

T ✓ AN ASSESSMENT OF ✓ COASTCROSS II ✓ BERMUDAGRASS AND KIKUYU

FOR GROWING OUT YOUNG BEEF ANIMALS /

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NT Thesis ( Ph.D; Grassland Science ) - University of Natal, Pietermaritzburg, 1983.

September 1983.  
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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.

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DECLARATION

This thesis and the associated research comprises my own original work except for assistance which is acknowledged, or where due reference is made in the text.

A handwritten signature in blue ink, appearing to read 'D.I. Bransby', written in a cursive style.

D.I. BRANSBY

## ACKNOWLEDGEMENTS

I am extremely grateful to Professor Neil Tainton, my supervisor, for his support and helpful suggestions in all aspects of this study. His keen interest in the research provided constant encouragement and his analytical mind and approach to research have been greatly stimulating. I am particularly grateful to him for his exceptional willingness to review this thesis and advise on its preparation amongst his numerous other responsibilities as Dean of the Faculty of Agriculture. I also thank Professor P. de V. Booyesen for his ideas and suggestions in the initial stages of the research, and Professor Peter Clarke for statistical guidance.

Due to the extended period and the relatively large scale of this research programme, it required a high physical input. For many months of assistance with what were often tedious tasks in the field I am indebted to Roger Nash, John Tidbury and Rosemary Gordon.

I thank Maureen Goddard for her excellent preparation of the text in this thesis and with the assistance of Rosemary Gordon, for the immaculate draft work on the figures. Above all, her remarkably cheerful disposition at all times was greatly appreciated. I also appreciate the patient understanding of my wife, Pat, her tolerance of my distraction from family responsibilities and her support during my personal ups and downs.

The cost of this research programme has run into many thousands of rands. The University of Natal is acknowledged for

providing the research facilities and many of the physical inputs. In addition, the Department of Agriculture, the Fertilizer Society of South Africa and the Meat Board are thanked for their substantial financial contributions.

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## SUMMARY

The immediate aim of this study was to relate herbage availability, liveweight gain and stocking rate to one another under continuous and rotational grazing so that management recommendations could be formulated for Coastcross II Bermudagrass and kikuyu. In addition, these data would be used for an economic evaluation of growing out young beef animals on these two pasture species. The broad long term goal was to use this information to persuade farmers to make more use of planted pastures and thereby reduce the stocking pressure on the veld. Besides pursuing the primary objectives, the study offered an opportunity to make an observational assessment of the put-and-take technique for use in grazing trials.

In relation to fixed stocking, variable stocking appeared to have no distinct advantage in this study. This conclusion is drawn from the fact that little success was achieved in applying put-and-take at a high level of precision. It was therefore recommended that future trials should make use of fixed stocking, except when variation in herbage availability is very large and predictable. In such cases the use of put-and-take would be warranted.

Liveweight gain of animals was linearly related to herbage availability. In two seasons liveweight gain of animals on Coastcross was higher for continuous grazing than for rotational grazing at equivalent herbage availability, but in other seasons there was no difference between the two methods of grazing. At equivalent levels of herbage availability liveweight gain was higher in early summer than in late summer.



Herbage availability decreased linearly within each season and on average, rotational grazing resulted in increasingly greater herbage availability than continuous grazing, as stocking rate was increased on Coastcross. However, no difference between the two grazing methods was evident on kikuyu.

Finally, the relationship between liveweight gain and stocking rate was also described by a linear function. On average, the stocking rate at which maximum liveweight gain per ha occurred (SRmax) was higher for rotational grazing than continuous grazing on Coastcross, but not on kikuyu. However, no difference was evident between the two grazing methods in each season.

During the study period annual rainfall varied from 506 mm to 990 mm. This offered a unique opportunity to examine the relation between some of the pasture production parameters measured and annual rainfall. The length of the grazing season and SRmax increased, but liveweight gain of animals at SRmax declined as annual rainfall increased. This caused seasonal liveweight gain at SRmax to increase initially, but then to reach a maximum and decrease as annual rainfall increased from 500 to 1000 mm.

From this information it was possible to build two models which can be used to predict liveweight gain per ha and profit per ha from stocking rate and annual rainfall. These models can either be built into farm planning programmes or used directly by agricultural advisors. In this thesis they have been used to show that there is a wide range in stocking rates and levels of annual rainfall within which it is possible to make substantial profits by grazing young beef animals on dryland pastures. This study has therefore provided forceful information which can be used to persuade farmers to make more use of planted pastures, and in so doing, conserve the veld.

