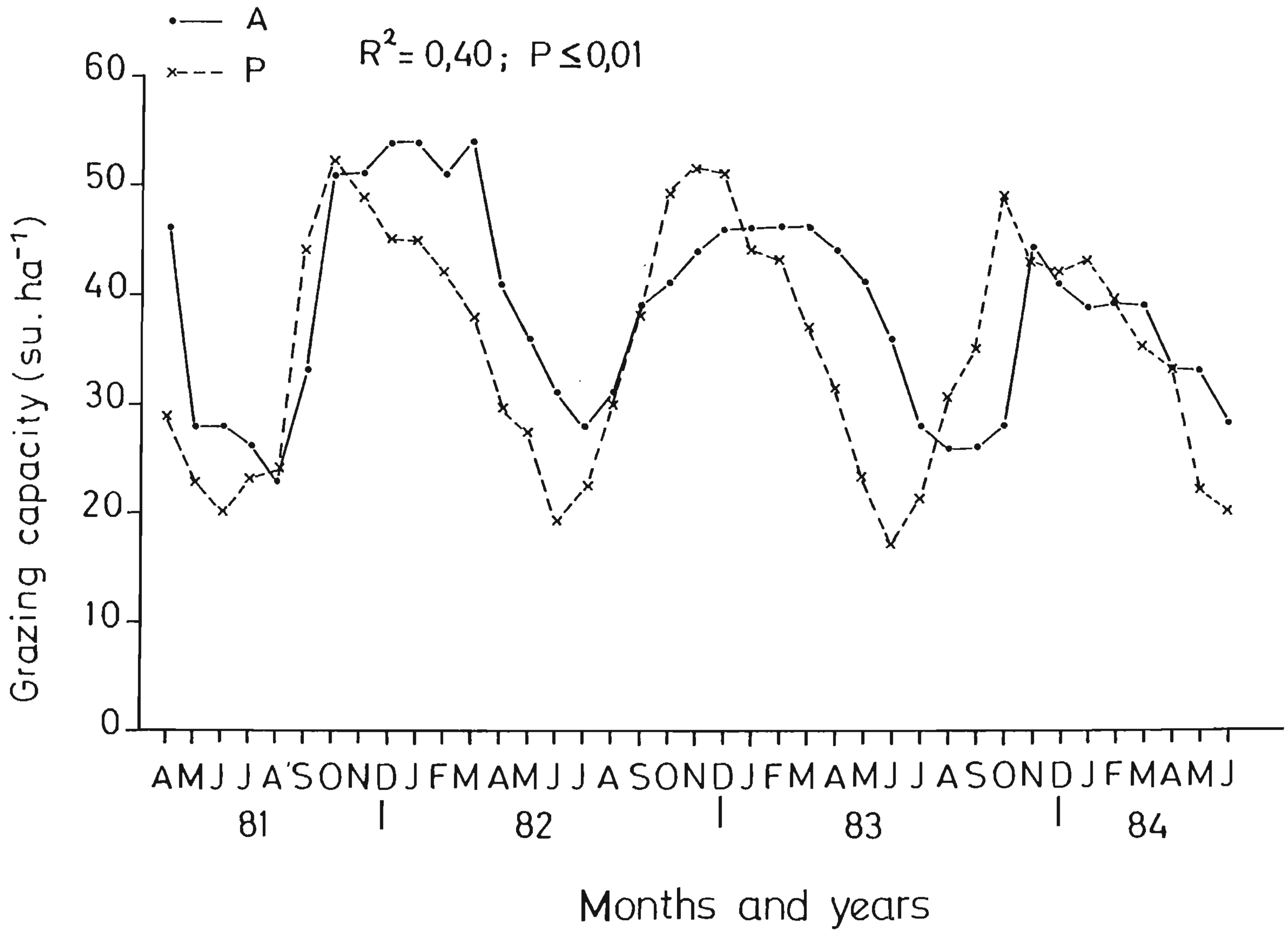


Figure 5.3 Comparison of the actual (A) and predicted (P) grazing capacity ($SU.ha^{-1}$) of an irrigated white clover plus ryegrass pasture at Outeniqua

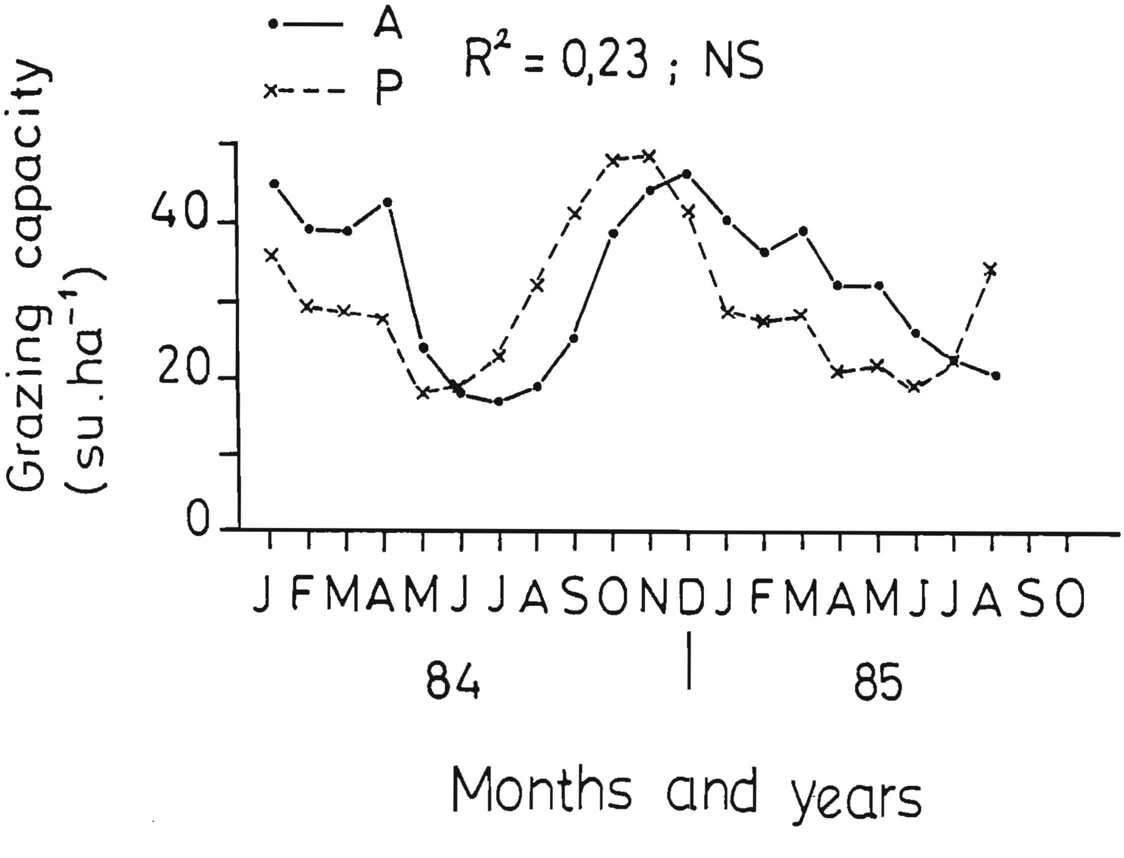


Figure 5.5 Comparison of the actual (A) and predicted (P) grazing capacity ($SU.ha^{-1}$) of an irrigated lucerne plus fescue pasture at Outeniqua

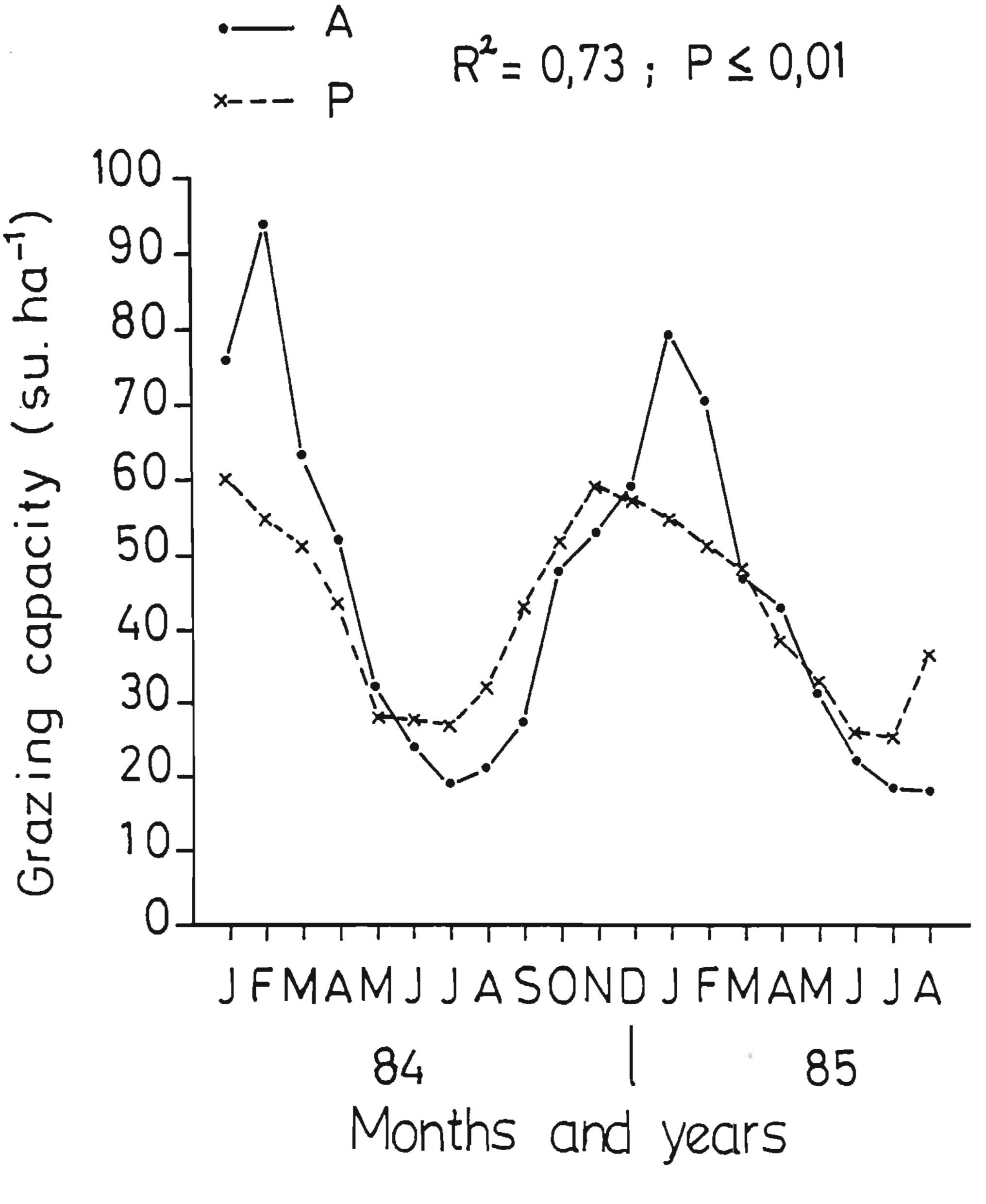
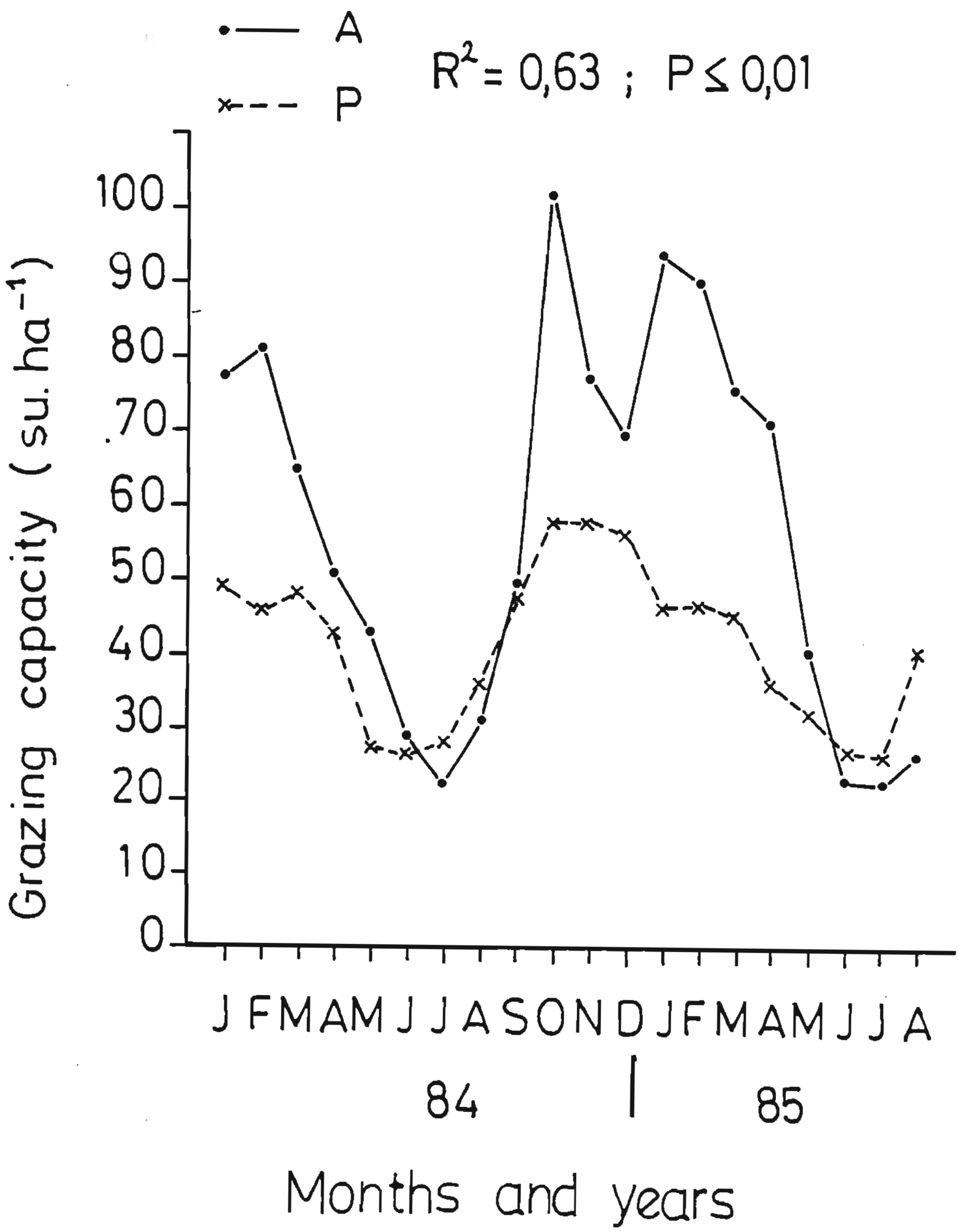


Figure 5.6 Comparison of the actual (A) and predicted (P) grazing capacity ($SU.ha^{-1}$) of an irrigated fescue pasture at Outeniqua



The model, however, estimates the grazing capacity instantaneously. The actual values therefore lag sligthly behind the predicted values and this resulted in some of the low correlations.

In all cases the estimate for the high potential soils fitted the actual data for Tygerhoek and Outeniqua the best. This can be attributed to two possible factors; in the first place the soils at the two sites could indeed have been of a higher potential than had been expected, or secondly the assumptions on the dry matter requirements of the grazing animals could have been too high. Due to the success of the model in the estimation of other aspects of animal production, which will be discussed later, the first mentioned factor seems to be the most probable. Another probable factor could have been that the grazing pressures applied in both trial 3 and 4 were too high. The actual data used in figure 5.2 were, however, those which had been derived at the medium, and therefore the most effective grazing pressure. The grazing pressures at Outeniqua (trial 4) were, however, mostly very high and it can therefore safely be concluded that this could have been a contributing factor at this site.

The output of the model was also compared with that of the second part of trial 3, i.e. the ewe plus lamb system. The results used, were those depicted in tables 4.12 and 4.13 and figures 4.34; 4.35; 4.38 and 4.39. The results of the comparison are depicted in table 5.5. As in the case of the determinations of the seasonal grazing capacities, it was found that the values estimated for a low potential soil were much lower and those for a high potential soil reasonably similar to the actual values. As the trial at Tygerhoek (trial 3) was laid out on a very deep Glenrosa soil, it can perhaps be assumed that this soil is indeed of a high potential.

TABLE 5.5 COMPARISON OF PREDICTED AND ACTUAL VALUES OF GRAZING CAPACITIES ($EU.HA^{-1}$) AND WOOL AND MEAT YIELDS UNDER IRRIGATION AT TYGERHOEK USING DATA OF TRIAL 3 AND CLIMATIC DATA DERIVED DURING THIS TRIAL (1981-1984)

<table>
<tr><th rowspan="2">Source of data</th><th colspan="2">Grazing capacity ($EU.ha^{-1}$)</th><th rowspan="2">Wool yield ($kg.ha^{-1}$)</th><th rowspan="2">Meat yield ($kg.ha^{-1}$)</th></tr>
<tr><th>*Wool</th><th>**Meat</th></tr>
<tr><td>Actual (trial 3):</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Continuous grazing</td><td>25,6</td><td>19,8</td><td>206</td><td>201</td></tr>
<tr><td>Rotational grazing</td><td>39,0</td><td>32,0</td><td>200</td><td>105</td></tr>
<tr><td>Predicted:</td><td></td><td></td><td></td><td></td></tr>
<tr><td>High potential soil</td><td colspan="2">27,8</td><td>151</td><td>229</td></tr>
<tr><td>Low potential soil</td><td colspan="2">17,8</td><td>93</td><td>140</td></tr>
</table>

* Calculated using the Jones & Sandland (1974) model and the wool yield as basis

** Calculated using the meat yield as basis

Another major problem was, however, that the actual values were themselves subject to the correct estimation of the optimum grazing capacity and therefore also had a measure of subjectivity incorporated in them. The actual values based on the meat yield (the grazing capacity during summer) differed from that based on the wool yield (the grazing capacity during the entire year). Further it was also found that the values derived on the continuously grazed system agreed most with the predicted values, while the actual wool yield values at both systems were higher than the estimated values. The fact that the meat yield estimated by the model was higher than the actual values, can perhaps be attributed to the decline in the actual legume content with age of the pasture, resulting in a lower animal production potential. If this is the case it is, however, very difficult to explain the higher actual wool yield.

These results therefore disclosed a further shortcoming of the model, i.e. the fact that it does not make provision for different grazing management systems. As has been indicated in previous chapters, different management systems result in large differences in the grazing capacity and animal production at the same locality.

5.4 Extrapolation

The model was utilised to predict the seasonal dry matter and grazing capacity and the animal production potential of single species and two-species pasture mixtures of the species evaluated at a number of sites. It was decided to use only two-species mixtures and pure stands as more complex mixtures would not only have increased the number of possible combinations to unrealistic levels, but would also have lead to problems with the estimation of the botanical composition of the pasture mixture. It was also decided to evaluate dryland and irrigated (high and low potential) situations separately, as the evaluation of different combinations of the three pasture types would have lead to an even larger number of possible combinations. The dryland sites used were Langgewens, Elsenburg, Tygerhoek and Outeniqua and the irrigated sites, Elsenburg, Tygerhoek, Outeniqua and Oudtshoorn.

5.4.1 Potential seasonal dry matter production of pure stands of the pasture species evaluated

Using long-term mean monthly climatic data derived at each site as input, the potential seasonal production (Kg DM. $ha^{-1}.M^{-1}$) (the output of subroutine POTEN), of the 11 species evaluated was calculated under dryland and under irrigation at each of the above mentioned sites. These results are those which were discussed in chapter 3, but as each species was discussed separately and the different species were never compared at each site, the results are repeated for this purpose.

5.4.1.1 Dryland

The results for the dryland situations are depicted in figures 5.7 to 5.9. From figure 5.7 the high winter and low summer estimated production potential of the annual legumes, subterranean clover and medics, under dryland conditions at all the sites, is evident. The estimated summer production potential of lucerne is, however, high at Elsenburg and Tygerhoek, while its production potential during winter is much lower than that of the above mentioned two annuals. At Outeniqua, the estimated production potential of red clover is, surprisingly enough, higher than that of lucerne for the greater part of the year.