## 1. INTRODUCTION

### 1.1 Background

Veld degradation in South Africa has continued steadily for many years and today it has reached very serious proportions (Acocks, 1953). The extent to which such degradation has reduced the carrying capacity of Natal veld is clearly shown by data prepared by officers of the Pasture Section of the Department of Agriculture's Natal Region, in association with the extension officer at Kokstad (Anon., 1981). For the different Bioclimatic Groups (Phillips, 1973), estimates were made of the potential grazing capacity and the current grazing capacity of the veld (Table 1.1). If these figures are weighted according to the area covered by each Bioclimatic Group, then degradation of the veld has reduced the carrying capacity on average by roughly 32%.

There can be no doubt that poor burning and grazing management have been partially responsible for the current state of the veld. However, overstocking is also a major cause of veld deterioration, and this problem is likely to increase with time. Escalating living and production costs are forcing farmers to expand their herds, although many are not in a financial position to purchase more land.

In recent years grassland scientists have increasingly recognized the extent to which the use of cultivated pastures is able to reduce stocking pressure on the veld: cultivated pastures can increase the carrying capacity of a farm and thus permit increased animal numbers and simultaneously reduce the load on the veld. The main obstacles to greater use of cultivated pastures

TABLE 1.1 Estimated potential grazing capacity and average current grazing capacity of the different Bioclimatic Groups of Natal.

| Bioclimate | Potential grazing capacity |       | Current grazing capacity |       |                |
|------------|----------------------------|-------|--------------------------|-------|----------------|
|            | ha/AU                      | AU/ha | ha/AU                    | AU/ha | % of potential |
| 1          | 1,4                        | 0,71  | 1,8                      | 0,56  | 79             |
| 2          | 1,4                        | 0,71  | 2,4                      | 0,42  | 59             |
| 3          | 1,0                        | 1,00  | 1,6                      | 0,62  | 62             |
| 4e         | 1,0                        | 1,00  | 1,3                      | 0,77  | 77             |
| 4f         | 1,4                        | 0,71  | 1,9                      | 0,53  | 75             |
| 5          | 3,1                        | 0,32  | 5,0                      | 0,20  | 63             |
| 6          | 1,6                        | 0,62  | 2,3                      | 0,43  | 69             |
| 8          | 2,5                        | 0,40  | 3,9                      | 0,26  | 65             |
| 7,9,10&11: |                            |       |                          |       |                |
| (a) Flat   | 3,5                        | 0,20  | 7,0                      | 0,10  | 50             |
| (b) Steep  |                            | 0,20  | 9,5                      | 0,07  | 35             |



are the high cost involved in establishment and maintenance, and the harsh South African climate which limits the performance of these pastures. Winters are almost totally without rain over most of the country and summers are hot and often accompanied by short droughts, even in the medium to high rainfall areas. This, together with the limited potential for irrigation and a high incidence of acid soils (which often have high levels of aluminium) reduces the potential for incorporating legumes into pastures in many areas. Dryland pastures are therefore restricted to the costly grass - nitrogen type which, coupled with the unpredictable climate, increases the risk of livestock enterprises and in some cases may make them economically non-viable.

Edwards and Booysen (1972) examined the potential of South Africa for pasture intensification. They concluded that 65% of the country had virtually no potential for growing improved pasture species, 23% was suitable for veld reinforcement only (introducing improved pasture species into the veld) and 12% was suited to complete replacement of the veld with cultivated pastures. From the map published by Edwards and Booysen (1972) it appears that about half the area suited to replacement of veld by cultivated pastures occurs in Natal, covering a total of approximately 70% of the province. The balance of the land in Natal was classified as suitable for veld reinforcement. This means that Natal has a high potential for using cultivated pastures to prevent overstocking of veld and for increasing the carrying capacity of the country as a whole. Furthermore, it means that farmers who continue to use veld alone for livestock production in the high potential areas of Natal are producing at a level which is well below the potential of their farms.



Even though there are a number of species that have become popular for use in cultivated pastures on farms in South Africa, there is still much to be learned about their potential in terms of animal production under local conditions. These species therefore need testing under grazing, particularly with beef cattle and sheep, since these are the animals that are dependent primarily on the veld. In response to this need Booyesen (undated) set out a number of proposals concerning the type of information required and the methods which should be used to collect it. He suggested (a) that before pastures could be efficiently incorporated into farming systems it was necessary to thoroughly characterize pasture species per se in terms of livestock production; (b) that in South Africa, as a result of the rotational grazing requirement of veld grassland scientists were inclined to apply rotational grazing on cultivated pastures as well, without consideration for the feasibility of continuous grazing, or its usefulness as a research tool; (c) that pasture characterization should be done under continuous grazing initially, so that results were free of the influence of the many management variables associated with rotational grazing and (d) that it was necessary to use variable stocking (put-and-take) in order to properly characterize pastures.

Following these suggestions the first variable stocking rate trial in South Africa was established in 1973. Since Eragrostis curvula was adapted to a wide range of climatic conditions and was probably the most widely grown pasture grass in the country at the time, it became an obvious choice for this trial. The experimental site was south of Vereeniging on the Transvaal Highveld and the aim of the trial was to establish optimum

intensities of utilization for this grass under both continuous and rotational grazing. Treatments therefore included four levels of utilization under continuous grazing and two levels of utilization under rotational grazing. Herbage availability was estimated by measuring the height of the mid-point of each side of a square 1 m x 1 m board which was dropped onto the pasture canopy from a standard height (Alexander, Sullivan & McCloud, 1962). For calibration of the board, the mean of these four measurements was related to the dry weight of herbage beneath it. Herbage availability was estimated regularly by means of 50 board placements per treatment, and animal numbers were adjusted according to these estimates.

After two years this experiment was terminated, and although results were not published, it had served as a useful pilot trial for similar research which was started in Natal. The most demanding aspect of applying variable stocking had been the estimation of herbage availability by means of the board method. A quicker method which involved the same principle as the board but a somewhat different apparatus (known as the disc pasture meter or disc meter), was therefore assessed (Bransby 1975; Bransby, Matches & Krause, 1977; Bransby & Tainton, 1977).

In Natal Eragrostis and kikuyu occupy most of the area under warm season cultivated pastures in more or less equal proportions (Heard, Tainton & Edwards, 1984). Further evaluation of E. curvula was therefore justified and this research was undertaken by the Department of Agriculture at their Kokstad Research Station in the Highland Sourveld (Brockett, Gray & Lyle, 1982). In addition, star grass (Cynodon nlemfuensis) was evaluated at their de Hoek Research Station in the Moist Tall Grassveld (Edwards & Mappledoram, 1979), in the Eastern Cape



(Aucamp & Nel, 1981) and Zimbabwe (Rodel, 1979; Parkin & Boulwood, 1981). However, both these species suffered from inherent low palatability and digestibility.

Coastcross II Bermudagrass was at this stage a relatively new introduction in South Africa, but initial assessments in small plots had shown it to be extremely promising in both its quality and yield. The next step was clearly to test it under grazing. With kikuyu commanding a similar status to Eragrostis as a summer pasture on Natal farms, it too needed to be characterized in terms of its potential for beef and sheep production. The study described in this thesis therefore concentrated on the characterization of dryland Coastcross II and kikuyu for beef production in a sub-humid region of South Africa

## 1.2 Coastcross II

According to Theron and Arnott (1977), Burton in 1975 described Coastcross II Bermudagrass as a sister grass to Coastcross I Bermudagrass which is widely grown in the southern USA. The latter is a sterile hybrid from Coastal Bermuda and an African Cynodon introduction (P.I. 255445) obtained in 1958 from the Grassland Research Station, Kitale, Kenya.

In 1964 vegetative material was obtained from Burton of the USDA Coastal Plain Experimental Station at Tifton Georgia, USA. The plant was registered in South Africa under the plant introduction number N 69/64. I'Ons (1974) was the first to publish information on the production potential of Coastcross II under South African conditions. His research was conducted on two soil types in Bioclimatic Group 6 as defined by Phillips (1973). In relation to some of the better strains of Cynodon aethopicus

and Cynodon nlemfuensis, I'Ons found that Coastcross II compared favourably in small plots with respect to dry matter (DM) yield as well as protein and TDN content.

Theron and Arnott (1977) are the only others who have reported on the production potential of Coastcross II in South Africa. They described its performance in small plot trials at a number of sites which varied widely in soil type and climate. In addition, they recorded animal performance from grazed Coastcross II on a number of farms, but no formal grazing trial was established.

From this work it was concluded that Coastcross II was well adapted to a wide variety of conditions in Natal. It seemed to be better able to withstand hot, dry conditions and low fertility than kikuyu. Despite this, it responded well to irrigation but as a rule did not do well on poorly drained soils, showing a preference for light textured sandy soils. Although Coastcross was not killed by frost, production was substantially reduced in cold high altitude areas. This is probably due to the complete absence of rhizomes, the ability of the grass to spread being controlled entirely by the production of stolons.

Coastcross was flexible not only in terms of growing conditions, but also in terms of its suitability for different methods of use. Experience had shown that it could be grazed, but also had good qualities for hay, silage and foggage. For South African conditions these attributes were particularly attractive because farmers rely on conserved feed to carry animals through the dry winter period. Consequently, Coastcross found its way onto a number of farms, thus increasing the need for evaluation under grazing.