Figure 5.7 Predicted mean monthly potential production rates (kg $DM.ha^{-1}.m^{-1}$) of five legumes at four dryland sites (Luc = lucerne, Med = medic, Sub = subterranean clover, Red = red clover and Whi = white clover)

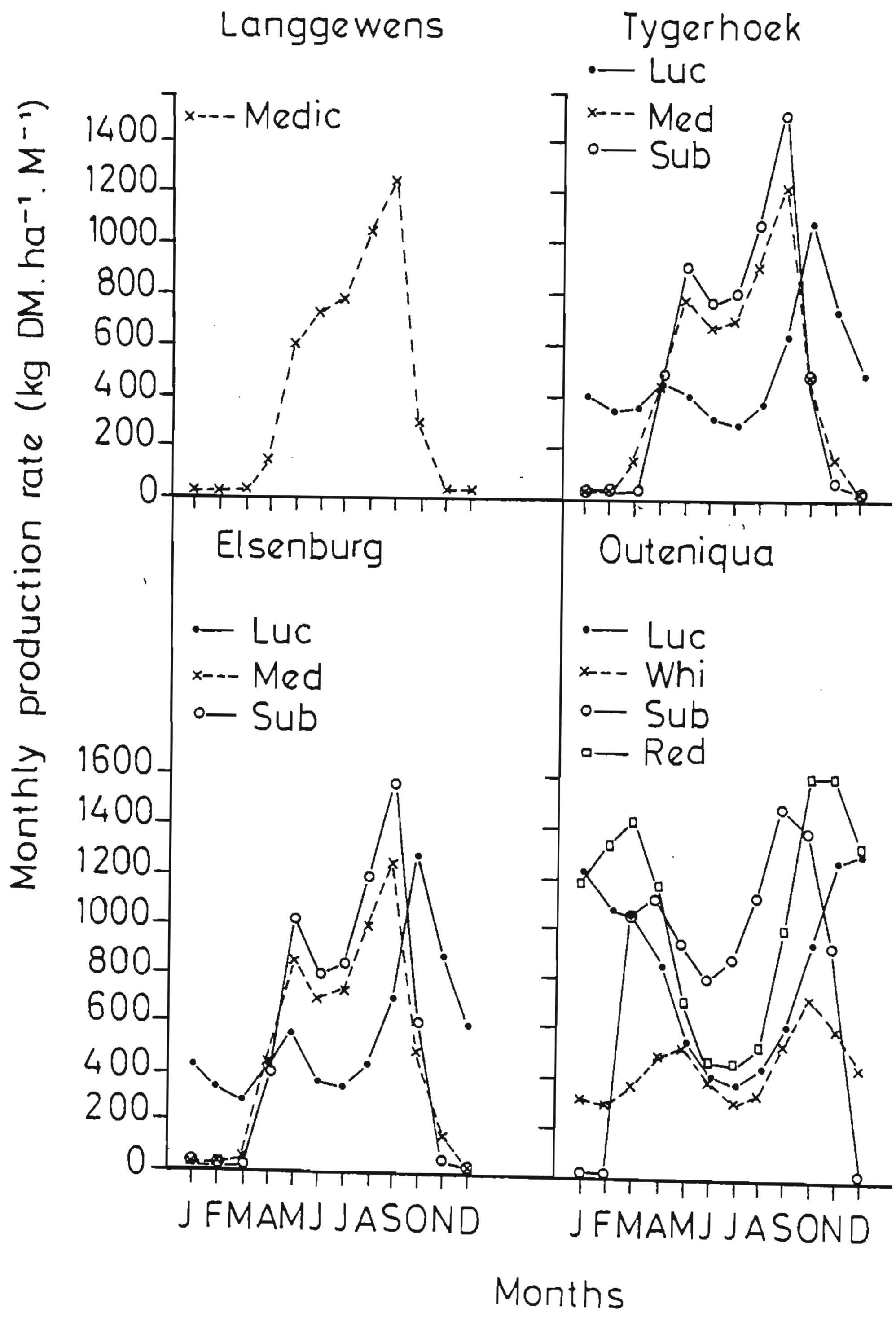


Figure 5.8 Predicted mean monthly potential production rate (kg $DM.ha^{-1}.m^{-1}$) of four grasses at three dryland sites (Arye = annual ryegrass, Fesc = fescue, Cock = cocksfoot and Phal = <u>Phalaris</u>)

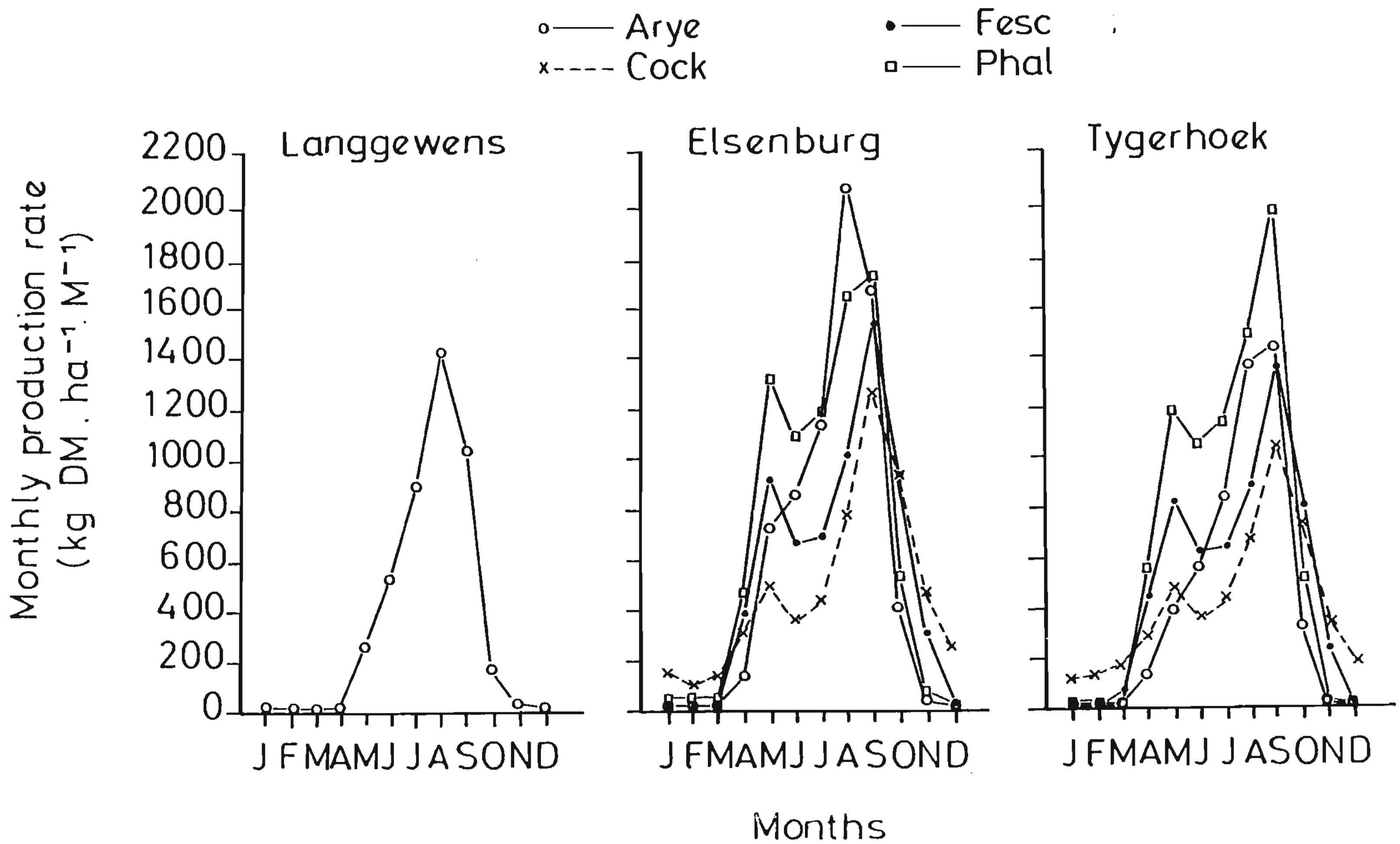
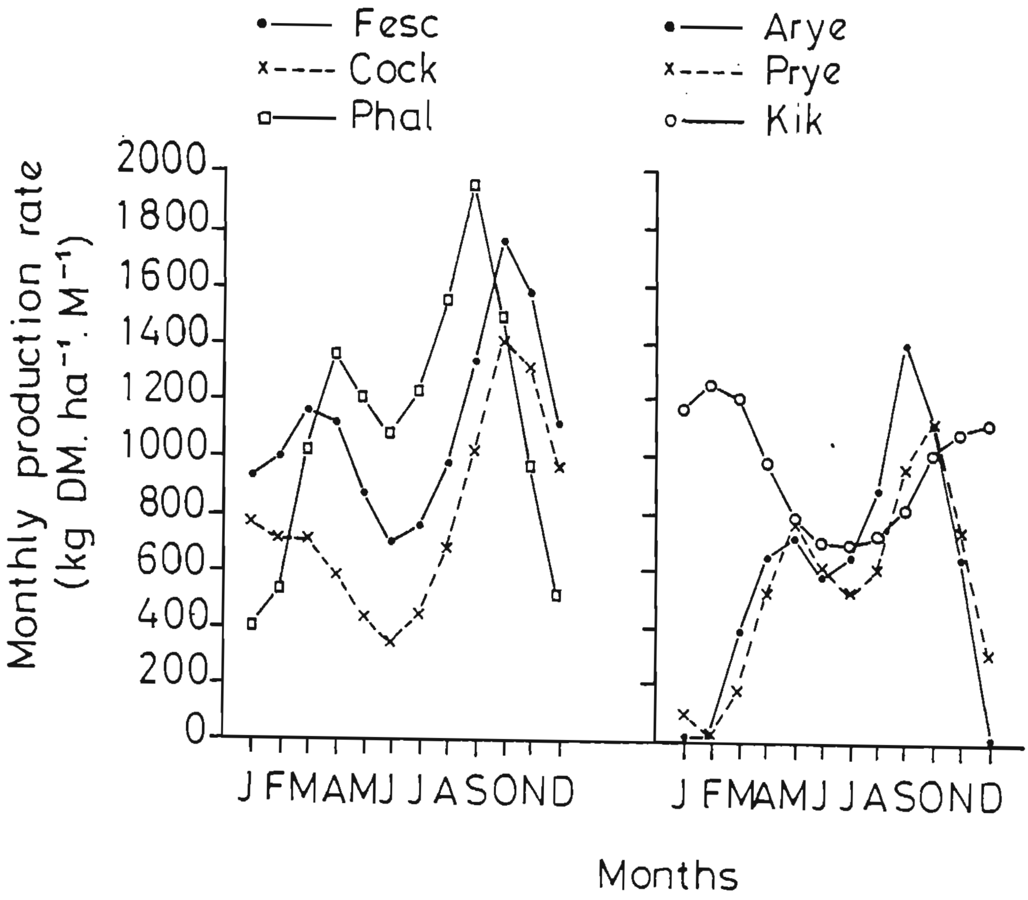


Figure 5.9 Predicted mean monthly potential production rates (kg $DM.ha^{-1}.m^{-1}$) of six grasses under dryland at Outeniqua (Arye = annual ryegrass, Fesc = fescue, Cock = cocksfoot, Phal = Phalaris, Prye = perennial ryegrass and Kik = kikuyu)



Under dryland, as depicted in figures 5.8 and 5.9, the winter production potential of Phalaris and annual ryegrass is the highest of all the grasses at all sites. At Elsenburg and Tygerhoek (figure 5.8) the estimated summer production potential of cocksfoot was slightly higher than that of fescue, but if the production potential of the two grasses is viewed right through the year, it is evident that the fescue has the greater potential of the two at these two sites.

At Outeniqua (figure 5.9), kikuyu has the greatest potential under dryland during summer and also has a surprisingly high winter production potential. Of the temperate grasses, fescue has the highest summer production potential at this site. Cocksfoot also tends to produce more actively during summer at Outeniqua, but it's production potential is generally very low when compared to fescue. An interesting aspect of the results is the similarity of the seasonal production of annual and perennial ryegrass. The production potential of these two grasses is, however, much lower than that of Phalaris.

5.4.1.2 Irrigated

The predicted results for irrigated high and low potential soil situations at four sites, are depicted in figures 5.10 to 5.15. On a high potential soil, the predicted seasonal production potential of lucerne is, as shown in figure 5.10, the highest of the three legumes evaluated at all sites. The production potential of white clover is lowest during the greater part of the year, but during winter it seems to compare favourably with that of red clover.

Of the grasses evaluated under irrigation on a high potential soil (figures 5.11 and 5.12), kikuyu seemed to have the highest estimated production potential during

Figure 5.10 Predicted mean monthly potential production rates (kg DM.ha^{-1}.m^{-1}) of three perennial legumes under irrigation on a high potential soil at four sites (Luc = lucerne, Red = red clover and Whi = white clover)

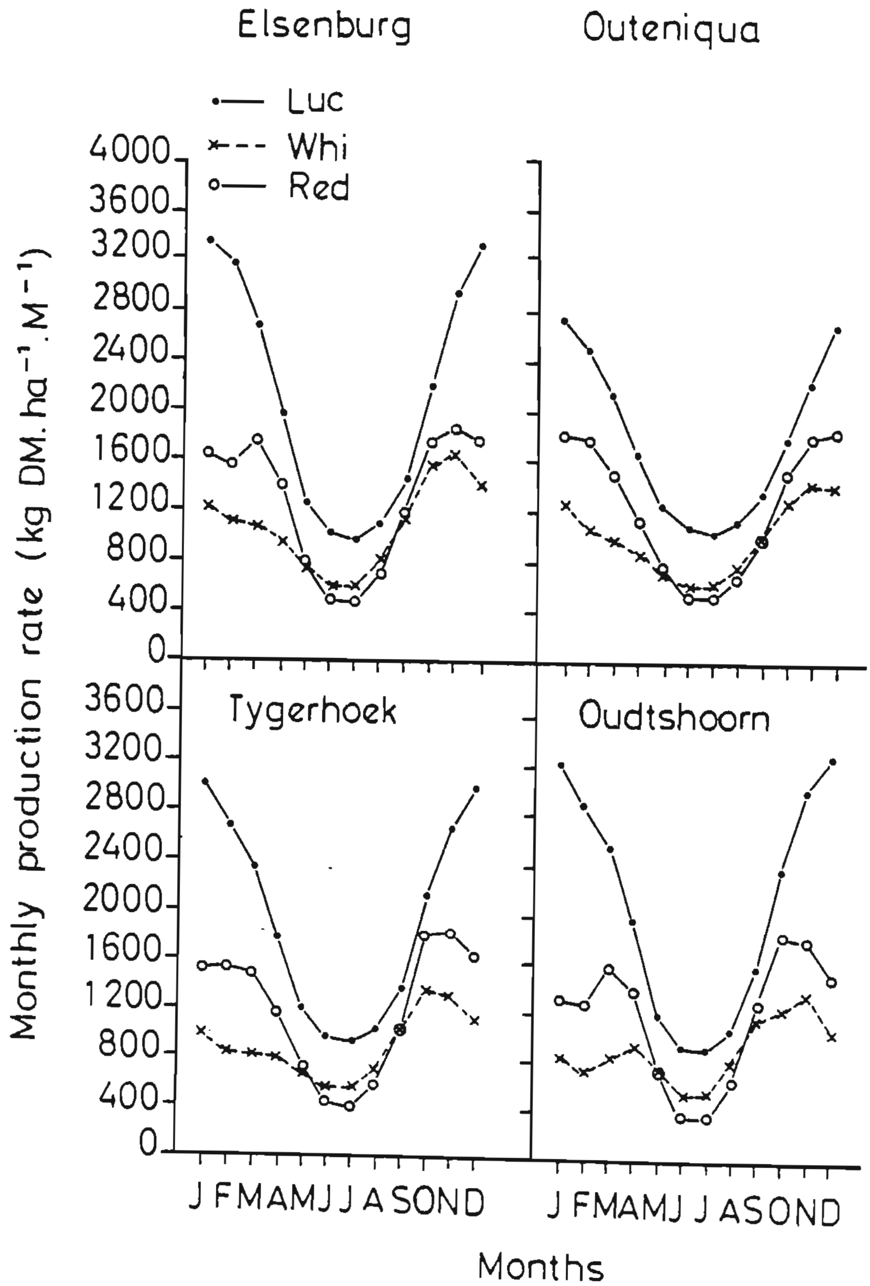


Figure 5.11 Predicted mean monthly potential production rates (kg DM.ha^{-1}.m^{-1}) of three perennial grasses under irrigation on a high potential soil at four sites (Fesc = fescue, Cock = cocksfoot, Phal = *Phalaris*)

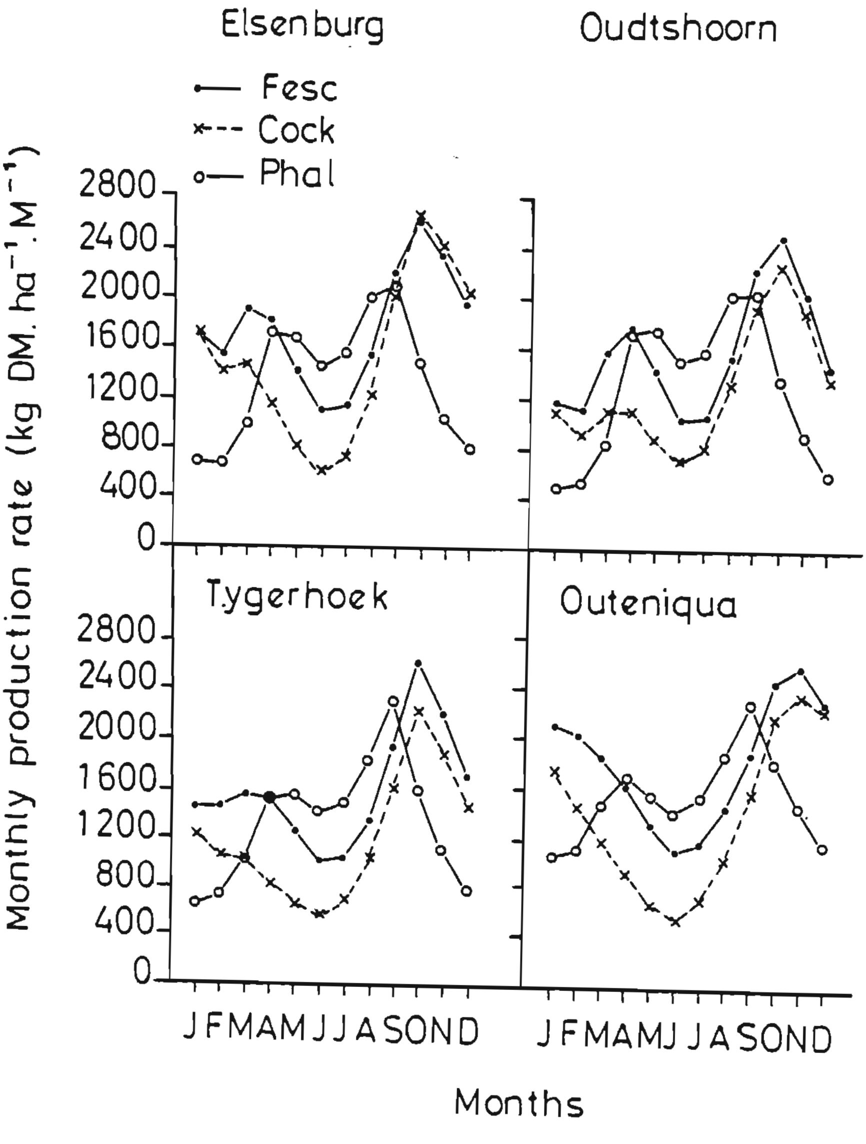


Figure 5.12 Predicted mean monthly potential production rates (kg $DM.ha^{-1}.m^{-1}$) of three grasses under irrigation on a high potential soil at four sites (Arye = annual ryegrass, Prye = perennial ryegrass and Kik = kikuyu)

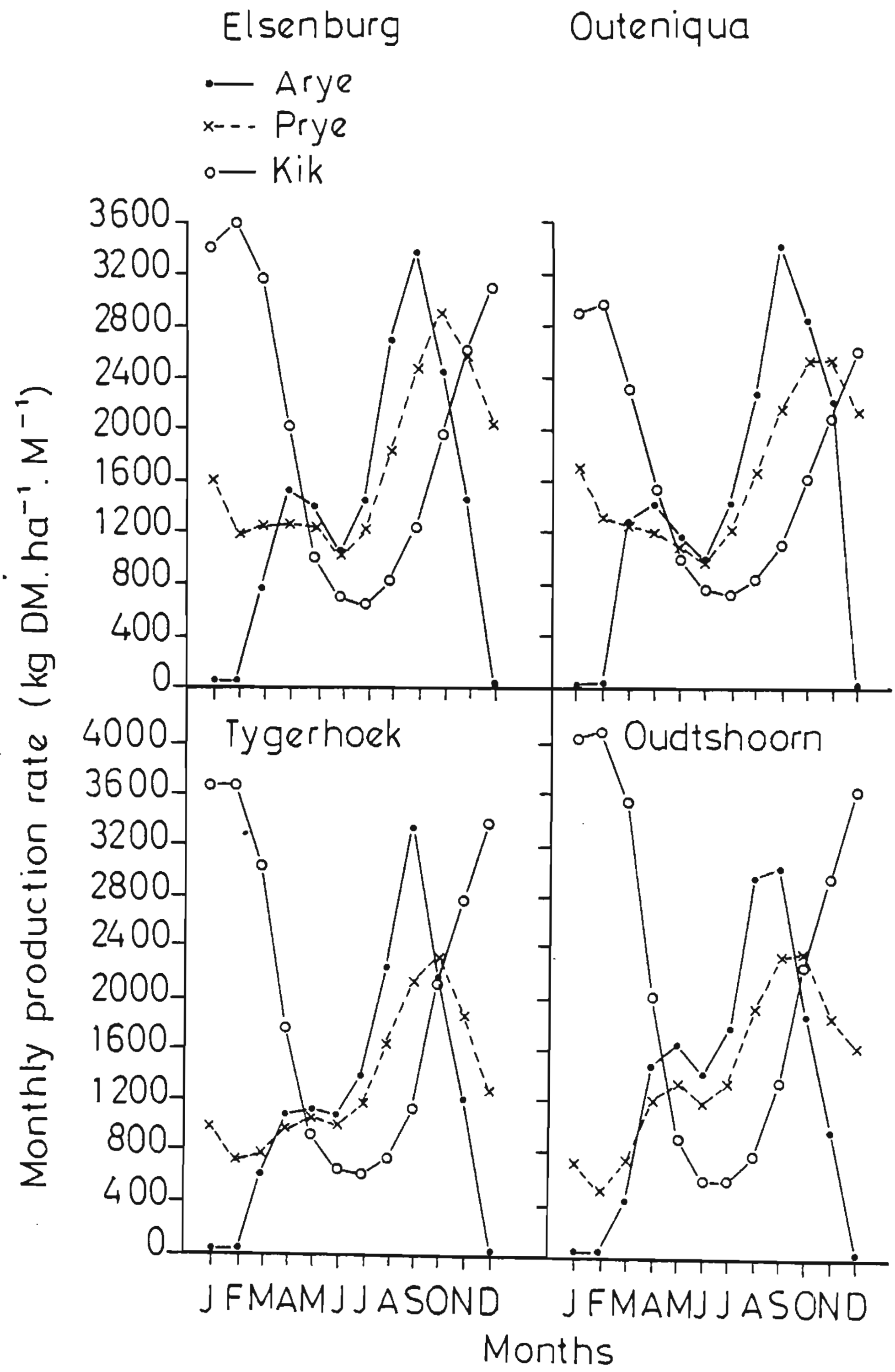


Figure 5.13 Predicted mean monthly potential production rates (kg $DM.ha^{-1}.m^{-1}$) of three perennial legumes under irrigation on a low potential soil at four sites (Luc = lucerne, Red = red clover and Whi = white clover)

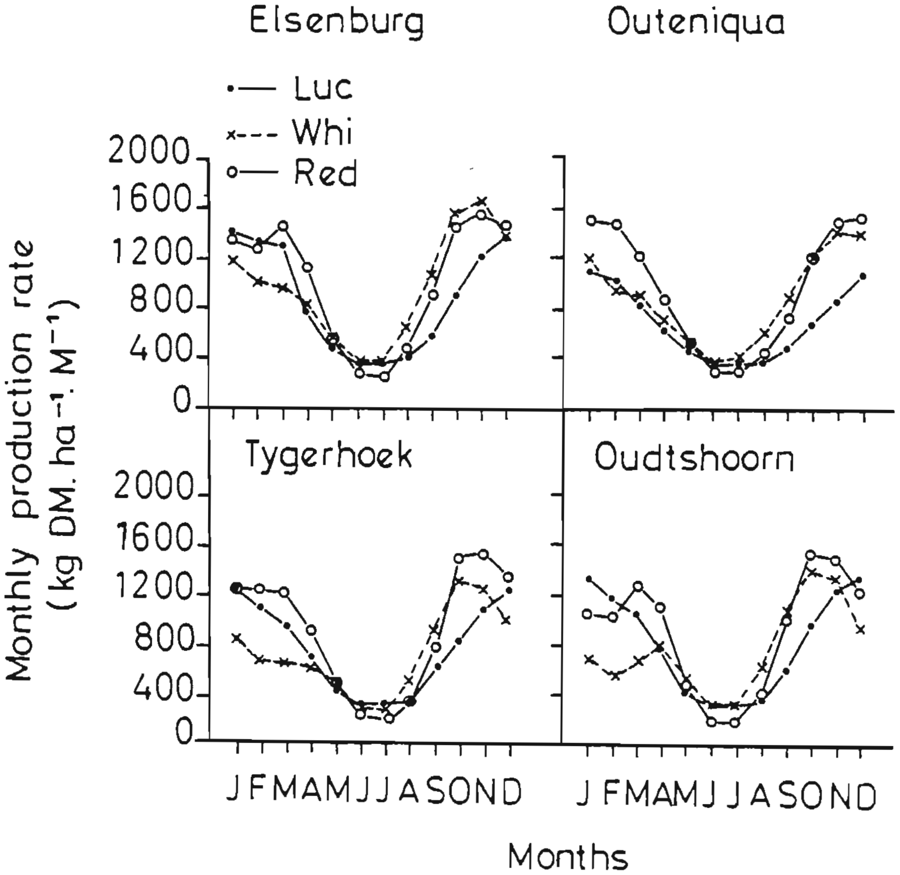


Figure 5.14 Predicted mean monthly potential production rates (kg DM.ha^{-1}.m^{-1}) of three perennial grasses under irrigation on a low potential soil at four sites (Fesc = fescue, Cock = cocksfoot, Phal = _Phalaris_)

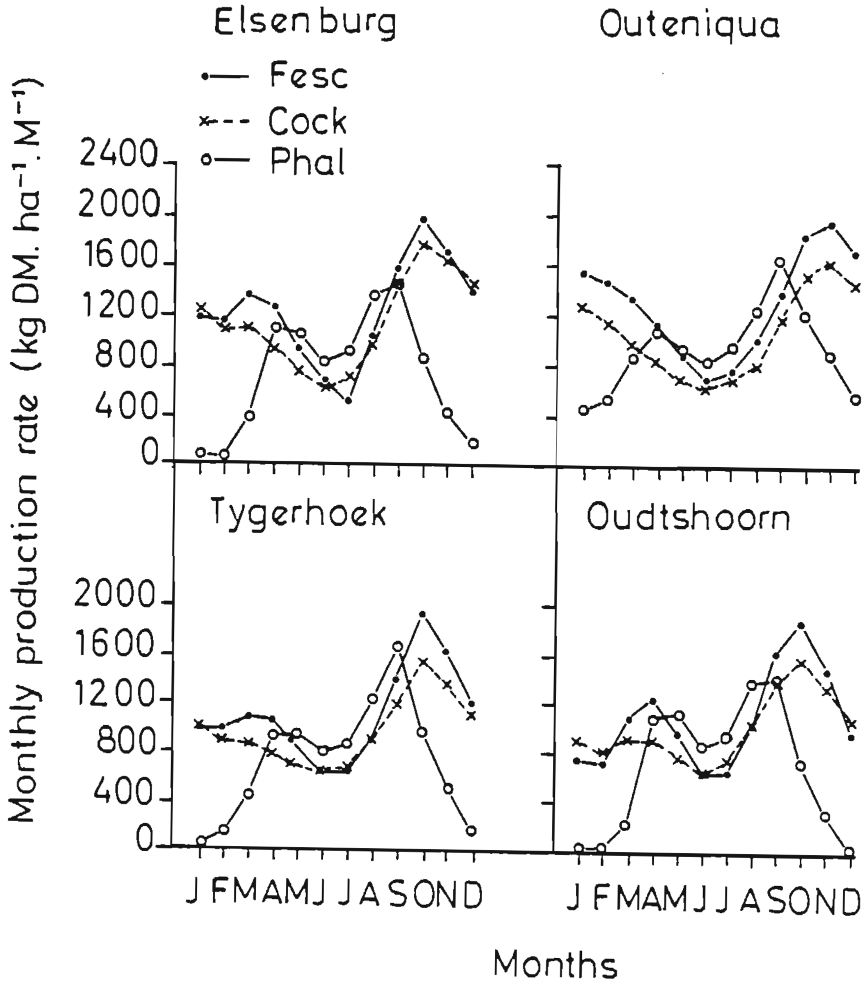
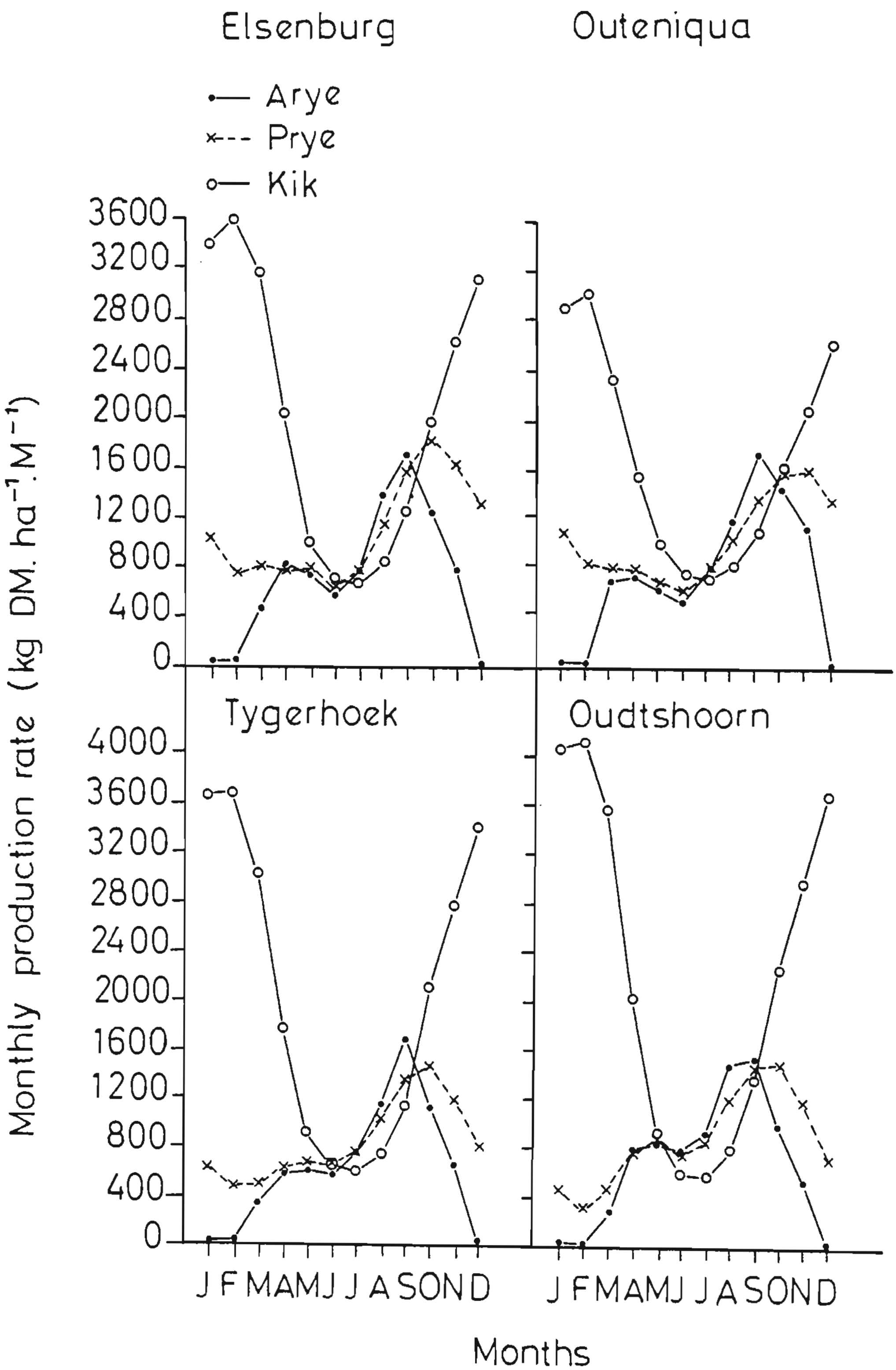


Figure 5.15 Predicted mean monthly potential production rates (kg DM.ha^{-1}.m^{-1}) of three grasses under irrigation on a low potential soil at four sites (Arye = annual ryegrass, Prye = perennial ryegrass and Kik = kikuyu)



summer, but the lowest production potential during winter. Of the temperate species, annual and perennial ryegrass and Phalaris, seems to have the highest estimated winter production potential on this type of soil. Of the three, Phalaris generally tends to have the highest production potential during mid winter on this type of soil. Cocksfoot and fescue, however, are the temperate grasses with the highest estimated summer production potential on a high potential soil under irrigation, and of these two, fescue seems to have the highest production potential through the whole year.

As depicted in figure 5.13 the estimated production potential of the three legumes evaluated, lucerne and red and white clover, differs much less under irrigation on a low potential, than on a high potential soil. In summer, the production potential of red clover seems generally higher than that of lucerne, while the production potential of white clover tends to be the lowest of the three legumes on a low potential soil. During winter, however, the production potential of the three legumes does not seem to differ on the last mentioned soil type.

From figures 5.14 and 5.15 it is clear that under irrigation on a low potential soil the estimated winter production potential of Phalaris tends to be the highest of all the grasses. Annual and perennial ryegrass, however, tend not to have a very high estimated production potential under conditions such as this in either summer or winter. The estimated production potential of fescue and cocksfoot seems to differ very little on the low potential irrigated soils. The most outstanding feature of the results is, however, the very high estimated production potential of kikuyu on this type of soil. It seems to have by far the highest production potential during summer and its production potential during winter seems to compare favourably with that of the ryegrasses.

5.4.2 The annual animal production potential of and the relative potential gross income on all possible single species and two-species pasture mixtures

The potential grazing capacity, the animal production potential and the gross income on all possible combinations of the 11 pasture species evaluated were estimated at each site, using long-term mean monthly climatic data as input. Two possible lambing times (May = M and September = S), five combinations of proportions of the total number of ewes lambing during each time (0,8M + 0S; 0,6M + 0,2S; 0,4M + 0,4S; 0,2M + 0,6S and 0M + 0,8S) and one weaning percentage (0,9) was evaluated. The minimum percentage of the ewes lambing at a specific time was 0 and the maximum 0,8 (or 80%). At each site the combination of lambing times resulting in the highest estimated gross income were tabulated for each of the possible combinations of pasture species and used for the comparison of the different pasture mixtures.

The fact that the model simulates ewe-lamb situations and does not make provision for situations where dry animals are involved, results therein that the data derived in the trial at Outeniqua (trial 4) could not be used for modelling or validation. No data were therefore available on the animal production potential of pure grass pastures and the model may underestimate the potential of these pastures. This should also result in an accentuation of the differences in estimated gross income between pure grass and grass/legume pastures, especially due to the high cost of the assumed nitrogen fertilization. The differences in estimated animal production and gross income on the two pasture types should therefore be seen as relative and not actual differences.

5.4.2.1 Dryland

The results for the dryland pastures are depicted in tables 5.6 to 5.9. At Langgewens the estimated mean annual potential grazing capacity of the three possible pasture mixtures does not differ much, but it seems to be generally highest on the medic based pastures. Due to the higher legume content of the pure medic pasture the estimated animal production potential and gross income on the last mentioned pasture seems to be highest. At this locality the optimum lambing time seems to be during May.

At Elsenburg and Tygerhoek the estimated mean annual grazing capacities and animal production potential of the lucerne based pasture mixtures seems to be highest. The estimated grazing capacities of the lucerne plus *Phalaris* and plus annual ryegrass pastures seem to be generally high, but the estimated animal production potential, and therefore also the relative gross income, tends to be highest on the mixtures of lucerne with medic and subterranean clover. At these two sites the estimated optimum lambing time on the pure lucerne and the lucerne plus grass pastures seems to be during September. On the mixtures of lucerne and the two annual legumes, subterranean clover and medics, however, it seems to be either during May (60%) and September (20%) or 40% during each of these two months. The model's choice of part of the lambing time during spring can to a certain extent be attributed to the problem that, as has already been indicated, the model at present does not take a risk factor into consideration. It can, however, also be attributed to the high estimated potential rate of pasture production during the period September to November.

Under dryland at Outeniqua a reasonably large number of different pasture mixtures seem capable of carrying a large

TABLE 5.6 PREDICTED AVERAGE ANNUAL GRAZING CAPACITY, WOOL AND MEAT PRODUCTION AND GROSS INCOME ON A NUMBER OF DRYLAND PASTURE MIXTURES AT THE OPTIMUM LAMBING TIME AT LANGGEWENS

PASTURE	AVERAGE GRAZING CAPACITY (EWE-UNITS (EU.HA^{-1})	WOOL PRODUCTION (KG.HA^{-1})	MEAT PRODUCTION (KG.HA^{-1})	RELATIVE GROSS INCOME (R.HA^{-1})	OPTIMUM LAMBING TIME (S=SEPTEMBER, M=MAY)
MED	4,3	20	52	113	0,8M 0 S
ARYE	3,7	7	3	-263	0,8M 0 S
MED + ARYE	4,3	16	29	27	0,8M 0 S

MED = Medic

ARYE = Annual ryegrass

TABLE 5.7 PREDICTED AVERAGE ANNUAL GRAZING CAPACITY, WOOL AND MEAT PRODUCTION AND GROSS INCOME ON A NUMBER OF DRYLAND PASTURE MIXTURES AT THE OPTIMUM LAMBING TIME AT ELSENBURG

PASTURE	AVERAGE GRAZING CAPACITY (EWE-UNITS ($EU.HA^{-1}$)	WOOL PRODUCTION ($KG.HA^{-1}$)	MEAT PRODUCTION ($KG.HA^{-1}$)	RELATIVE GROSS INCOME ($R.HA^{-1}$)	OPTIMUM LAMBING TIME (S=SEPTEMBER, M=MAY)	
LUC	6,8	46*	70*	265*	0 M	0,8S
MED	5,2	27	62	168	0,8M	0 S
SUB	5,8	28	69*	190	0,8M	0 S
FESC	6,3	18	7	-228	0,8M	0 S
COCK	5,9	19	5	-225	0,2M	0,6S
PHAL	7,3	18	8	-230	0,8M	0 S
ARYE	6,3	15	6	-242	0,8M	0 S
LUC + MED	7,9*	54*	87*	340*	0,4M	0,4S
LUC + SUB	8,7*	58*	97*	381*	0,6M	0,2S
LUC + FESC	8,4*	44*	54	195*	0 M	0,8S
LUC + COCK	6,9	36	42	133	0 M	0,8S
LUC + PHAL	10,6*	52*	72*	265*	0 M	0,8S
LUC + ARYE	10,0*	50*	72*	261*	0 M	0,8S
MED + SUB	5,6	28	67	185	0,8M	0 S
MED + FESC	6,0	23	38	74	0,8M	0 S
MED + COCK	6,2	28	47	118	0,8M	0 S
MED + PHAL	6,6	24	35	63	0,8M	0 S
MED + ARYE	6,1	23	35	60	0,8M	0 S
SUB + FESC	6,3	24	43	90	0,8M	0 S
SUB + COCK	6,8	30	54	146	0,8M	0 S
SUB + PHAL	6,7	24	38	70	0,8M	0 S
SUB + ARYE	6,3	23	38	69	0,8M	0 S
FESC + COCK	6,6	21	7	-215	0,8M	0 S
FESC + PHAL	7,3	20	8	-220	0,8M	0 S
FESC + ARYE	6,9	19	7	-226	0,8M	0 S
COCK + PHAL	7,9*	25	8	-205	0,8M	0 S
COCK + ARYE	7,4	22	7	-214	0,8M	0 S
PHAL + ARYE	7,0	17	7	-233	0,8M	0 S

*Highest values

LUC = Lucerne
MED = Medic
SUB = Subterranean clover
FESC = Fescue
COCK = Cocksfoot
PHAL = Phalaris
ARYE = Annual ryegrass

TABLE 5.8 PREDICTED AVERAGE ANNUAL GRAZING CAPACITY, WOOL AND MEAT PRODUCTION AND GROSS INCOME ON A NUMBER OF DRYLAND PASTURE MIXTURES AT THE OPTIMUM LAMBING TIME AT TYGERHOEK