The task of assessing the potential of Coastcross II for beef production was taken up at the University of Natal, Pietermaritzburg and by Stockowners Cooperative Company at their research unit at Tweedie. Research planned for Stockowners was in a relatively moist, cool environment and concentrated on supplement requirements of beef cattle grazing Coastcross (Harwin & Theron, 1982). At the University of Natal the intention was to characterize the pasture per se by grazing it with young beef animals.

Although Coastcross II originated from the USA, there appears to be no evidence in the literature of it being tested in that country under a range of stocking rates. Neither have there been any reports of comparisons between continuous and rotational grazing on this grass by American authors.

### 1.3 Kikuyu

Despite the long history of kikuyu in South Africa, most of the grazing information available for this species is in the form of records from dairy farms. However, since dairy animals receive concentrate feed in the parlour as well as grazing on pastures, extrapolation of stocking rates from dairy animals to beef animals is likely to be inaccurate. Similarly, estimates of the potential of the grass for liveweight gain of beef cattle from milk production figures are likely to be subject to considerable error. Kikuyu, therefore, required an assessment of its potential for growing out young beef cattle.

The characteristics of kikuyu which make it particularly attractive as a pasture grass are its good response to fertilizer

and irrigation, and especially its exceptional ability to withstand severe defoliation. The latter attribute is related to the production of a thick mat of rhizomes which enable kikuyu also to withstand frost, even though it is a warm season species. Apart from the fact that it can become an aggressive weed, kikuyu has few disadvantages. It can be conserved as foggage or silage, but has too high a moisture content for hay. Under grazing however, animal performance is often lower than would be expected from herbage quality analyses.

Cross (1979a, 1979b) reviewed the work done on kikuyu in South Africa. The earliest scientific report from a kikuyu grazing trial in South Africa was that of Taylor (1949) who studied milk production of dairy cows. Austin (1980) studied the acceptability of differentially fertilized kikuyu and more recently Barrow, Tainton and Bransby (1982) published results from a trial in which kikuyu was differentially fertilized with nitrogen and grazed with beef steers. The merit of the latter trial was primarily in the economic analysis. With respect to the biological aspects of the trial the main limitations were that the experiment was run for only one season, and each treatment was applied at only one stocking rate.

Since kikuyu is classified as a proclaimed weed in most parts of the USA, very little attention has been paid to its potential as a pasture grass in that country. It is used to a limited extent in New Zealand, but in Australia it is widely used for pastures in high rainfall regions and in some parts it has become naturalized. Mears (1970) was the last author to publish a comprehensive review of work done on kikuyu and later Mears (1974) and Mears and Humphreys (1974a, 1974b) published results from a trial in which kikuyu was fertilized at four levels of nitrogen, each of these



treatments being grazed at three stocking rates. However, the pastures which they evaluated in this trial had other species mixed in with kikuyu, although kikuyu appeared to be the dominant grass.

#### 1.4 Method of grazing

Rotational and continuous grazing are the two methods most commonly used to graze pastures. In South Africa, these two methods have been compared in a number of grazing trials on veld (Foran, 1974). However, there is no comparative work published for cultivated pastures. Foran (1974) pointed out that results from comparisons between rotational and continuous grazing were often inconsistent and that the response to grazing method was probably associated with the particular veld type. However, this lack of agreement in results from such experiments could be due also to a number of other factors, for both veld and pastures: apart from pasture type, the number of paddocks and rate of animal movement in rotational grazing systems, and the stocking rate could affect the outcome of such comparisons. And yet there is no evidence in the literature of continuous grazing having been compared to rotational grazing under a range of stocking rates, or alternatively, to a number of rotational grazing systems with, for example, different numbers of paddocks.

#### 1.5 Stocking rate and herbage availability

Stocking rate is perhaps the most important single factor in grazing management which affects animal production from pasture (Edwards, 1981). However, stocking rate affects animal

performance indirectly through its effect on herbage availability. For this reason it is common for pasture researchers to estimate availability of herbage in stocking rate trials, but surprisingly little success has been achieved in relating animal performance to herbage availability (Mears & Humphreys, 1974b; Edwards & Mappledoram, 1979; Parkin & Boulton, 1981). This could possibly arise from the techniques used for estimating herbage availability which range from clipping quadrats to visual estimation. In this respect, the development of the disc meter offered new opportunities and thus increased the chance of developing a better understanding of the role of herbage availability in the effect of stocking rate on liveweight gain.