PASTURE	AVERAGE GRAZING CAPACITY (EWE-UNITS (EU.HA^{-1})	WOOL PRODUCTION (KG.HA^{-1})	MEAT PRODUCTION (KG.HA^{-1})	RELATIVE GROSS INCOME (R.HA^{-1})	OPTIMUM LAMBING TIME (S=SEPTEMBER, M=MAY)	
LUC	6,2	44*	63*	237*	0 M	0,8S
MED	5,1	27	61*	168	0,8M	0 S
SUB	5,5	28	66*	180	0,8M	0 S
FESC	5,7	16	6	-231	0,8M	0 S
COCK	4,9	16	4	-230	0,4M	0,4S
PHAL	7,2	18	8	-230	0,8M	0 S
ARYE	4,4	9	4	-257	0,8M	0 S
LUC + MED	7,4*	51*	82*	317*	0,6M	0,2S
LUC + SUB	8,1*	56*	91*	358*	0,6M	0,2S
LUC + FESC	7,7*	42*	50	177	0 M	0,8S
LUC + COCK	6,2	34	39	120	0 M	0,8S
LUC + PHAL	10,3*	50*	63	231*	0 M	0,8S
LUC + ARYE	8,0*	44*	61*	216*	0 M	0,8S
MED + SUB	5,4	28	65*	181*	0,8M	0 S
MED + FESC	5,5	22	36	66	0,8M	0 S
MED + COCK	5,5	26	42	101	0,8M	0 S
MED + PHAL	6,6	25	34	64	0,8M	0 S
MED + ARYE	5,2	22	34	61	0,8M	0 S
SUB + FESC	5,8	23	40	79	0,8M	0 S
SUB + COCK	6,0	27	48	122	0,8M	0 S
SUB + PHAL	6,5	23	37	66	0,8M	0 S
SUB + ARYE	5,3	21	37	65	0,8M	0 S
FESC + COCK	5,7	19	6	-222	0,8M	0 S
FESC + PHAL	6,9	19	7	-224	0,8M	0 S
FESC + ARYE	5,6	16	6	-233	0,8M	0 S
COCK + PHAL	7,3*	23	8	-210	0,8M	0 S
COCK + ARYE	5,1	17	5	-228	0,8M	0 S
PHAL + ARYE	6,3	16	7	-236	0,8M	0 S

*Highest values

LUC = Lucerne
MED = Medic
SUB = Subterranean clover
FESC = Fescue
COCK = Cocksfoot
PHAL = *Phalaris*
ARYE = Annual ryegrass

TABLE 5.9 PREDICTED AVERAGE ANNUAL GRAZING CAPACITY, WOOL AND MEAT PRODUCTION AND GROSS INCOME ON A NUMBER OF DRYLAND PASTURE MIXTURES AT THE OPTIMUM LAMBING TIME AT OUTENIQUA

PASTURE	AVERAGE GRAZING CAPACITY (EWE-UNITS ($EU.HA^{-1}$)	WOOL PRODUCTION ($KG.HA^{-1}$)	MEAT PRODUCTION ($KG.HA^{-1}$)	RELATIVE GROSS INCOME ($R.HA^{-1}$)	OPTIMUM LAMBING TIME (S=SEPTEMBER, M=MAY)	
LUC	10,7	70	101*	428	0 M	0,8S
SUB	10,0	58	116*	427	0,8M	0 S
RED	13,8	91*	136*	601*	0 M	0,8S
FESC	14,3*	54	13	-115	0 M	0,8S
COCK	9,8	35	9	-171	0 M	0,8S
PHAL	13,9	50	14	-123	0,8M	0 S
PRYE	6,7	22	6	-214	0,4M	0,4S
ARYE	7,1	21	7	-219	0,8M	0 S
KIK	12,5	46	10	-143	0,2M	0,6S
LUC + SUB	13,2	95*	137*	627*	0,2M	0,6S
LUC + RED	12,5	83*	123*	538*	0 M	0,8S
LUC + FESC	13,1	67	64	287	0 M	0,8S
LUC + COCK	10,6	55	57	234	0 M	0,8S
LUC + PHAL	14,7*	78*	72	346	0 M	0,8S
LUC + PRYE	10,8	62	72	305	0 M	0,8S
LUC + ARYE	11,6	67	83	357*	0 M	0,8S
LUC + KIK	11,9	60	61	257	0 M	0,8S
SUB + RED	14,7*	104*	147*	685*	0 M	0,8S
SUB + FESC	14,3*	69	68	299	0,6M	0,2S
SUB + COCK	12,1	62	70	294	0,6M	0,2S
SUB + PHAL	13,0	63	69	285	0,8M	0 S
SUB + PRYE	9,4	47	66	237	0,8M	0 S
SUB + ARYE	8,9	41	62	200	0,8M	0 S
SUB + KIK	13,6	70	70	312	0,4M	0,4S
RED + FESC	14,3*	75	77	350	0 M	0,8S
RED + COCK	12,3	66	73	317	0 M	0,8S
RED + PHAL	15,8*	87*	90	430*	0 M	0,8S
RED + PRYE	12,9	73	89	393	0 M	0,8S
RED + ARYE	13,5	78*	102*	447*	0 M	0,8S
RED + KIK	13,4	71	79	345	0 M	0,8S
FESC + COCK	12,6	47	11	-134	0 M	0,8S
FESC + PHAL	15,2*	58	13	-104	0 M	0,8S
FESC + PRYE	12,7	48	11	-134	0 M	0,8S
FESC + ARYE	13,1	50	12	-127	0 M	0,8S
FESC + KIK	13,7	51	12	-123	0 M	0,8S
COCK + PHAL	13,4	51	12	-124	0,2M	0,6S
COCK + PRYE	9,5	36	9	-165	0 M	0,8S
COCK + ARYE	10,2	39	9	-158	0 M	0,8S
COCK + KIK	11,7	43	10	-146	0 M	0,8S
PHAL + PRYE	11,9	44	12	-144	0,6M	0,2S
PHAL + ARYE	12,1	44	12	-142	0,6M	0,2S
PHAL + KIK	14,4*	56	13	-106	0,4M	0,4S
PRYE + ARYE	7,3	24	7	-206	0,6M	0,2S
PRYE + KIK	11,7	43	10	-149	0,2M	0,6S
ARYE + KIK	12,4	46	11	-139	0 M	0,8S

*Highest values

LUC = Lucerne
SUB = Subterranean clover
RED = Red clover
FESC = Fescue
COCK = Cocksfoot
PHAL = *Phalaris*
PRYE = Perennial ryegrass
ARYE = Annual ryegrass
KIK = Kikuyu

number of animals, but the mixtures based on Phalaris generally seem to have the highest estimated grazing capacity. The red clover plus Phalaris pasture seems overall to have the highest estimated grazing capacity. The highest estimated animal production potential and gross income occurs on the mixtures based on red clover subterranean clover and lucerne, with Phalaris and annual ryegrass being the main grass components. At this locality the optimum lambing time, on the highest yielding mixtures, seems to be during September.

5.4.2.2 Irrigated

The results derived for high and low potential irrigated situations are depicted in tables 5.10 to 5.17. Under irrigation the relative potential of the different pasture mixtures, measured by their grazing capacity, seems to be very much the same on sites with the same soil potential. The lucerne based pasture mixtures seem to have the highest estimated potential grazing capacity on a high potential soil on all the sites evaluated, while the pastures based on kikuyu have the highest potential on a low potential soil. On a high potential soil the lucerne based pasture mixtures subsequently also tended to have the highest estimated animal production potential and relative potential gross income. On a low potential soil the high estimated grazing capacities of the kikuyu based pastures result in a very high estimated wool production potential, but a low estimated meat production potential. Because of this the grass/legume pastures based on red and white clover and annual ryegrass and Phalaris tended to have the highest relative potential gross income. Kikuyu based grass/legume mixtures have never been found to be a practical proposition, as the legume component usually seems unable to compete with the kikuyu, resulting in the mixture developing into a pure grass pasture very quickly. On both the high

TABLE 5.10 PREDICTED AVERAGE ANNUAL GRAZING CAPACITY, WOOL AND MEAT PRODUCTION AND GROSS INCOME ON A NUMBER OF IRRIGATED PASTURE MIXTURES ON A HIGH POTENTIAL SOIL AT ELSENBURG

PASTURE	AVERAGE GRAZING CAPACITY ($EU.HA^{-1}$)	WOOL PRODUCTION ($KG.HA^{-1}$)	MEAT PRODUCTION ($KG.HA^{-1}$)	RELATIVE GROSS INCOME ($R.HA^{-1}$)	OPTIMUM LAMBING TIME (S=SEPTEMBER, M=MAY)
LUC	40,6*	262*	380*	1864*	0 M 0,8S
WHI	20,4	142	209	984	0 M 0,8S
RED	24,6	160*	244*	1137*	0 M 0,8S
FESC	34,2	129	30	- 102	0 M 0,8S
COCK	28,1	100	26	- 193	0 M 0,8S
PHAL	25,2	94	26	- 197	0,8M 0 S
PRYE	32,4	121	29	- 122	0 M 0,8S
ARYE	26,7	79	17	- 301	0 M 0,8S
KIK	39,1*	124	30	- 163	0 M 0,8S
LUC + WHI	34,3	223*	326*	1581*	0 M 0,8S
LUC + RED	34,8	226*	330*	1599*	0 M 0,8S
LUC + FESC	38,9	207*	225*	1170*	0 M 0,8S
LUC + COCK	36,5	195*	214*	1102*	0 M 0,8S
LUC + PHAL	39,5*	221*	264*	1343*	0 M 0,8S
LUC + PRYE	39,0*	211*	225*	1187*	0 M 0,8S
LUC + ARYE	43,3*	246*	312*	1568*	0 M 0,8S
LUC + KIK	40,1*	194*	206	1046	0 M 0,8S
WHI + RED	22,9	154	230*	1079*	0 M 0,8S
WHI + FESC	29,2	146	132	700	0 M 0,8S
WHI + COCK	25,0	124	117	593	0 M 0,8S
WHI + PHAL	26,1	137	138	704	0 M 0,8S
WHI + PRYE	28,1	143	124	672	0 M 0,8S
WHI + ARYE	28,7	153	164	833	0 M 0,8S
WHI + KIK	33,7	144	131	652	0 M 0,8S
RED + FESC	30,7	155	148	777	0 M 0,8S
RED + COCK	26,9	135	133	672	0 M 0,8S
RED + PHAL	29,0	159	164	855	0 M 0,8S
RED + PRYE	30,2	156	144	774	0 M 0,8S
RED + ARYE	32,2	176	192	991	0 M 0,8S
RED + KIK	33,9	149	144	709	0 M 0,8S
FESC + COCK	31,8	119	29	- 129	0 M 0,8S
FESC + PHAL	32,6	126	28	- 106	0 M 0,8S
FESC + PRYE	33,7	128	30	- 100	0 M 0,8S
FESC + ARYE	35,2	134	31	- 85	0 M 0,8S
FESC + KIK	39,0*	136	33	- 99	0 M 0,8S
COCK + PHAL	30,4	119	27	- 126	0 M 0,8S
COCK + PRYE	30,8	114	28	- 144	0 M 0,8S
COCK + ARYE	32,6	122	29	- 122	0 M 0,8S
COCK + KIK	36,2	121	32	- 145	0 M 0,8S
PHAL + PRYE	31,5	121	28	- 123	0 M 0,8S
PHAL + ARYE	27,4	97	27	- 197	0,8M 0 S
PHAL + KIK	39,7*	139	32	- 94	0,2M 0,6S
PRYE + ARYE	33,5	125	30	- 115	0 M 0,8S
PRYE + KIK	39,4*	139	35	- 83	0 M 0,8S
ARYE + KIK	43,8*	154	38	- 43	0,2M 0,6S

*Highest values

LUC	= Lucerne	PHAL	= *Phalaris*
WHI	= White clover	PRYE	= Perennial ryegrass
RED	= Red clover	ARYE	= Annual ryegrass
FESC	= Fescue	KIK	= Kikuyu
COCK	= Cocksfoot		

TABLE 5.11 PREDICTED AVERAGE ANNUAL GRAZING CAPACITY, WOOL AND MEAT PRODUCTION AND GROSS INCOME ON A NUMBER OF IRRIGATED PASTURE MIXTURES ON A LOW POTENTIAL SOIL AT ELSENBURG

PASTURE	AVERAGE GRAZING CAPACITY (EU.HA^{-1})	WOOL PRODUCTION (KG.HA^{-1})	MEAT PRODUCTION (KG.HA^{-1})	RELATIVE GROSS INCOME (R.HA^{-1})	OPTIMUM LAMBING TIME (S=SEPTEMBER, M=MAY)
LUC	16,3	103	152*	676*	0 M 0,8S
WHI	18,0	119	185*	827*	0 M 0,8S
RED	19,5	123*	193*	859*	0 M 0,8S
FESC	24,1*	90	22	- 219	0 M 0,8S
COCK	21,8	81	20	- 241	0 M 0,8S
PHAL	13,0	42	14	- 363	0,8M 0 S
PRYE	20,4	77	19	- 256	0 M 0,8S
ARYE	12,6	36	12	- 390	0,8M 0 S
KIK	39,1*	124*	30	- 163	0 M 0,8S
LUC + WHI	17,5	115	178*	795*	0 M 0,8S
LUC + RED	18,2	116	178*	796*	0 M 0,8S
LUC + FESC	21,7	108	99	494	0 M 0,8S
LUC + COCK	20,1	100	95	461	0 M 0,8S
LUC + PHAL	20,0	111	124	596	0 M 0,8S
LUC + PRYE	19,8	102	96	474	0 M 0,8S
LUC + ARYE	19,5	108	129	603	0 M 0,8S
LUC + KIK	32,5*	131*	106	529	0 M 0,8S
WHI + RED	19,0	123*	191*	856*	0 M 0,8S
WHI + FESC	21,7	110	114	548	0 M 0,8S
WHI + COCK	20,2	103	110	517	0 M 0,8S
WHI + PHAL	20,1	119	153*	719*	0 M 0,8S
WHI + PRYE	19,7	104	109	518	0 M 0,8S
WHI + ARYE	19,4	112	147*	672*	0 M 0,8S
WHI + KIK	33,2*	137*	128	618	0 M 0,8S
RED + FESC	22,7	114	117	565	0 M 0,8S
RED + COCK	21,4	106	102	499	0,2M 0,6S
RED + PHAL	21,9	126*	158*	745*	0 M 0,8S
RED + PRYE	21,0	111	114	557	0 M 0,8S
RED + ARYE	21,3	121*	157*	727*	0 M 0,8S
RED + KIK	32,9*	137*	125	608	0 M 0,8S
FESC + COCK	23,1	86	21	- 227	0 M 0,8S
FESC + PHAL	23,1	88	20	- 221	0 M 0,8S
FESC + PRYE	22,7	85	21	- 229	0 M 0,8S
FESC + ARYE	22,6	85	20	- 231	0 M 0,8S
FESC + KIK	35,0*	116	29	- 167	0 M 0,8S
COCK + PHAL	21,7	84	20	- 229	0 M 0,8S
COCK + PRYE	21,3	80	20	- 244	0 M 0,8S
COCK + ARYE	21,2	80	20	- 244	0 M 0,8S
COCK + KIK	34,3*	113	28	- 180	0 M 0,8S
PHAL + PRYE	20,2	78	18	- 251	0 M 0,8S
PHAL + ARYE	13,4	44	14	- 357	0,8M 0 S
PHAL + KIK	37,7*	122*	29	- 161	0 M 0,8S
PRYE + ARYE	19,7	74	18	- 263	0 M 0,8S
PRYE + KIK	35,0*	115	29	- 172	0,2M 0,6S
ARYE + KIK	37,4*	120*	30	- 168	0 M 0,8S

*Highest values

LUC = Lucerne
WHI = White clover
RED = Red clover
FESC = Fescue
COCK = Cocksfoot

PHAL = *Phalaris*
PRYE = Perennial ryegrass
ARYE = Annual ryegrass
KIK = Kikuyu

TABLE 5.12 PREDICTED AVERAGE ANNUAL GRAZING CAPACITY, WOOL AND MEAT PRODUCTION AND GROSS INCOME ON A NUMBER OF IRRIGATED PASTURE MIXTURES ON A HIGH POTENTIAL SOIL AT TYGERHOEK

PASTURE	AVERAGE GRAZING CAPACITY ($EU.HA^{-1}$)	WOOL PRODUCTION ($KG.HA^{-1}$)	MEAT PRODUCTION ($KG.HA^{-1}$)	RELATIVE GROSS INCOME ($R.HA^{-1}$)	OPTIMUM LAMBING TIME (S=SEPTEMBER, M=MAY)
LUC	36,9*	242*	350*	1712*	0 M 0,8S
WHI	17,1	123	177	829	0 M 0,8S
RED	22,4	145	221*	1015*	0 M 0,8S
FESC	30,9	116	27	- 138	0 M 0,8S
COCK	22,3	81	20	- 247	0 M 0,8S
PHAL	25,2	94	26	- 196	0,8M 0 S
PRYE	25,4	93	22	- 211	0 M 0,8S
ARYE	21,9	64	18	- 326	0,4M 0,4S
KIK	38,9*	122	31	- 169	0 M 0,8S
LUC + WHI	31,0	205*	298*	1442*	0 M 0,8S
LUC + RED	31,6	207*	304*	1464*	0 M 0,8S
LUC + FESC	35,1*	189*	206*	1062*	0 M 0,8S
LUC + COCK	32,3	177*	201*	1019*	0 M 0,8S
LUC + PHAL	36,3*	205*	242*	1233*	0 M 0,8S
LUC + PRYE	34,7	194*	219*	1130*	0 M 0,8S
LUC + ARYE	39,1*	225*	284*	1424*	0 M 0,8S
LUC + KIK	38,4*	183*	189	962*	0 M 0,8S
WHI + RED	20,5	138	206*	953	0 M 0,8S
WHI + FESC	26,0	129	112	592	0 M 0,8S
WHI + COCK	20,2	104	97	482	0 M 0,8S
WHI + PHAL	23,7	122	114	582	0,2M 0,6S
WHI + PRYE	22,6	116	103	536	0 M 0,8S
WHI + ARYE	24,8	128	136	667	0 M 0,8S
WHI + KIK	33,5	137	116	576	0 M 0,8S
RED + FESC	27,9	142	138	707	0 M 0,8S
RED + COCK	23,0	118	124	600	0 M 0,8S
RED + PHAL	27,9	151	155	803	0 M 0,8S
RED + PRYE	25,9	139	137	710	0 M 0,8S
RED + ARYE	29,5	161*	182	915	0 M 0,8S
RED + KIK	33,4	142	136	660	0 M 0,8S
FESC + COCK	27,5	103	25	- 175	0 M 0,8S
FESC + PHAL	30,3	117	26	- 135	0 M 0,8S
FESC + PRYE	28,9	111	26	- 152	0 M 0,8S
FESC + ARYE	31,8	121	28	- 126	0 M 0,8S
FESC + KIK	37,8*	130	33	- 118	0 M 0,8S
COCK + PHAL	26,1	100	24	- 181	0,2M 0,6S
COCK + PRYE	24,5	92	22	- 210	0 M 0,8S
COCK + ARYE	27,1	99	24	- 196	0 M 0,8S
COCK + KIK	34,8	114	30	- 174	0 M 0,8S
PHAL + PRYE	26,0	97	25	- 192	0,4M 0,4S
PHAL + ARYE	26,0	94	24	- 210	0,4M 0,4S
PHAL + KIK	40,0*	140	33	- 89	0 M 0,8S
PRYE + ARYE	27,0	96	23	- 211	0 M 0,8S
PRYE + KIK	38,0*	131	33	- 115	0 M 0,8S
ARYE + KIK	43,1*	150	39	- 53	0 M 0,8S

*Highest values

LUC = Lucerne
WHI = White clover
RED = Red clover
FESC = Fescue
COCK = Cocksfoot
PHAL = *Phalaris*
PRYE = Perennial ryegrass
ARYE = Annual ryegrass
KIK = Kikuyu

TABLE 5.13 PREDICTED AVERAGE ANNUAL GRAZING CAPACITY, WOOL AND MEAT PRODUCTION AND GROSS INCOME ON A NUMBER OF IRRIGATED PASTURE MIXTURES ON A LOW POTENTIAL SOIL AT TYGERHOEK

PASTURE	AVERAGE GRAZING CAPACITY ($EU.HA^{-1}$)	WOOL PRODUCTION ($KG.HA^{-1}$)	MEAT PRODUCTION ($KG.HA^{-1}$)	RELATIVE GROSS INCOME ($R.HA^{-1}$)	OPTIMUM LAMBING TIME (S=SEPTEMBER, M=MAY)	
LUC	14,7	94	139*	609*	0 M	0,8S
WHI	13,9	94	145*	634*	0 M	0,8S
RED	17,5	108	172*	744*	0 M	0,8S
FESC	21,3*	79	19	- 249	0 M	0,8S
COCK	18,6	71	17	- 272	0 M	0,8S
PHAL	13,0	43	14	- 358	0,8M	0 S
PRYE	16,0	59	14	- 312	0 M	0,8S
ARYE	11,3	33	11	- 400	0,6M	0,2S
KIK	38,9*	122*	31	- 169	0 M	0,8S
LUC + WHI	14,7	97	150*	657*	0 M	0,8S
LUC + RED	16,2	104	162*	706*	0 M	0,8S
LUC + FESC	19,2	96	89	429	0 M	0,8S
LUC + COCK	17,4	90	87	410	0 M	0,8S
LUC + PHAL	18,9	103	54	359	0,8M	0 S
LUC + PRYE	16,8	91	90	429	0 M	0,8S
LUC + ARYE	17,5	98	117*	535*	0 M	0,8S
LUC + KIK	32,4*	127*	100	495	0 M	0,8S
WHI + RED	16,3	104	163*	712*	0 M	0,8S
WHI + FESC	18,5	93	91	428	0 M	0,8S
WHI + COCK	16,7	87	89	410	0 M	0,8S
WHI + PHAL	16,8	95	114	518	0 M	0,8S
WHI + PRYE	15,6	84	87	400	0 M	0,8S
WHI + ARYE	15,8	90	115	508	0 M	0,8S
WHI + KIK	33,2*	129*	109	525	0 M	0,8S
RED + FESC	20,3	102	106	499	0 M	0,8S
RED + COCK	18,9	97	105	487	0 M	0,8S
RED + PHAL	20,4	116*	147*	684*	0 M	0,8S
RED + PRYE	18,6	100	111	526	0 M	0,8S
RED + ARYE	19,6	111*	148*	670*	0 M	0,8S
RED + KIK	32,6*	132*	119*	569*	0 M	0,8S
FESC + COCK	20,1	76	18	- 258	0 M	0,8S
FESC + PHAL	20,6	79	18	- 247	0 M	0,8S
FESC + PRYE	19,4	74	17	- 264	0 M	0,8S
FESC + ARYE	20,2	76	18	- 259	0 M	0,8S
FESC + KIK	34,5*	112*	29	- 181	0 M	0,8S
COCK + PHAL	18,8	73	17	- 264	0 M	0,8S
COCK + PRYE	17,7	68	16	- 281	0 M	0,8S
COCK + ARYE	18,2	69	16	- 279	0 M	0,8S
COCK + KIK	34,0*	109	28	- 194	0 M	0,8S
PHAL + PRYE	16,0	58	15	- 311	0,4M	0,4S
PHAL + ARYE	12,6	42	13	- 363	0,8M	0 S
PHAL + KIK	37,7*	121*	30	- 162	0 M	0,8S
PRYE + ARYE	15,7	57	14	- 320	0 M	0,8S
PRYE + KIK	35,2*	112*	28	- 187	0 M	0,8S
ARYE + KIK	37,5*	118*	30	- 174	0 M	0,8S

*Highest values

LUC = Lucerne
WHI = White clover
RED = Red clover
FESC = Fescue
COCK = Cocksfoot
PHAL = Phalaris
PRYE = Perennial ryegrass
ARYE = Annual ryegrass
KIK = Kikuyu

TABLE 5.14 PREDICTED AVERAGE ANNUAL GRAZING CAPACITY, WOOL AND MEAT PRODUCTION AND GROSS INCOME ON A NUMBER OF IRRIGATED PASTURE MIXTURES ON A HIGH POTENTIAL SOIL AT OUTENIQUA

PASTURE	AVERAGE GRAZING CAPACITY ($EU.HA^{-1}$)	WOOL PRODUCTION ($KG.HA^{-1}$)	MEAT PRODUCTION ($KG.HA^{-1}$)	RELATIVE GROSS INCOME ($R.HA^{-1}$)	OPTIMUM LAMBING TIME (S=SEPTEMBER, M=MAY)	
LUC	34,5*	232*	319*	1596*	0 M	0,8S
WHI	19,1	136	197*	929	0 M	0,8S
RED	23,8	155	232*	1084*	0 M	0,8S
FESC	35,4*	133	32	- 90	0 M	0,8S
COCK	26,0	92	24	- 217	0 M	0,8S
PHAL	30,0	116	28	- 130	0,4M	0,4S
PRYE	31,2	118	29	- 131	0 M	0,8S
ARYE	26,3	73	24	- 302	0,8M	0 S
KIK	32,8	108	26	- 195	0 M	0,8S
LUC + WHI	29,8	202*	253*	1305*	0 M	0,8S
LUC + RED	30,3	203*	285*	1401*	0 M	0,8S
LUC + FESC	35,3*	187*	183	981*	0 M	0,8S
LUC + COCK	31,5	172*	173	917	0 M	0,8S
LUC + PHAL	34,9*	192*	198*	1055*	0 M	0,8S
LUC + PRYE	34,0	186*	184*	992*	0 M	0,8S
LUC + ARYE	38,3*	216*	250*	1288*	0 M	0,8S
LUC + KIK	34,0	171*	172	890	0 M	0,8S
WHI + RED	21,9	148	218*	1025*	0 M	0,8S
WHI + FESC	29,7	146	126	679	0 M	0,8S
WHI + COCK	23,3	116	107	541	0 M	0,8S
WHI + PHAL	26,9	142	127	684	0,2M	0,6S
WHI + PRYE	26,8	136	117	631	0 M	0,8S
WHI + ARYE	28,9	152	157	803	0 M	0,8S
WHI + KIK	28,4	128	117	583	0 M	0,8S
RED + FESC	31,1	155	144	762	0 M	0,8S
RED + COCK	25,3	127	126	631	0 M	0,8S
RED + PHAL	30,0	159	153	814	0 M	0,8S
RED + PRYE	28,9	149	139	739	0 M	0,8S
RED + ARYE	32,4	174*	191*	975*	0 M	0,8S
RED + KIK	29,2	135	133	654	0 M	0,8S
FESC + COCK	31,7	117	29	- 138	0 M	0,8S
FESC + PHAL	34,4*	134	31	- 81	0 M	0,8S
FESC + PRYE	33,7	127	31	- 101	0 M	0,8S
FESC + ARYE	36,9*	138	34	- 71	0 M	0,8S
FESC + KIK	35,1*	126	31	- 121	0 M	0,8S
COCK + PHAL	30,6	120	27	- 120	0 M	0,8S
COCK + PRYE	29,1	108	27	- 163	0 M	0,8S
COCK + ARYE	32,1	119	29	- 131	0 M	0,8S
COCK + KIK	30,8	106	27	- 185	0 M	0,8S
PHAL + PRYE	32,0	126	28	- 103	0 M	0,8S
PHAL + ARYE	32,6	112	27	- 129	0 M	0,8S
PHAL + KIK	35,1*	129	29	- 112	0 M	0,8S
PRYE + ARYE	33,5	125	30	- 110	0 M	0,8S
PRYE + KIK	34,0	123	31	- 124	0 M	0,8S
ARYE + KIK	38,7*	139	35	- 78	0,2M	0,6S

*Highest values

LUC = Lucerne
WHI = White clover
RED = Red clover
FESC = Fescue
COCK = Cocksfoot
PHAL = *Phalaris*
PRYE = Perennial ryegrass
ARYE = Annual ryegrass
KIK = Kikuyu

TABLE 5.15 PREDICTED AVERAGE ANNUAL GRAZING CAPACITY, WOOL AND MEAT PRODUCTION AND GROSS INCOME ON A NUMBER OF IRRIGATED PASTURE MIXTURES ON A LOW POTENTIAL SOIL AT OUTENIQUA

PASTURE	AVERAGE GRAZING CAPACITY ($EU.HA^{-1}$)	WOOL PRODUCTION ($KG.HA^{-1}$)	MEAT PRODUCTION ($KG.HA^{-1}$)	RELATIVE GROSS INCOME ($R.HA^{-1}$)	OPTIMUM LAMBING TIME (S=SEPTEMBER, M=MAY)	
LUC	13,6	90	126*	561*	0 M	0,8S
WHI	16,4	110*	170*	758*	0 M	0,8S
RED	18,8	118*	183*	813*	0 M	0,8S
FESC	25,1*	92	28	- 213	0 M	0,8S
COCK	20,6	77	19	- 256	0 M	0,8S
PHAL	17,9	66	17	- 287	0,6M	0,2S
PRYE	19,6	74	18	- 262	0 M	0,8S
ARYE	14,5	44	9	- 382	0 M	0,8S
KIK	32,8*	108*	26	- 195	0 M	0,8S
LUC + WHI	15,4	103	157*	698*	0 M	0,8S
LUC + RED	16,7	107	161*	718*	0 M	0,8S
LUC + FESC	21,3	102	84	425	0 M	0,8S
LUC + COCK	18,1	90	79	383	0 M	0,8S
LUC + PHAL	18,3	96	85	423	0 M	0,8S
LUC + PRYE	17,8	91	79	390	0 M	0,8S
LUC + ARYE	17,5	96	105	494	0 M	0,8S
LUC + KIK	27,3*	114*	88	441	0 M	0,8S
WHI + RED	17,9	116*	180*	803*	0 M	0,8S
WHI + FESC	21,8	107	105	507	0 M	0,8S
WHI + COCK	18,9	96	99	466	0 M	0,8S
WHI + PHAL	19,3	106	117*	559*	0 M	0,8S
WHI + PRYE	18,4	97	99	471	0 M	0,8S
WHI + ARYE	18,5	104	130*	595*	0 M	0,8S
WHI + KIK	27,8*	121*	112	539	0 M	0,8S
RED + FESC	22,8	112*	111	541	0 M	0,8S
RED + COCK	20,2	103	107	506	0 M	0,8S
RED + PHAL	21,3	116*	129*	621*	0 M	0,8S
RED + PRYE	20,1	105	109	521	0 M	0,8S
RED + ARYE	20,9	116*	149*	686*	0 M	0,8S
RED + KIK	27,8*	122*	114	553	0 M	0,8S
FESC + COCK	23,1	85	21	- 232	0 M	0,8S
FESC + PHAL	23,7	91	21	- 211	0 M	0,8S
FESC + PRYE	22,9	85	21	- 230	0 M	0,8S
FESC + ARYE	23,8	88	22	- 221	0 M	0,8S
FESC + KIK	30,2*	104	26	- 192	0 M	0,8S
COCK + PHAL	20,9	81	19	- 239	0 M	0,8S
COCK + PRYE	20,2	76	19	- 255	0 M	0,8S
COCK + ARYE	20,6	77	19	- 255	0 M	0,8S
COCK + KIK	28,9*	98	24	- 212	0 M	0,8S
PHAL + PRYE	20,1	78	18	- 251	0 M	0,8S
PHAL + ARYE	18,1	66	15	- 295	0 M	0,8S
PHAL + KIK	30,6*	106	25	- 189	0 M	0,8S
PRYE + ARYE	19,4	73	18	- 266	0 M	0,8S
PRYE + KIK	29,3*	100	25	- 205	0 M	0,8S
ARYE + KIK	31,5*	105	26	- 195	0 M	0,8S

*Highest values

LUC = Lucerne
WHI = White clover
RED = Red clover
FESC = Fescue
COCK = Cocksfoot
PHAL = *Phalaris*
PRYE = Perennial ryegrass
ARYE = Annual ryegrass
KIK = Kikuyu

TABLE 5.16 PREDICTED AVERAGE ANNUAL GRAZING CAPACITY, WOOL AND MEAT PRODUCTION AND GROSS INCOME ON A NUMBER OF IRRIGATED PASTURE MIXTURES ON A HIGH POTENTIAL SOIL AT OUDTSHOORN

PASTURE	AVERAGE GRAZING CAPACITY ($EU.HA^{-1}$)	WOOL PRODUCTION ($KG.HA^{-1}$)	MEAT PRODUCTION ($KG.HA^{-1}$)	RELATIVE GROSS INCOME ($R.HA^{-1}$)	OPTIMUM LAMBING TIME (S=SEPTEMBER, M=MAY)	
LUC	39,7*	257*	381*	1850*	0 M	0,8S
WHI	17,8	128	184	868	0 M	0,8S
RED	22,7	147	227*	1041*	0 M	0,8S
FESC	30,8	115	26	- 147	0 M	0,8S
COCK	24,3	91	22	- 215	0 M	0,8S
PHAL	23,7	85	25	- 225	0,8M	0 S
PRYE	26,7	95	24	- 208	0,2M	0,6S
ARYE	22,9	65	24	- 309	0,8M	0 S
KIK	43,0*	132	34	- 143	0 M	0,8S
LUC + WHI	33,6	219*	327*	1569*	0 M	0,8S
LUC + RED	33,8	220*	330*	1584*	0 M	0,8S
LUC + FESC	37,5	204*	235*	1198*	0 M	0,8S
LUC + COCK	35,2	193*	228*	1147*	0 M	0,8S
LUC + PHAL	39,3*	223*	279*	1400*	0 M	0,8S
LUC + PRYE	38,3	216*	252*	1293*	0 M	0,8S
LUC + ARYE	43,5*	252*	322*	1624*	0 M	0,8S
LUC + KIK	41,9*	197*	210	1056*	0 M	0,8S
WHI + RED	20,9	142	212*	986	0 M	0,8S
WHI + FESC	26,1	130	113	598	0 M	0,8S
WHI + COCK	21,6	113	103	526	0 M	0,8S
WHI + PHAL	24,0	122	109	564	0,2M	0,6S
WHI + PRYE	24,1	121	108	559	0 M	0,8S
WHI + ARYE	27,3	135	142	699	0 M	0,8S
WHI + KIK	37,4	149	124	624	0 M	0,8S
RED + FESC	28,1	144	140	722	0 M	0,8S
RED + COCK	24,2	127	130	650	0 M	0,8S
RED + PHAL	28,0	152	161	821	0 M	0,8S
RED + PRYE	27,5	148	141	750	0 M	0,8S
RED + ARYE	31,8	175*	186	970	0 M	0,8S
RED + KIK	36,8	153	144	707	0 M	0,8S
FESC + COCK	28,1	105	25	- 175	0 M	0,8S
FESC + PHAL	29,0	109	27	- 155	0,4M	0,4S
FESC + PRYE	29,8	111	25	- 157	0 M	0,8S
FESC + ARYE	31,9	120	30	- 123	0,4M	0,4S
FESC + KIK	41,6*	141	36	- 89	0 M	0,8S
COCK + PHAL	26,2	99	25	- 185	0,4M	0,4S
COCK + PRYE	26,5	98	23	- 195	0 M	0,8S
COCK + ARYE	29,2	107	26	- 168	0,2M	0,6S
COCK + KIK	39,2*	128	34	- 145	0 M	0,8S
PHAL + PRYE	26,1	94	26	- 202	0,6M	0,2S
PHAL + ARYE	25,3	89	26	- 219	0,8M	0 S
PHAL + KIK	44,3*	152	35	- 68	0 M	0,8S
PRYE + ARYE	27,8	97	27	- 199	0,6M	0,2S
PRYE + KIK	43,2*	147	36	- 74	0 M	0,8S
ARYE + KIK	49,1*	170	41	- 7	0 M	0,8S

*Highest values

LUC = Lucerne
WHI = White clover
RED = Red clover
FESC = Fescue
COCK = Cocksfoot
PHAL = *Phalaris*
PRYE = Perennial ryegrass
ARYE = Annual ryegrass
KIK = Kikuyu

and the low potential soils, the optimum lambing time seems to be during September.

5.4.3 Potential seasonal grazing capacity of a number of selected pasture mixtures

The estimated potential seasonal grazing capacity of a number of pasture mixtures selected from tables 5.6 to 5.17 on the basis of estimated potential annual animal production and relative gross income, as well as of a number of pasture mixtures selected on the basis of there present importance in practice, were calculated in terms of dry sheep-units ($SU.ha^{-1}$) at a number of dryland and irrigated sites. The sites were Langgewens (dryland), Elsenburg (dryland and irrigated), Tygerhoek (dryland and irrigated), Outeniqua (dryland and irrigated) and Oudtshoorn (irrigated).

5.4.3.1 Dryland

The results for the dryland sites are depicted in figures 5.16 to 5.19. From figure 5.16 it is clear that there is little difference between the estimated potential monthly grazing capacity of medic and medic plus annual ryegrass pastures at Langgewens. The estimated grazing capacity of the two pasture mixtures seem highly seasonal, with no potential during summer and a gradual increase during winter, with a peak tending to occur during late winter and early spring.

Although, they are not the highest producing at the two sites, the estimated potential grazing capacity of pasture mixtures based on the annual legumes subterranean clover and medics at Elsenburg and Tygerhoek, are also compared in figures 5.17 and 5.18. These pastures seem to have a highly seasonal grazing capacity at these two sites, with the highest values tending to occur during late winter and

Figure 5.16 Predicted potential seasonal grazing capacity ($SU.ha^{-1}$) of pasture mixtures under dryland at Langgewens (MED = medic; ARYE = annual ryegrass)

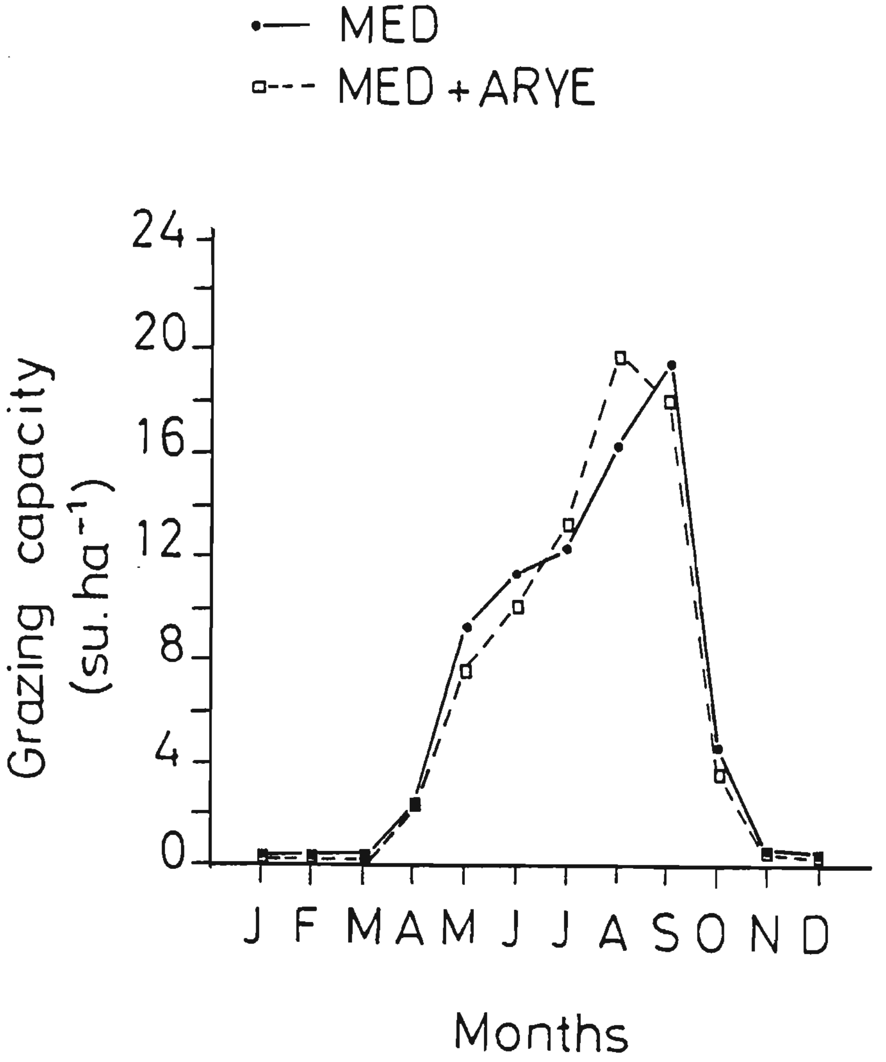


Figure 5.17 Predicted potential seasonal grazing capacity ($SU.ha^{-1}$) of pasture mixtures under dryland at Elsenburg (MED = medic, LUC = lucerne, SUB = subterranean clover, ARYE = annual ryegrass, PHAL = *Phalaris*)