In 1978, Hart summarized various proposals for generalized models of the relation between stocking rate and gain per head (Fig. 1.1). Of these models, that described by Jones and Sandland (1974) is particularly attractive because it is a simple linear function with liveweight gain per ha being described by a quadratic function (Fig. 1.2). This model facilitates the determination of an optimum biologic stocking rate and subsequently Booyen, Tainton and Foran (1975), and Booyen (1975) built on to it so that, given a certain cost-price structure, it was possible to determine an economic optimum stocking rate. In addition, Booyen (1975) proposed that the optimum biological and economic stocking rate for rotational grazing was higher than for continuous grazing, and that the profit at the optimum economic stocking rate would also be higher for rotational grazing than for continuous grazing (Fig. 1.3). However, this theory has never been tested in practice.



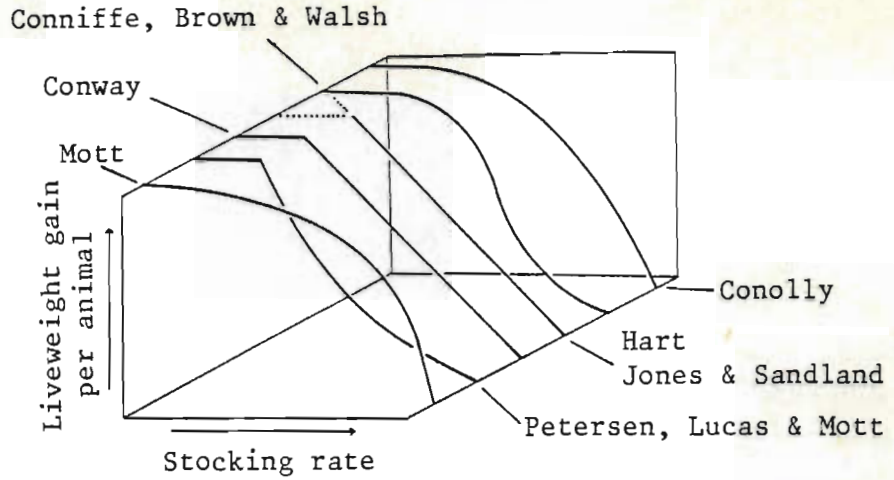


Fig. 1.1. Proposed relationships between stocking rate and liveweight gain per animal (Hart, 1978).

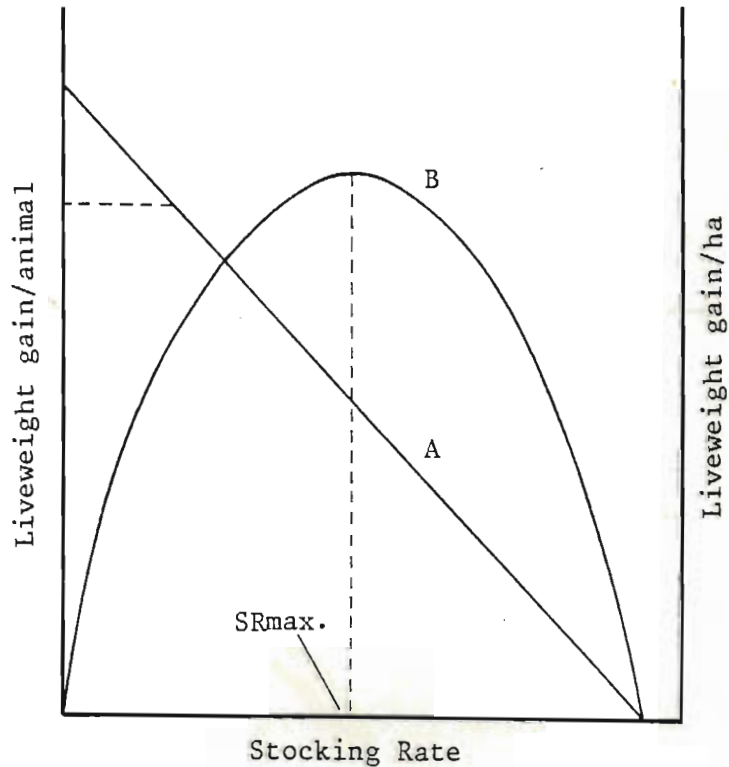


Fig. 1.2. A model relating liveweight gain per animal (A) and liveweight gain per ha (B) to stocking rate (after Jones & Sandland, 1974).