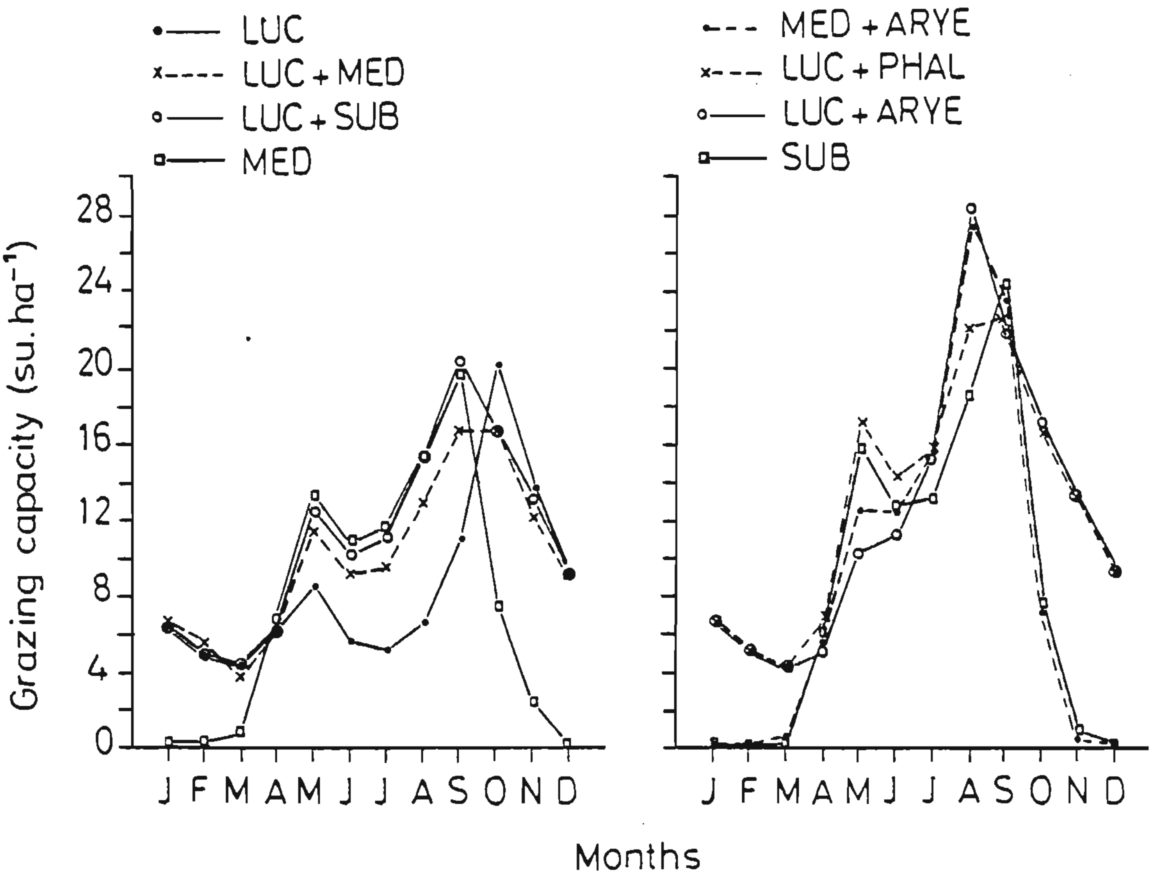


Figure 5.22 Predicted potential seasonal grazing capacity ($SU.ha^{-1}$) of pasture mixtures under irrigation on a high potential soil at Outeniqua (LUC = lucerne, RED = red clover, ARYE = annual ryegrass, FESC = fescue, PHAL = Phalaris, KIK = kikuyu)

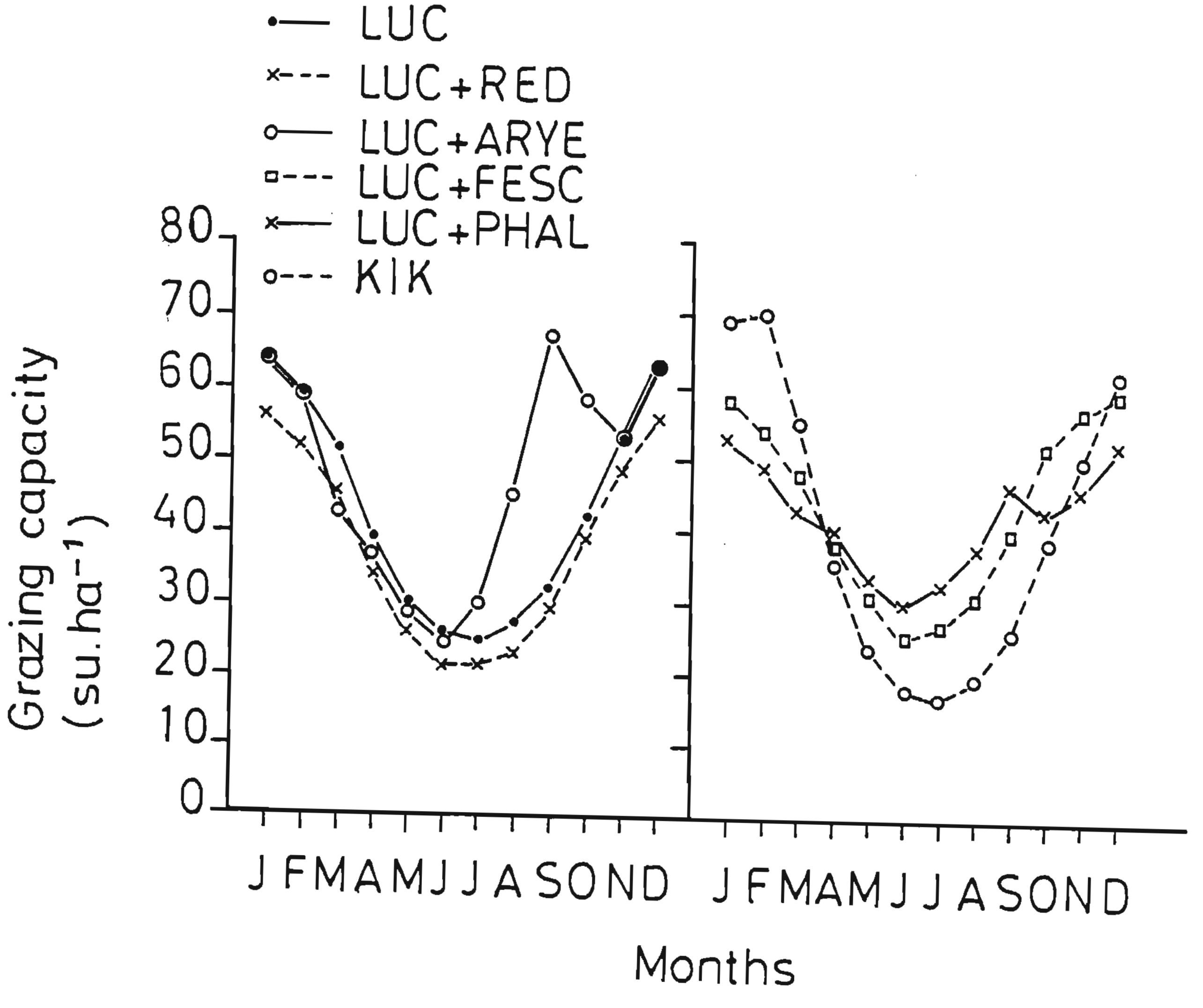


Figure 5.23 Predicted potential seasonal grazing capacity ($SU.ha^{-1}$) of pasture mixtures under irrigation on a high potential soil at Outeniqua (LUC = lucerne, RED = red clover, ARYE = annual ryegrass, FESC = fescue, PHAL = Phalaris, KIK = kikuyu)

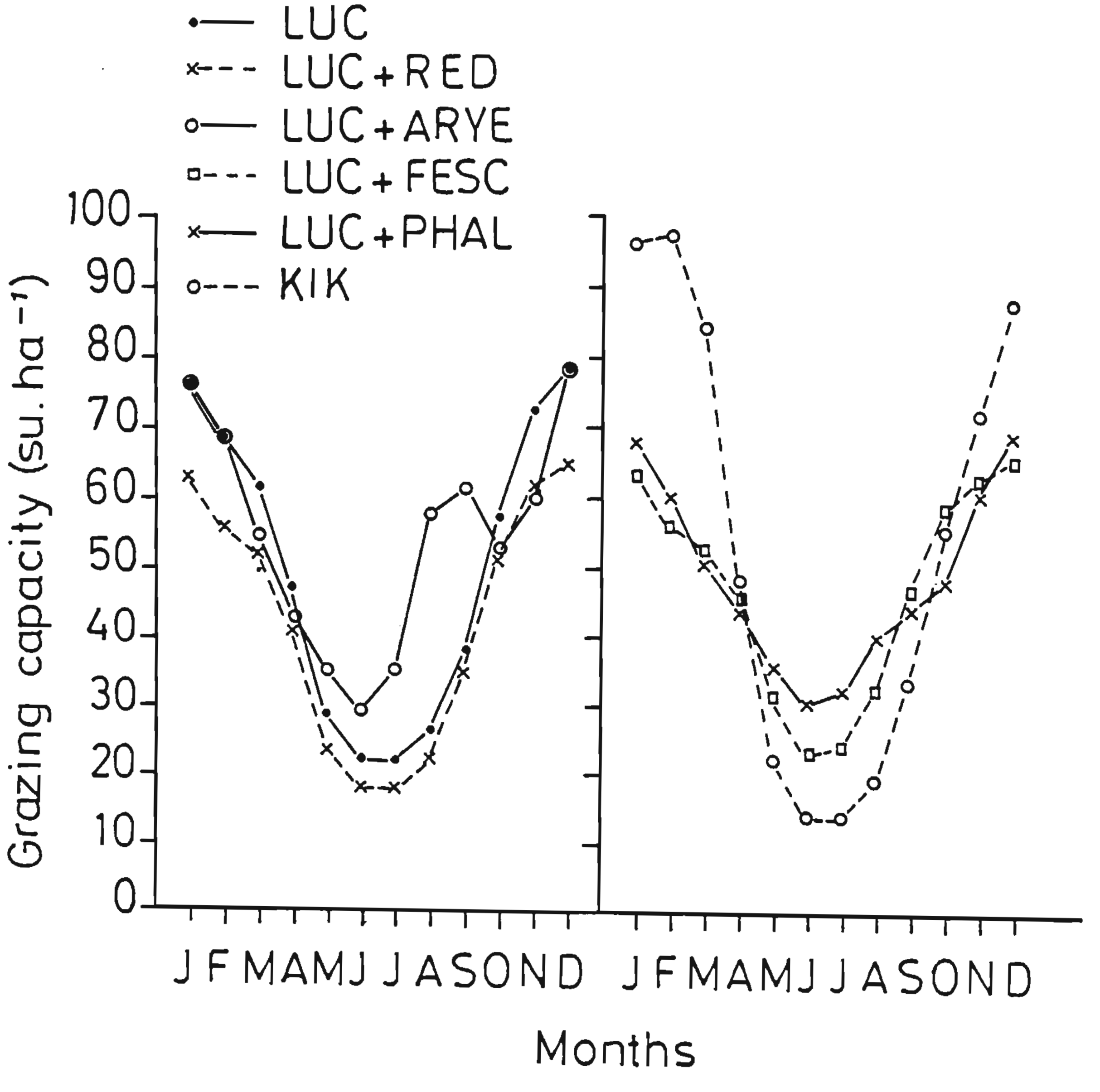


Figure 5.24 Predicted potential seasonal grazing capacity ($SU.ha^{-1}$) of pasture mixtures under irrigation on a low potential soil at Elsenburg (RED = red clover, WHI = white clover, ARYE = annual ryegrass, FESC = fescue, PHAL = *Phalaris*, KIK = kikuyu)

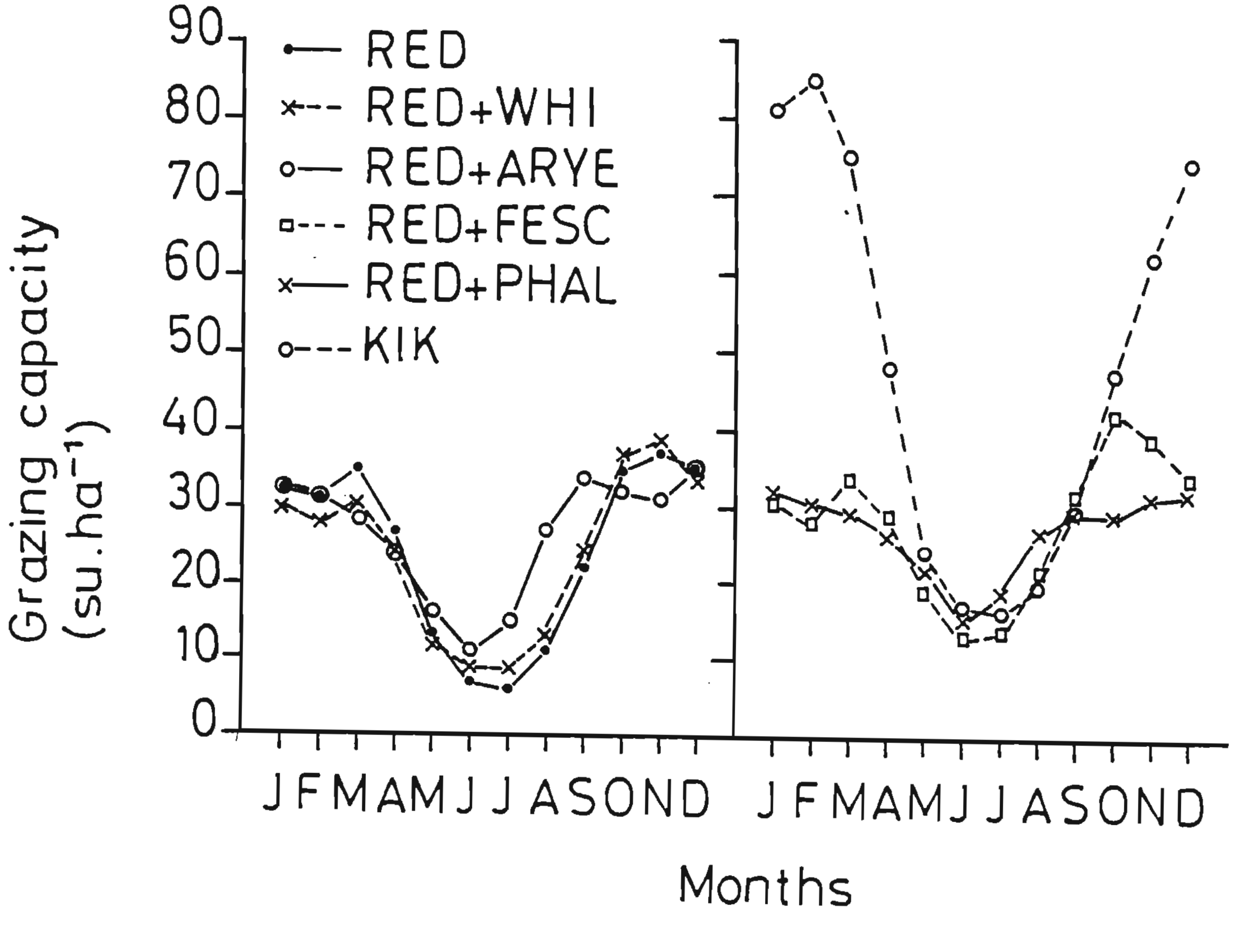


Figure 5.25 Predicted potential seasonal grazing capacity ($SU.ha^{-1}$) of pasture mixtures under irrigation on a low potential soil at Tygerhoek (RED = red clover, WHI = white clover, ARYE = annual ryegrass, FESC = fescue, PHAL = Phalaris, KIK = kikuyu)

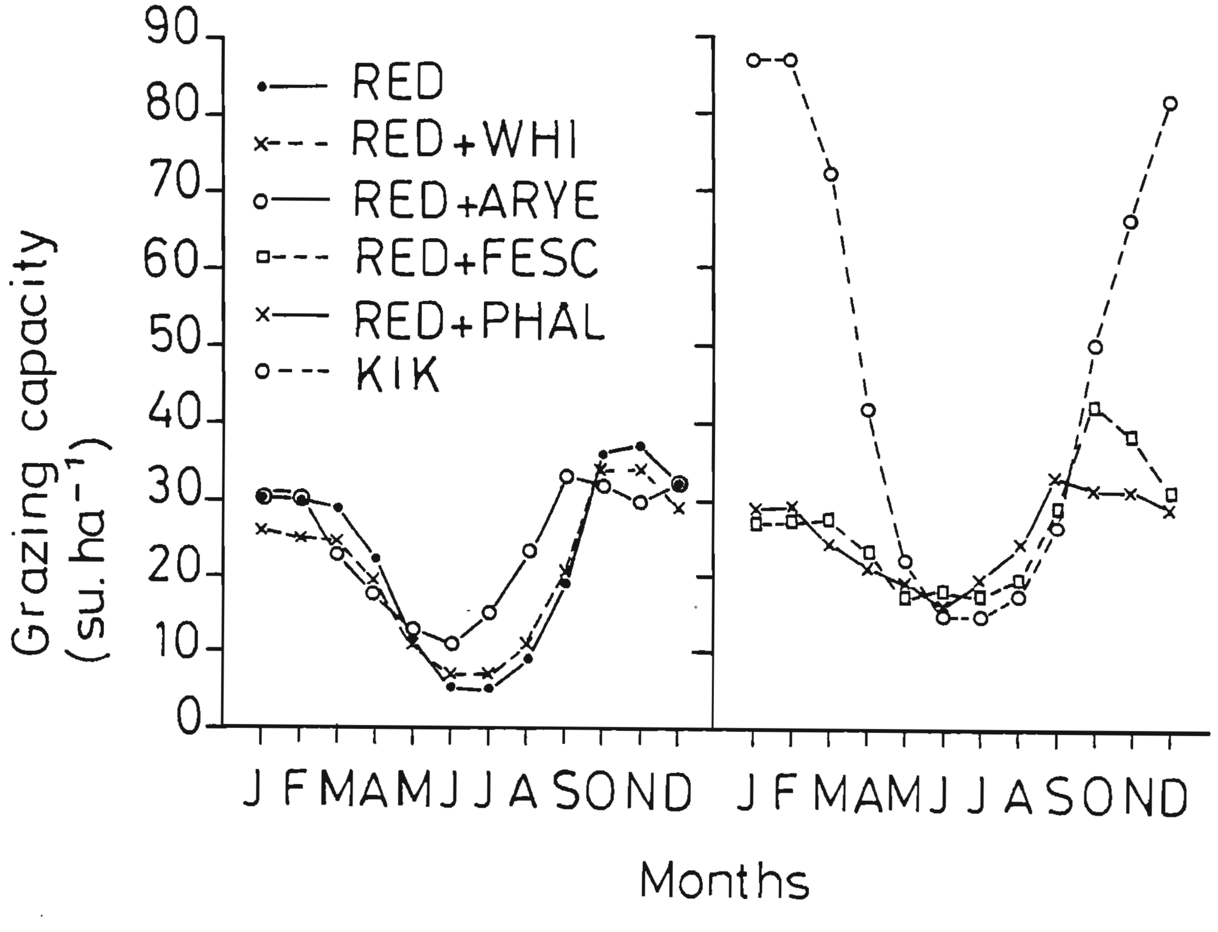


Figure 5.26 Predicted potential seasonal grazing capacity ($SU.ha^{-1}$) of pasture mixtures under irrigation on a low potential soil at Outeniqua (RED = red clover, WHI = white clover, ARYE = annual ryegrass, FESC = fescue, PHAL = Phalaris, KIK = kikuyu)