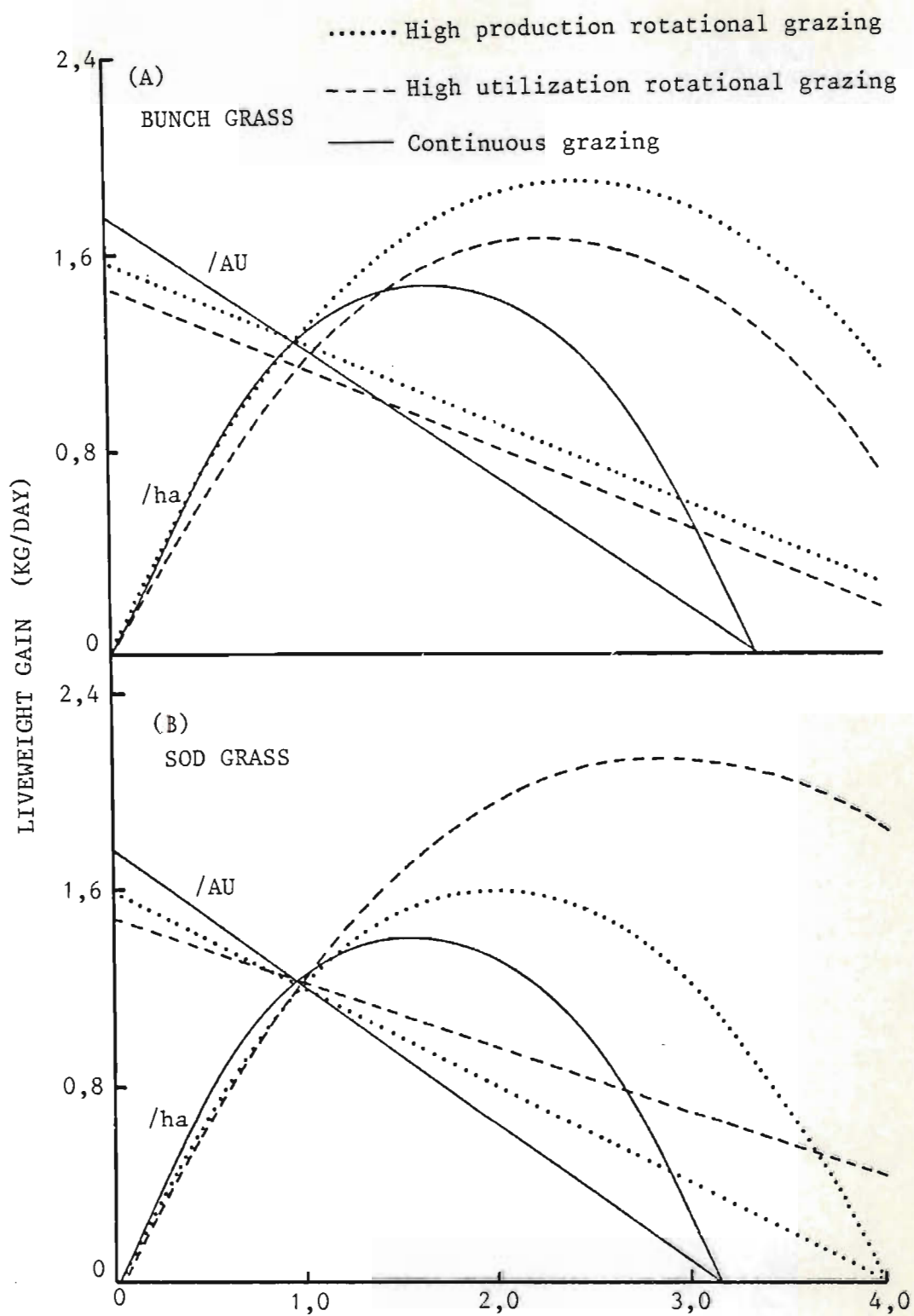


Fig. 1.3. Gain/head and gain/ha for two different sward types under continuous grazing and two different rotational grazing systems (Booyesen, 1975).

## 1.6 Objectives

The primary objective of this study was to relate herbage availability, liveweight gain and stocking rate to one another under rotational and continuous grazing, thereby facilitating the formulation of grazing management proposals for kikuyu and Coastcross, and an economic evaluation of growing out young beef cattle on these pastures. If the findings of this research indicated that growing out young beef animals on dryland pastures was economically feasible, it would encourage farmers to increase the carrying capacity of their farms by establishing more cultivated pastures, and thereby assist in achieving the broad, long term aim of reducing the grazing load on the veld.

## 2. GENERAL PROCEDURE

The aspects of procedure which are detailed in this chapter are those which concerned the whole research programme. Aspects of procedure which concerned a particular facet of the research only are described in the respective chapters in which these facets are discussed.

### 2.1 Location and Bioclimate

The research was conducted at the University of Natal Ukulinga Research farm near Pietermaritzburg. The site was level to very gently sloping, and the soil was classified as a Westleigh form (MacVicar, Loxton, Lambrechts, le Roux, von M.Harnse, de Villiers, Verster, Merryweather & van Rooyen, 1977). In general it was shallow, ranging from 150 mm to 450 mm, and overlay shale. According to MacVicar et al. (1977), shallow Westleigh soils have low permeability. This was apparent in wet weather when the soil had a tendency to waterlog, while during dry weather it became very hard and developed cracks. Under grazing the soil tended to become extremely compact from trampling. The soil pH was 4,6 in KCl and about 5,5 in water, with an aluminium content of 1 ppm or 0,01 ME%. In view of the soil limitations, annual cropping on sites such as this would be hazardous, and although pasture production would also be limited by the nature of the soil, an advantage of the site was that the research would be conducted under conditions in which pastures were not in competition with a food crop for land. Furthermore, the



extrapolation value of the research to farm practice in terms of soil type was good due to the high incidence of soils with similar characteristics to those of a Westleigh in the sub-humid regions of Natal.

According to Phillips (1973), Ukulinga Research Farm falls into Bioclimatic Group 6 which he called the Moist Tall Grassveld. However, the range in annual rainfall for this Bioclimatic Group was listed as 800-1000 mm, but the 32 year average for Ukulinga was 703 mm. This implies that the rainfall of the experimental site was tending towards the Dry Tall Grassveld (Bioclimatic Group 8) and the Interior and Valley Thornveld (Bioclimatic Group 10). Nevertheless, since annual rainfall varied from 506 mm to 990 mm (Table 2.1) during the experimental period, results should have application to Bioclimatic Groups 6, 7, 8, 9, 10 and 11 which in total cover 44,5% of Natal. These records also show that the average rainfall for the experimental seasons corresponded closely with the long term records.

The experimental site has an annual mean temperature of approximately 18°C with mid-summer days as hot as 40°C and winter nights occasionally below 0°C. Frosts are infrequent during the almost completely dry winter and short mid-summer droughts are common. The natural vegetation of the sub-humid regions in which this research would be applicable varies from open woodland with a moderately tall, mixed grassveld to mixed thickets and sweet grassland. Soil erosion, bush encroachment and veld deterioration are common problems (Table 1.1). Beef is the major livestock enterprise.

TABLE 2.1 Monthly and total annual rainfall (mm) from June to July for the six test years in relation to a 32 year mean.

| Month | 1976/77 | 1977/78 | 1978/79 | 1979/80 | 1980/81 | 1981/82 | Mean and SD<br>for test years | 32 year means<br>and SD |
|-------|---------|---------|---------|---------|---------|---------|-------------------------------|-------------------------|
| July  | 3,1     | 0,0     | 7,4     | 22,0    | 0,6     | 7,2     | 6,72 ± 8,12                   | 9,55 ± 16,27            |
| Aug   | 27,8    | 11,8    | 23,3    | 45,1    | 10,4    | 56,5    | 29,15 ± 18,39                 | 29,10 ± 24,80           |
| Sept  | 65,7    | 36,5    | 73,1    | 42,8    | 86,5    | 27,4    | 55,33 ± 23,18                 | 42,27 ± 32,72           |
| Oct   | 133,5   | 89,8    | 114,0   | 80,8    | 33,1    | 23,9    | 79,18 ± 43,49                 | 61,53 ± 38,27           |
| Nov   | 45,8    | 81,9    | 111,7   | 56,7    | 138,9   | 100,4   | 89,23 ± 34,91                 | 82,00 ± 34,92           |
| Dec   | 57,0    | 222,2   | 133,1   | 57,6    | 68,8    | 32,4    | 95,18 ± 70,82                 | 97,93 ± 55,08           |
| Jan   | 159,7   | 174,6   | 93,0    | 86,3    | 111,7   | 88,1    | 118,90 ± 38,73                | 118,49 ± 48,73          |
| Feb   | 20,9    | 134,5   | 129,4   | 27,2    | 31,9    | 64,6    | 68,08 ± 51,75                 | 92,92 ± 43,76           |
| March | 102,7   | 97,4    | 57,8    | 25,2    | 76,6    | 111,6   | 78,55 ± 32,59                 | 87,82 ± 48,11           |
| April | 18,2    | 132,4   | 48,6    | 39,3    | 16,8    | 25,4    | 46,78 ± 43,73                 | 47,38 ± 31,21           |
| May   | 13,5    | 7,6     | 50,2    | 23,2    | 29,1    | 4,0     | 21,27 ± 17,01                 | 25,45 ± 35,79           |
| June  | 14,8    | 1,2     | 1,5     | 0,0     | 12,5    | 9,7     | 6,62 ± 6,49                   | 8,63 ± 12,85            |
| Total | 662,7   | 989,9   | 843,1   | 506,2   | 616,9   | 555,0   | 695                           | 703                     |
| Exp.* | 573,4   | 890,9   | 712,1   | 337,6   | 467,8   | 285,6   |                               |                         |

\* Rainfall between 1 September and three weeks before the last date on which cattle were weighed