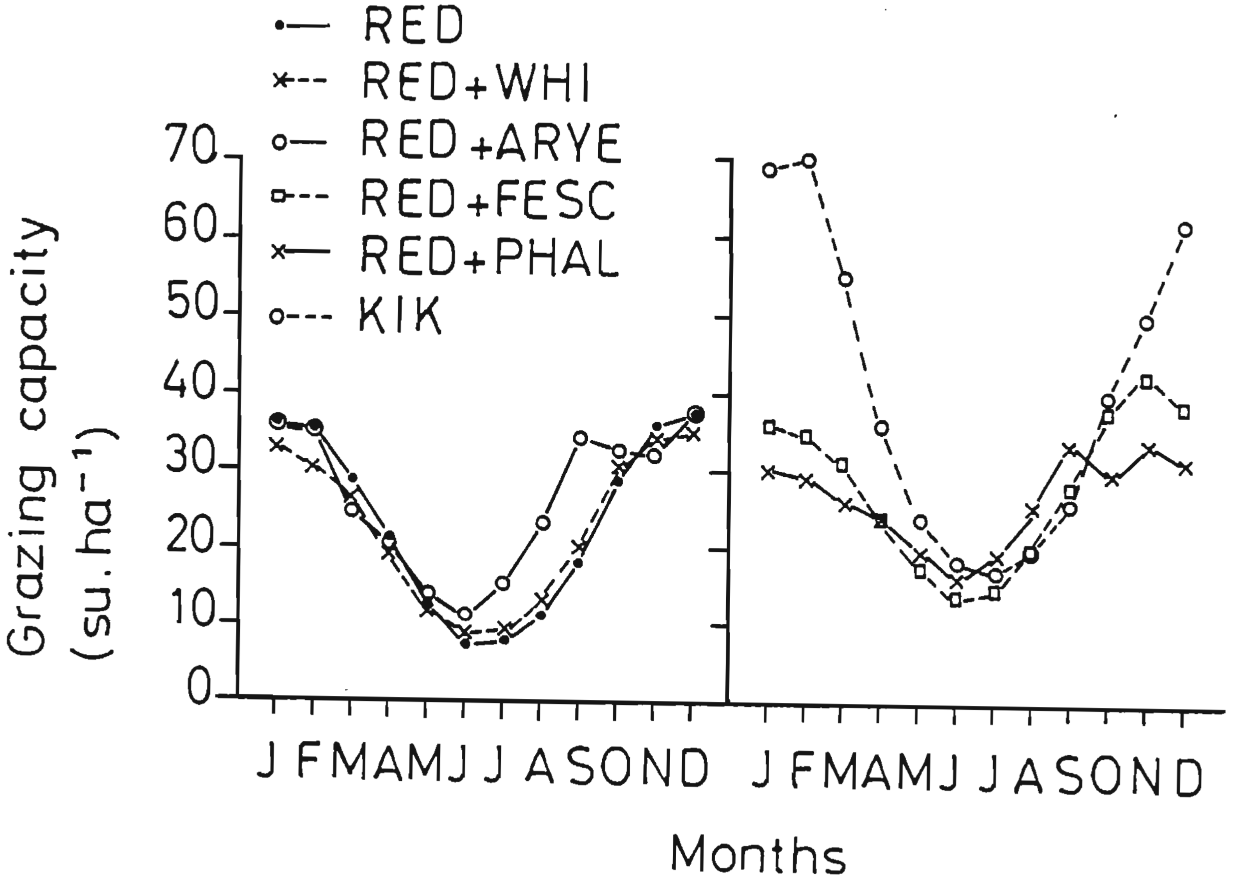
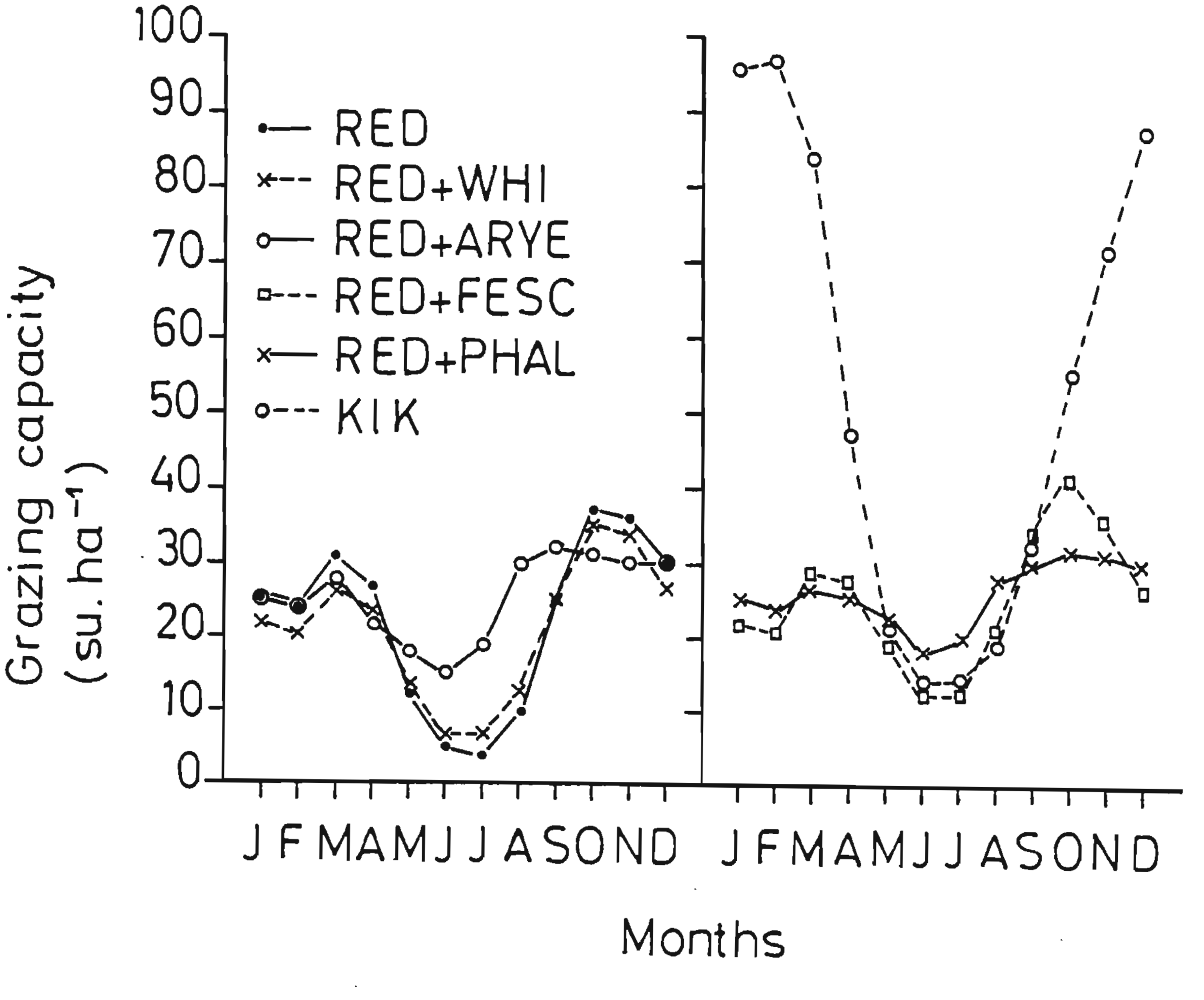


Figure 5.27 Predicted potential seasonal grazing capacity ($SU.ha^{-1}$) of pasture mixtures under irrigation on a low potential soil at Oudtshoorn (RED = red clover, WHI = white clover, ARYE = annual ryegrass, FESC = fescue, PHAL = Phalaris, KIK = kikuyu)



The estimated relative grazing capacities do not seem to differ much between sites with the same soil potential. The kikuyu pasture seem to have the highest estimated potential grazing capacity during summer on both soil types on all sites and, although its potential seems to be relatively low during winter on a high potential soil, it seems to have capacities equal to many of the other pasture types during this time of the year on a low potential soil.

The grass/legume mixtures seem to differ very little in estimated grazing capacity on a low potential soil on all sites, but on the high potential soil situation the differences seem to be much larger. On the high potential soil, the pure lucerne and the lucerne plus annual ryegrass pastures seem to have the highest estimated grazing capacity during summer on all sites. The capacities calculated for the mixtures of lucerne with annual ryegrass and Phalaris, however, seemed to be highest during winter on this type of soil. On the low potential soil the estimated grazing capacity of the red clover plus annual ryegrass, however, tended to be highest on all sites.

5.5 Conclusions

The animal production potential predicted by the model generally agrees reasonably well with actual values. However, as no data were available on the animal production potential of pure grass pastures, the model may be inclined to underestimate the potential gross income of such pastures. Care should therefore be taken when interpreting the relative gross income potential of the different pasture and the differences should be seen as relative rather than actual.

The other shortcomings of the model, as well as the reasons for certain deviations of the predicted from the actual values have already been discussed fully earlier on in the chapter and will therefore not be repeated. The major problem encountered during the validation, however, seems to be the fact that some of the actual data used for the validation of the model were also only estimated values calculated from data derived from grazing trials. The model should, however, be seen as preliminary only and, perhaps even more important, as a basis for the development of a more efficient model. The results, however, clearly indicated that models such as this, which are based on relatively simple principles, can be very successful. The results were also good enough to merit the use of the model for a tentative extrapolation exercise.

The extrapolation to a number of dryland and irrigated sites clearly indicate that, although pure grass pastures, such as kikuyu on a low potential soil under irrigation, often have a higher grazing capacity than grass/legume pastures, the higher animal production potential of the latter group, plus the high cost of nitrogen fertilization on the pure grass pastures, result in the legume based pasture having the highest estimated relative gross income.

Under dryland conditions the choice of pasture species, out of the group evaluated, for a site such as Langgewens which is representative of a Swartland situation, seem to be limited to annual medics and ryegrass. In this case pure medic pastures seem to have the highest estimated animal production potential and gross income.

In the South Coast at Tygerhoek, pastures based on lucerne, with Phalaris and annual ryegrass as grass component, seem to have the highest estimated potential grazing capacity, but combinations of lucerne and the annual legumes, medics and subterranean clover, seem to have the highest potential animal production. The latter mentioned pastures have, however, been found not to be as successful in practice, as the annual species tend to produce very little when sown within a the highly competitive perennial such as lucerne. Mixtures of lucerne and the above mentioned grasses are, however, a very practical proposition, although further research on the compatability of lucerne and relevant perennial grasses is necessary.

At the other dryland site in the South Coast, Outeniqua, lucerne and red clover based mixtures, with Phalaris as the grass component, seem to have the highest estimated potential grazing capacity, while mixtures of red and subterranean clover and lucerne seem to have the highest animal production potential. The mixtures of lucerne and subterranean clover and of lucerne and perennial grasses have the same practical problems as at Tygerhoek, but the mixtures with red clover as the legume base have much more promise. It is, however, at this stage very difficult to say whether the last mentioned legume would be successful under grazing conditions under dryland in this area.

Under irrigation the same group of species seem to be highest producing on the sites Elsenburg, Tygerhoek, Outeniqua and Oudtshoorn. Grass/legume mixtures based on lucerne seem to have the greatest estimated potential animal production and gross income on a high potential soil, while mixtures based on kikuyu seem to have the highest grazing capacity on a low potential soil. The mixtures with kikuyu are, however, not a practical proposition, as the legume component is usually unable to compete with this grass, resulting in the rapid development of a pure kikuyu pasture. As irrigated grass/legume pasture mixtures with the temperate grasses Phalaris and annual ryegrass and the legumes red and white clover as components also seem to have a high estimated animal production potential and relative gross income on a low potential soil, these pastures seem to be a better proposition for a situation such as this.

The results of the extrapolation exercise largely indicated which pasture mixtures have the greatest estimated potential in terms of grazing capacity, animal production and gross income. Further research on the performance of the mixtures with the greatest potential under actual grazing conditions is, however, necessary before the mixtures can be recommended with any confidence.

6 GENERAL CONCLUSIONS

Of the five sub-regions of the Winter Rainfall Region, the South Coast sub-region seems to be the area with the highest and the Swartland the area with the second highest potential for dryland established pastures. All five sub-regions, however, also have irrigable areas near the various mountain ranges and rivers, within which irrigated established pastures are playing a role of ever increasing importance. The majority of these pastures are grass/legume mixtures. For this reason, the research reported in this thesis was mainly based on pasture species which form successful components of such pastures and have been found to have the highest potential, not only in terms of present production, but also in terms of future genetic improvement.

Due to the extremely variable climate within the region and also the complexity of the different farming systems into which pastures have to be integrated, a very large number of species were evaluated, i.e. five legumes: Lucerne (_M sativa_), medics (_M truncatula_), subterranean clover (_T subterraneum_), red clover (_T pratense_) and white clover (_T repens_), and six grasses: kikuyu (_P clandestinum_), tall fescue (_F arundinacea_), cocksfoot (_D glomerata_), _Phalaris aquatica_ and annual (_L multiflorum_) and perennial ryegrass (_L perenne_).

These species were evaluated in cutting trials, executed under dryland at Langgewens, Elsenburg, Tygerhoek and Outeniqua, and under irrigation at Welgevallen, Outeniqua and Oudtshoorn. In these trials most of the species, i.e. with the exception of the medics and subterranean clover, were cut at three frequencies, i.e. four-, six- and eight-weekly. Although it was generally found that site, i.e. soil and climatic differences, had a much greater influence on production rate than cutting frequency, the majority of the species were highest producing when cut every six to eight weeks. The only exceptions were white clover, which was highest producing at a four- to six-weekly cut, and the two ryegrass types, which did not respond significantly to cutting frequency.

The results of the cutting trials also indicated that the seasonal and actual monthly production potential of the different cultivars of a particular species differed less than that of the different species. This fact, and also the fact that cultivar evaluation as such was not the main objective of the study, meant that the results of the different cultivars could be pooled over cutting treatments. The results derived from this have been taken as representative of the species as a whole. These data could therefore subsequently be used for the determination of the seasonal production potential of each species at a particular trial site and, more importantly, they could be used for the development of a climate:pasture production model for each species.

The climate:pasture production models which were eventually developed, were based on the application of a simple growth index concept (GI) to the results of the cutting trials. This was very successful. In the majority of the species, GI values, calculated as the product of a temperature index (TI), a solar radiation index (RI) and a moisture index (MI), using mean monthly climatic data as input, explained the variations in seasonal production adequately. In the case of cocksfoot and annual and perennial ryegrass, however, a fourth index, RTI, derived as a function of solar radiation and temperature, had to be introduced and greatly improved the results.

It was found that the variation in production between sites, and over seasons at the same site under dryland was highly correlated with GI while soil potential had little influence on growth rate. This was attributed to the overriding influence of soil moisture supply under dryland. Under irrigation, however, soil potential had a substantial influence on the production potential of the majority of the species. Lucerne was the pasture type on which soil potential had the greatest influence under irrigation, while kikuyu was the only pasture species on which soil potential had no noticeable influence. In the case of the species responsive to differences in soil potential, a destinction could, however, only be made between a low and a high potential irrigated soil, as the number of soil types were too limited to make a more accurate quantification of the effect of soil potential possible.

The success of the correlation between GI and pasture production rate enabled the extrapolation of the derived production rate data to more seasons, on the same sites, using long-term mean monthly climatic data as input. Under dryland the production rates of the different pasture species were largely limited by moisture supply. It was therefore found that the predicted seasonal production pattern of the different species differed quite substantially between sites during the same months. Under irrigation the main limiting factors were, however, soil potential, temperature and solar radiation. It was therefore generally found that, under irrigation, the predicted potential production rates for different months differed more between seasons and sites differing in soil potential, than between sites with the same soil potential.

Two dryland grazing trials, both at Tygerhoek, and two irrigated grazing trials, one each at Tygerhoek and Outeniqua, were executed. In these the grazing capacity of different pasture mixtures was compared under different management regimes. In all these trials it was found that the legume content of grass/legume pastures had an overriding influence on the production per animal. A highly significant positive relationship was found to exist between the legume content and the production per animal. This was attributed to the higher total digestable nutrient and crude protein content of pastures with a high legume content, and especially a high clover content. Pure grass pastures and pastures with a high grass content generally had a higher grazing capacity than pure legume or grass/legume pastures high in legume content. However, due to a lower production potential per animal, the pastures with a high grass content generally had a lower animal production potential per unit area.

At Tygerhoek under dryland, the grazing capacity and the wool and meat production potential of lucerne and medic pastures were compared at a range of stocking rates, i.e. four, five, six, seven and eight merino ewes per hectare. It was subsequently found that the grazing capacity and animal production potential of lucerne pastures were much higher than that of medic pastures. This was attributed to the higher amount of available green material during summer and the higher average legume content of the available green material during the year on the lucerne pastures. It was not possible to determine the grazing capacity of these two pastures very accurately, due to the insensitivity of the stocking rate to animal response relationship. A stocking rate of about five ewes per hectare on the medic and six per hectare on the lucerne pastures was, however, estimated to be the most practical.

In a second dryland trial at Tygerhoek, the effect of the control of grass weeds by chemical means on the animal production potential of lucerne, medic and subterranean clover pastures was evaluated at four stocking rates, i.e. six, eight, ten and twelve dry merino sheep per hectare.

Chemical grass control increased the meat and wool production per animal at low stocking rates, due to an increase in the legume content of the pastures. However, as stocking rates increased, the difference in animal production between the treated and untreated pastures tended to diminish to such an extent, that the feasability of grass control measures, by the use of chemical herbicides, was doubted.

Under irrigation at Tygerhoek, the grazing capacity of a complex grass/legume mixture, consisting of lucerne, red clover, white clover, tall fescue, cocksfoot and perennial ryegrass, was determined. This was done by, in the first place, using variable stocking rates and three constant grazing pressures (1,5; 2,25 and 3,0 Kg DM.dry sheep-unit^{-1}.d^{-1}) in a six camp grazing system. Secondly three set stocking rates of merino ewes, lambing during September, were applied using either a six camp rotational or a continuous grazing management system.

It was subsequently found that the optimum mean annual stocking rate of this pasture was about 40 dry sheep units per hectare, at a grazing pressure of 2,25 kg DM.sheep^{-1}.d^{-1} over a period of three years. It was also found that rotational grazing resulted in a decrease in the clover content, an increase in the grass content, the maintenance of the lucerne component and a higher grazing capacity, in comparison with a continuously grazed system. The higher clover content of the continuously grazed camps resulted in a higher animal production per unit area during the first two seasons, but during the last season the animal production was highest on the rotationally grazed pastures.

In the irrigated trial at Outeniqua, the grazing capacity and animal production potential of seven pasture mixtures, i.e. pure perennial ryegrass, pure tall fescue, white clover plus ryegrass, white clover plus fescue, white clover plus cocksfoot, lucerne plus fescue and lucerne plus cocksfoot, were evaluated at a single but variable grazing pressure, i.e. 1,65 and 1,55 Kg DM.dry sheep-unit^{-1}.d^{-1}, and two grazing management systems, a five and a seven camp system. The dry matter production potential, grazing capacity and legume content of the pastures were highest on the seven camp system. The response of the animal production potential on the seven pasture mixtures to grazing management, however, varied much more than the previously mentioned parameters. The wool production and the ADG also differed in their response to grazing management. Generally, however, the animal production on the white clover based pastures was promoted by a seven camp system, while that of the lucerne based pastures was, surprisingly, either not influenced by grazing management or promoted by a five camp system. The fescue based pastures generally had the highest grazing capacity, while the white clover based pastures generally had the highest animal production potential. The lucerne and white clover based pastures, however, had about the same grazing capacity.

Results found in the grazing trials seemed to indicate that the Jones & Sandland (1974) relationship between stocking rate and animal production was not always successful as a basis for the determination of the optimum stocking rate. Using the data of two of the trials, it was found that a relationship very similar to that of Jones & Sandland (1974) could be derived. The results, however, also indicated that the correct estimation of the optimum stocking rate by this model was largely dependent on the sensitivity of the stocking rate to animal production relationship. In cases where the relationship was very insensitive, an overestimation of the optimum stocking rate was likely. This is usually the case when the duration of the trial is very long or when very large variations in available material and quality of available material occur during the trial period.

Due to the success of the climate:pasture production models, a larger interactive climate:pasture:animal production model, with a merino type of sheep as basis, was eventually developed. This model uses the climate:pasture production models as a basis and also uses the same climatic data as input. It further makes provision for five levels of soil potential: dryland, well drained; dryland, wet; irrigated, high potential; irrigated, low potential but well drained; irrigated, low potential but wet. Within each group a total of three pasture mixtures can be compiled, chosen out of lists supplied for each situation by the model and based on the climate and soil potential. The model also provides for the choice of six different lambing times, and any possible combination of lambing and weaning percentage and calculates the monthly and mean annual grazing capacity of each pasture and the whole farm. It subsequently also calculates the wool and meat production based on the grazing capacity, the legume content of the pasture material and the availability of grazing material. Using mean soil analysis data of the Winter Rainfall Region as basis, and mean values for wool, meat, fertilizer and animal handling costs, it also estimates the gross income of the farm.

The model was validated by comparing its results with those derived in the grazing trials. The main problem was, however, that it was very difficult to quantify the animal production potential of the pastures evaluated. By changing the grazing pressures, different grazing capacities could have been derived in the grazing trials, leading to their over or underestimation by the model. Problems with the application of the Jones & Sandland (1974) model under dryland, as has already been discussed, also led to problems in the quantification of the animal production potential of pastures based on the results of the grazing trials. It was, however, generally found that the predicted results tended to agree reasonably well with the actual data derived in the grazing trials and it was concluded that the model could be used, on a very limited basis, to extrapolate the results derived in the plot and grazing trials to other sites and other seasons at the same sites.

The extrapolation exercise indicated that pure grass pastures had the highest grazing capacity, but that grass/legume mixtures had the highest animal production potential and economic viability. Under dryland at Langgewens in the Swartland, the choice of pastures seem to be limited to medics or medics plus annual ryegrass. For Elsenburg and Tygerhoek the model indicated that pastures based on lucerne with or without Phalaris may have the highest potential. At Outeniqua under dryland, pastures based on lucerne or red clover, with Phalaris as main grass component, seem to have the highest potential.

Under irrigation the same pastures seem to be highest producing at Elsenburg, Tygerhoek, Outeniqua and Oudtshoorn. On a high potential soil the model indicates that grass/ legume mixtures based on lucerne and Phalaris may have the highest animal production potential. On a low potential soil, however, grass/legume mixtures with kikuyu as grass component seem to have the greatest potential. Due to the practical problem of kikuyu being very incompatible with legumes, more practical and economically viable mixtures with an almost equally high production potential would, however, seem to be those based on white and/or red clover, with Phalaris or annual and perennial ryegrass as the grass components.

REFERENCES

Alberda, Th. & Sibma, L., 1968. Dry matter production and light interception of crop surfaces. 3. Actual herbage production in different years as compared with potential values. J. Brit. Grassld. Soc., 23, 206 - 215.

Allden, W. G., 1962. Rate of herbage intake and grazing time in relation to herbage availability. Proc. Aust. Soc. Anim. Prod., 4, 163 - 166.

Angstrom, A., 1925. On radiation and climate. Geogr. annlr., 7, 122 - 142.

Appleby, A. P.; Olson, P. D. & Colbert, D. R., 1976. Winter wheat yield reduction from interference by Italian ryegrass. Agron. J., 68, 463 - 466.

Arnold, G. W., 1975. Herbage intake and grazing behaviour in ewes of four breeds at different physiological states. Aust. J. Agric. Res., 26, 1017 - 1024.

Baier, W. & Robertson, G. W., 1966. A new versatile soil moisture budget. Can. J. Plant. Sci., 46, 299 - 315.

Baier, W., 1973. Crop-weather analysis model. 1. Summary. Int. J. Biometeor., 17, 313 - 320.

Barret, D. W. & Campbell, N. A., 1973. An evaluation of effects of competition between wheat and Wimmera ryegrass (*Lolium rigidum*) during early stages of growth. Aust. J. Exp. Agric. & Anim. Husb., 13, 581 - 586.

Beyers, C. P. de L., 1983. Bemesting van aangeplante weidings. Winterreën, Spes. Uitgawe no 5, 54 - 59.

Black, J. N., 1963. The interrelationship of solar radiation and leaf area index in determining the rate of dry matter production of swards of subterranean clover (Trifolium subterraneum). Aust. J. Agric. Res., 14, 20 - 38.

Bot, J.; Sweet, S. & Hollings, N., 1984. A guide to the use of pesticides in the Republic of South Africa. P. P. R. I.

Bransby, D. I. & Tainton, N. M., 1977. The disc pasture meter: possible applications in grazing management. Proc. Grassld. Soc. Sth. Afr., 12, 115 - 118.

Bransby, D. I., 1984. A model for predicting livemass gain from stocking rate and annual rainfall. J. Grassld. Soc. Sth. Afr., 1, 22 - 26.

Brougham, R. W., 1958. Interception of light by foliage of pure and mixed stands of pasture plants. Aust. J. Agric. Res., 9, 39 - 52.

Brougham, R. W., 1959. The effects of season and weather on the growth rate of a ryegrass and clover pasture. N. Z. Jl. Agric. Res., 2, 283 - 286.

Brougham, R. W., 1960. The relationship between critical leaf area, total chlorophyll content and maximum growth rate of some pasture and crop plants. Ann. Bot. Lond. (N.S.), 24, 463 - 474.

Brougham, R. W. & Glenday, A. C., 1969. Weather fluctuations and the daily rate of growth of pure stands of three grass species. N. Z. Jl. Agric. Res., 12, 125 - 136.

Cairns, A. L. P., 1979. The biology of weeds. Agric. & Vet. Chem. Assoc. S.A., 5 - 12.

Campbell, R. J.; Robards, G. E. & Saville, D. G., 1972. The effect of grass seed on sheep production. Proc. Aust. Soc. Anim. Prod., 9, 225 - 229.

Carter, E. D., 1980. The survival of medic seeds following ingestion of intact pods by sheep. Aust. Agron. Conf., Galton, Qld., 178.

Carter, E. D., 1981. Seed and seedling dynamics of annual medic pastures in South Australia. Proc. XIV Int. Grassld. Congr., Univ. Kentucky, U. S. A.

Carter, E. D.; Wolfe, E. C. & Francis, C. M., 1982. Problems of maintaining pastures in the cereal-livestock areas of Southern Australia. Proc. Aust. Agron. Conf., Wagga-Wagga, N. S. W., 68 - 82.

Castle, M. E., 1976. A simple instrument for estimating herbage yield. J. Brit. Grassld. Soc., 31, 37 - 40.

Chang, J., 1968. Climate and agriculture. An ecological survey. Aldine Publ. Comp., Chicago.

Cocks, P. S., 1974. Potential production of grass and clover monocultures in a mediterranean-type environment - an experimental approach. Aust. J. Agric. Res., 25, 835 - 846.

Cocks, P. S., 1975. Volunteer plants in annual pastures. J. Agric. S. Aust., 78, 95 - 99.

Coetzee, F. J. & Schifano, G., 1970. Geological map of the Republic of South Africa and the Kingdoms of Lesotho and Zwaziland. Geological Survey, Pretoria.

Colman, R. L.; Lazenby, A. & Grierson, J., 1974. Nitrogen fertilizer responses and seasonal production of temperate and warm climate grasses on the Northern Tablelands of New South Wales. Aust. J. Exp. Agric. & Anim. Husb., 14, 362 - 372.

Conniffe, D.; Browne, D. & Walshe, M. J., 1970. Experimental design for grazing trials. J. Agric. Sci. Camb., 74, 339 - 342.

Cooper, J. P., 1960. The use of controlled life-cycles in the forage grasses and legumes. Herb. Abstr., 30, 71 - 79.

Cowlishaw, S. J., 1969. The carrying capacity of pastures. J. Brit. Grassld. Soc., 24, 207 - 214.

Danckwerts, J. E. & King, P.G., 1984. Conservative stocking or maximum profit: a grazing management dilemma ? J. Grassld. Soc. Sth. Afr., 1, 25 - 28.

Dane, C. M. W., 1979. Weed killers for use in lucerne and clovers in the Winter Rainfall Region. Agric. & Vet. Chem. Assoc. S.A., 268 - 283.

De Wit, C. T., 1959. Potential photosynthesis of crop surfaces. Neth. J. Agric. Sci., 7, 141 - 149.

Donahue, R. L.; Evans, E. F. & Jones, L. I., 1956. The range and pasture book. Prentice Hall, Inc., England Cliffs, N. J.

Edwards, P. J., 1980. The use of stocking rate/animal performance models in research and extension. Proc. Grassld. Soc. Sth. Afr., 15, 73 - 77.

Fitzgerald, R. D., 1976. Effects of stocking rate, lambing time and pasture management on wool and lamb production on annual subterranean clover pasture. Aust. J. Agric. Res., 27, 261 - 265.

Fitzpatrick, E. A. & Nix, H. A., 1975. The climatic factor in Australian grassland ecology. In: Australian grasslands. Ed. R. M. Moore. Aust. Nat. Univ. Press, Canberra.

Freer, M. & Jones, D. B., 1984. Feeding value of subterranean clover, lucerne, phalaris and Wimmera ryegrass for lambs. Aust. J. Exp. Agric. & Anim. Husb., 24, 156 - 164.

Fukai, S. & Silsbury, J. H., 1978. A growth model for Trifolium subterraneum swards. Aust. J. Agric. Res., 29, 51 - 65.

Gibb, M. J. & Treacher, T. T., 1983. The performance of lactating ewes offered diets containing different proportions of fresh perennial ryegrass and white clover. Anim. Prod., 37, 433 - 440.

Gibb, M. J. & Treacher, T. T., 1984. The performance of weaned lambs offered diets containing different proportions of fresh perennial ryegrass and white clover. Anim. Prod., 39, 413 - 420.

Hanks, R. J., 1974. Model for predicting plant yield as influenced by water use. Agron. J., 66, 660 - 665.

Holliday, R., 1966. Solar energy consumption in relation to crop yield. Agric. Prog., 41, 24 -34.

Hutchinson, K. J., 1967. A coring technique for the measurement of pasture of low availability to sheep. J. Brit. Grassld. Soc., 22, 131 - 134.

Johns, G. G. & Smith, R. C. G., 1975. Accuracy of soil water budgets based on a range of relationships for the influence of soil water availability on actual use. Aust. J. Agric. Res., 26, 871 - 883.

Jones, R. J. & Sandland, R. L., 1974. The relation between animal gain and stocking rate. Derivation of the relation from the results of grazing trials. J. Agric. Sci. Camb., 83, 335 - 342.

Kenney, P. A. & Black, J. L., 1984. Factors affecting diet selection by sheep. 1. Potential intake rate and acceptibility of feed. Aust. J. Agric. Res., 35, 551 - 563.

Kenny, P. T., 1984. The growth of weaner sheep on clover or grass pastures during summer in Western Victoria. Aust. J. Exp. Agric. & Anim. Husb., 24, 144 - 149.

Kenny, P. T. & Reed, K. E. M., 1984. Effects of pasture type on the growth and wool production of weaner sheep during summer and autumn. Aust. J. Exp. Agric. & Anim. Husb., 24, 322 - 331.

Lamprechts, Sandra C., 1983. Diseases of Medicago spp. in South Africa. M. Sc. Agric. thesis, U. S.

Landsberg, J. J., 1977. Some usefull equations for biological studies. Expl. Agric., 13, 273 - 286.

Langenhoven, J. D., 1978. 'n Ondersoek na die fosforvereistes van Trifolium subterraneum L. en Medicago truncatula Gaertn. op gronde van die Glenrosa-vorm in die Winterreënstreek. M. Sc.-landbouverhand., U. S.

Langer, R. H. M. (Ed), 1973. Pastures and pasture plants. A. H. & A. W. Reed, London.

Leigh, J. H. & Noble, J. C. (Eds), 1972. Plants for sheep in Australia. A review of pasture, browse and fodder crop research, 1948 - 70. Angus & Robertson, Sydney.

Le Roux, D. J., 1983. Onkruid in weidings in die Winterreënstreek. Winterreën, Spes. uitgawe no 5, 60 - 66.

Lewis-Beck, M. S., 1980. Applied regression. An introduction. Sage Public., London.

Lloyd Davies, H., 1962. Intake studies in sheep involving high fluid intake. Proc. Aust. Soc. Anim. Prod., 4, 167 - 171.

Loomis, R. S. & Williams, W. A., 1963. Maximum crop productivity: An estimate. Crop. Sci., 3, 67 - 72.

Louw, W. J., 1965. 'n Ondersoek na die konstantes a en b in die Angstrom formule vir die bepaling van totale stralings-energie uit sonskynuurgegewens. M. Sc.-landbouverhand., U. O. V. S.

Lynch, L. G., 1976. Use of growth indices to, explain pasture cut yields. J. Soil. Cons. N. S. W., 32, 47 - 53.

McCree, K. J. & Troughton, J. A., 1966. Non-existence of an optimum leaf area index for the production rate of white clover grown under constant conditions. Plant Physiol., 41, 1615 - 1622.

McGown, R. L., 1973. An evaluation of the influence of available water storage capacity on growing season length and yield of tropical pastures, using simple water balance models. Agric. Met., 11, 53 - 63.

McKinney, G. T., 1974. Management of lucerne for sheep grazing on the Southern Tablelands of New South Wales. Aust. J. Exp. Agric. & Anim. Husb., 14, 726 - 734.

Milne, J. A.; Hodgson, J.; Thompson, R.; Souter, W. G. & Barthram, G. T., 1982. The diet ingested by sheep grazing swards differing in white clover and perennial ryegrass content. Grass & Forage Sci., 37, 209 - 218.

Mitchell, K. J. & Lucanus, R., 1962. Growth of pasture species under controlled environment. 3. Growth at various levels of constant temperature with 8 to 16 hours of uniform light per day. N. Z. Jl. Agric. Res., 5, 135 - 144.

Mitchell, P., 1982. Value of a rising plate meter for estimating herbage mass of grazed perennial ryegrass-white clover swards. Grass & Forage Sci., 37, 81 - 87.

Monteith, J. L., 1966. Physical limitations to crop growth. Agric. Prog., 41, 9 - 23.

Morley, F. H. W.; Bennett, D. & McKinney, G. T., 1969. The effect of rotational grazing with breeding ewes on phalaris-subterranean clover pastures. Aust. J. Exp. Agric. & Anim. Husb., 9, 74 - 84.

Mott, G. O., 1960. Grazing pressure and the measurement of pasture production. Proc. VIII Intern. Grassld. Congr., Reading, 606 - 611.

Myers, L. F. & Squires, V. R., 1970. Control of barley grass (Hordeum leporinum) by grazing management in irrigated pastures. Aust. J. Exp. Agric. & Anim. Husb., 10, 151 - 155.

Owen, J. B. & Ridgmann, W. J., 1968. The design and interpretation of experiments to study animal production from grazed pastures. J. Agric. Sci. Camb., 71, 327 - 335.

Petersen, R. G. & Lucas, H. L., 1968. Computing methods for the evaluation of pastures by means of animal respons. Agron. J., 60, 682 - 687.

Pienaar, C. J. & Volschenk, J. E., 1970. Aangeplante weidings onder droëlandtoestande in die Winterreën-streek van die R. S. A., Boerdery S. A., 46, 15 - 33.

Pownall, D. B.; Lucas, R. J. & Abrahamson, M., 1984. The influence of pasture allowance on the performance of autumn shorn lambs. Proc. N. Z. Soc. Anim. Prod., 44, 49 - 51.

Rattray, P. V., 1978. Pasture constraints to sheep production. Proc. Agron. Soc. N. Z., 8, 103 - 108.

Rattray, P. V. & Jagusch, K. T., 1978. Pasture allowances for the breeding ewe. Proc. N. Z. Soc. Anim. Prod., 38, 121 - 126.

Reeves, T. G. & Smith, I. S., 1975. Pasture management and cultural methods for the control of annual ryegrass (Lolium rigidum) in wheat. Aust. J. Exp. Agric. & Anim. Husb., 15, 527 - 530.

Reeves, T. G., 1976. The effect of annual ryegrass (Lolium rigidum) on yield of wheat. Weed Res., 16, 57 - 63.

Rose, C. W.; Begg, J. E.; Byrne, G. F.; Torsell, B. W. R. & Goncz, J. H., 1972. A simulation model of growth-field environment relationships for Townsville Stylo (Stylosanthus humilis H. B. K.) pasture. Agric. Met., 10, 161 - 183.

Rose, C. W., 1973. The role of modelling and field experiments in understanding complex systems. In: Developments in field experiment design and analysis. Proc. Symp. Univ. New Eng., C. A. B., Eds: V. J. Bofinger & J. L. Wheeler.

Schneider, D. J., 1981. First report on annual ryegrass toxicity in the Republic of South Africa. Onderst. J. Vet. Res., 48, 251 - 255.

Scott, B. J.; Quilty, J. A. & Milthorpe, P. L., 1972. Evaluation of annual pasture legumes for the low rainfall arable areas of the western division of New South Wales. J. Soil. Cons. N. S. W., 28, 181 - 190.

Scott, B. J. & Brownlee, H., 1976. Assesment of annual legumes for pastures on the low rainfall wheat belt of central western New South Wales. Aust. J. Exp. Agric. & Anim. Husb., 16, 739 - 747.

Sim, J. T. R., 1958. Agronomy research in the Winter Rainfall Region, 1892 - 1953. Sci. Pamphl. no 373, Dept. Agric U. of S. A.

S. I. R. I., 1985. Climate statistics for the Winter Rainfall Region up to 1983. Sect. Agromet., Elsenburg, Dept. Agric. & Water Suppl.

Slatyer, R. O., 1956. Evapotranspiration in relation to soil moisture. Neth. J. Agric. Sci., 4, 73 - 76.

Smith, R. C. G. & Williams, W. A., 1973. Model development for a deferred-grazing system. J. Range Mngmt., 26, 454 - 460.

Smith, R. C. G. & Johns, G. G., 1975. Seasonal trends and variability of soil moisture under temperate pastures on the Northern Tablelands of New South Wales. Aust. J. Exp. Agric. & Anim. Husb., 15, 250 - 255.

Smith, R. C. G. & Stephens, M. J., 1976. Importance of soil moisture and temperature on the growth of improved pasture on the Northern Tablelands of New South Wales. Aust. J. Agric. Res., 27, 63 - 70.

Spedding, C. R. W. & Diekmahns, E. C., 1971. Grasses and legumes in British agriculture. C. A. B., Alden & Mowbray Ltd., Oxford.

Stanhill, G., 1962. The effect of environmental factors on the growth of alfalfa in the field. Neth. J. Agric. Sci., 10, 247 - 253.

Staphorst, J. L. & Strijdom, B. W., 1974. Effect of treatment with dimethoate insecticide on nodulation and growth of M. sativa. Phytophyl., 6, 205 - 208.

Starke, J. J., 1955. The influence of micro-elements on the yield and composition of Ladino clover in the George area. M. Sc. Agric. thesis, U. S.

Stewart, T. A.; Haycock, R. E. & McBurney, S. A., 1983. Beef from white clover/grass or high N grass swards - Economic results from ten years. Agric. N. Irel., 58, 75 - 79.

Stewart, T. A. & McCullough, I. I., 1985. Comparison of silage made from red clover/grass, white clover/grass and high nitrogen grass swards for beef production. Anim. Prod., 40, 267 - 277.

Stockdale, C. R., 1984. Evaluation of techniques for estimating the yield of irrigated pastures intensively grazed by dairy cows. 2. The rising plate meter. Aust. J. Exp. Agric. & Anim. Husb., 24, 305 - 311.

Stockdale, C. R. & Kelly, K. B., 1984. A comparison of a rising plate meter and an electronic capacitence meter for estimating the yield of patures grazed by dairy cows. Grass & Forage Sci., 39, 391 - 394.

Streeksontwikkelingsprogram, 1981. Dept. Landbou en Visserye, Winterreënstreek.

Stynes, B. A. & Wise, J. L., 1980. The distribution and importance of annual ryegrass toxicity in Western Australia and its occurrence in relation to cropping rotations and cultural practices. Aust. J. Agric. Res., 31, 557 - 569.

Terblanche, P. N. J., 1974. Evaluering van 'n gemengde aangeplante weiding in 'n Mediterreënse omgewing deur middel van Merino-ooie. M. Sc.-landbouverhand., U. S.

Trumble, H. C., 1939. The climatic control of agriculture in South Australia. Trans. Roy. Soc. S. Aust., 61, 41 - 62.

van Heerden, J. M. & Wassermann, V. D., 1977. Die invloed van plantdatum op die blomvorming en produksie van twaalf Mediterreënse weidingspeulgewasse in 'n Mediterreënse omgewing. Hand. Weidingsver. S. Afr., 12, 45 - 49.

van Heerden, J. M., 1981. Aanbevelings vir weidingsmengsels in die Winterreënstreek. Winterreën, 2, 23 - 26.

van Heerden, J. M. & Wassermann, V. D., 1981. Die invloed van grondtemperatuur op die fenologiese ontwikkeling en groei van drie eenjarige weidingspeulgewasse. Agroplantae, 13, 1 - 6.

van Heerden, J. M., 1983. Die seisoenale drakrag en bestuur van aangeplante gras/peulgewasweidings onder besproeiing. Winterreën, Spes. Uitgawe no 5, 67 - 78.

van Heerden, J. M., 1984. Influence of temperature and daylength on the phenological development of annual *Medicago* spp., with particular reference to *M. truncatula*, cv. Jemalong. S. Afr. J. Plant & Soil, 1, 73 - 74.

van Heerden, J. M. & Beukes, D. J., 1984. Die besproeiingsbehoefte van drie meerjarige weidingsmengsels in die Winterreënstreek. S. A. Besproeiing, Junie, 23 - 34.

Venn, N. R., 1984. Control of grasses in pastures and legume crops with fluazifop-butyl. Aust. J. Exp. Agric. & Anim. Husb., 24, 612 - 616.

Vickery, P. J. & Hedges, D. A., 1972. A productivity model of improved pastures grazed by Merino sheep. Proc. Aust. Soc. Anim. Prod., 9, 16 - 22.

Walker, J., 1975. Take-all diseases of Gramineae: A review of recent work. Rev. Pl. Path., 54, 113 - 114.

Walters, M. C., 1968. A study of *Sminthurus viridus* L. (Collembola) in the Western Cape Province. Entomol. Mem. Dep. Agric. S. A., no 16.

Wassermann, V. D. & Wicht, J. E., 1972. A preliminary evaluation of rose clover (*Trifolium hirtum* All.) and cupped clover (*Trifolium cherleri* L.) as pasture legumes in the cereal areas of the Winter Rainfall Region. Proc. Grassld. Soc. Sth. Afr., 7, 93 - 98.

Wassermann, V. D., 1979. Some views on the potential of legume based pastures in South Africa. Proc. Grassld. Soc. Sth. Afr., 7, 93 - 98.

Wassermann, V. D., 1981. Temperate pasture mixtures for the Winter Rainfall areas. Farm S. A., C.4, Div. Agric. Info., Pretoria.

Weihing, R. M., 1963. Growth of ryegrass as influenced by temperature and solar radiation. Agron. J., 55, 519 - 521.

Wheeler, J. L.; Burns, J. C.; Mochrie, R. D. & Gross, H. D., 1973. The choice of fixed or variable stocking rates in grazing experiments. Expl. Agric., 9, 289 - 302.

White, D. H.; Elliot, B. R.; Sharkey, M. J. & Reeves, T G., 1977. Efficiency of land-use systems involving crops and pastures. J. Aust. Inst. Agric. Sci., 44, 21 - 27.

Whyte, R. O.; Nilsson-Leissner, G & Trumble, H. C., 1953. Legumes in agriculture. F.A.O. agric. studies no 21.

Whyte, R. O.; Moir, T. R. G. & Cooper, J. P., 1959. Grasses in agriculture. F. A. O. agric. studies no 42.

Wicht, J. E., 1970. Studies on the effect of light energy and temperature on Trifolium subterraneum L. and Trifolium hirtum All. in a natural environment. M.Sc. Agric. thesis, U. S.

Wicht, J. E.; Loubser, J. W. & Landman, M., 1978. The Swartland land utilization and management trial. Crop. Prod., 7, 41 - 47.