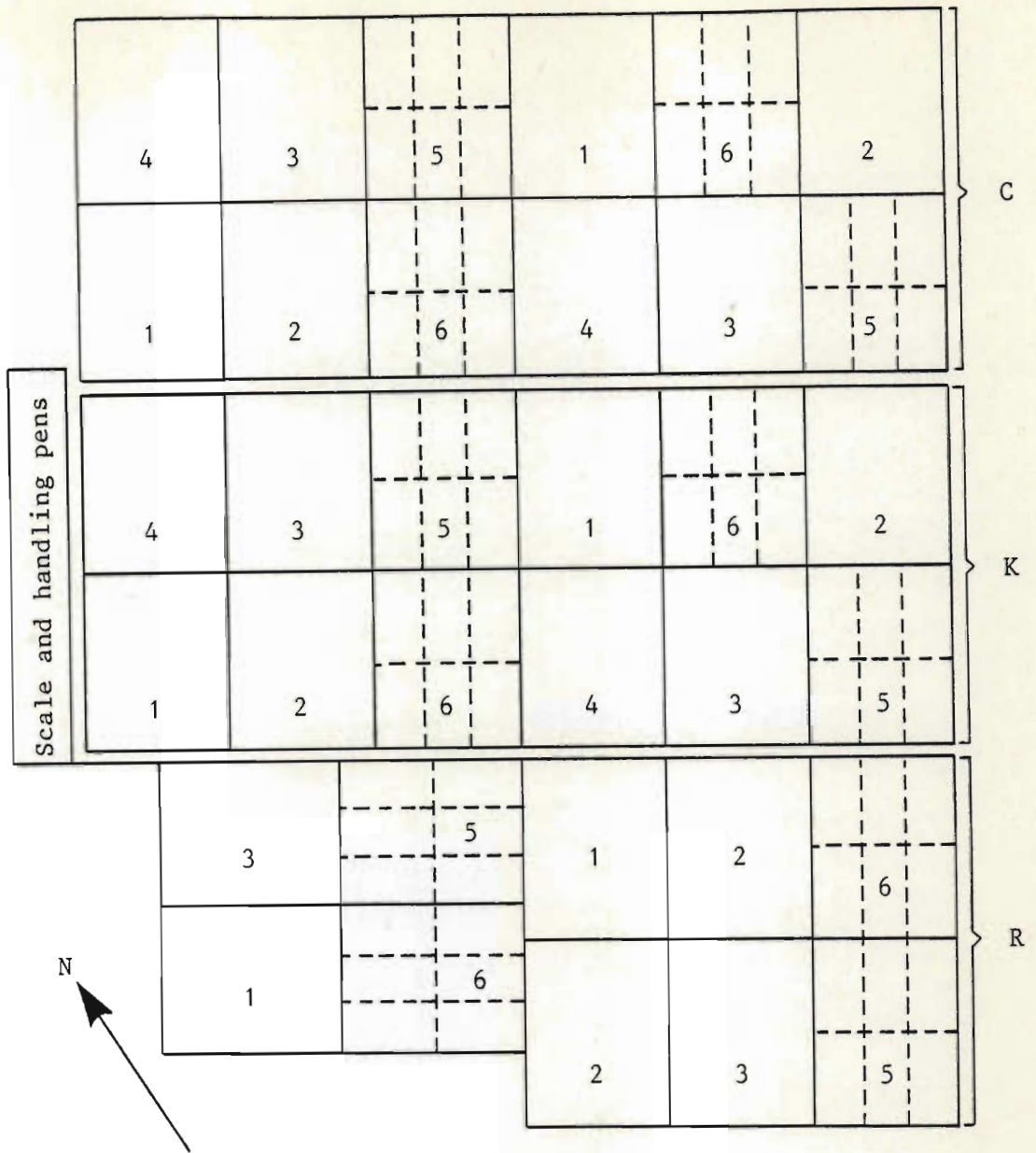
## 2.2 Experimental design

Coastcross II was established on 4.47 ha in the spring (October) of 1975 and was leniently grazed with sheep in late summer. During winter in 1976 the area was fenced into 12 paddocks which measured 54 m wide and 69 m long. Four of these paddocks were divided further into six sub-paddocks for rotational grazing. The experiment was laid out in a randomized blocks design with two replications and six treatments. Continuous grazing was applied under variable stocking (Mott, 1960) at heavy, medium and light utilization levels and under fixed stocking at a light stocking rate. Rotational grazing was applied under variable stocking at a heavy and a light utilization level. Treatments were repeated on the same paddocks each year and results therefore incorporate cumulative effects.

In 1977 kikuyu was established adjacent to Coastcross on an equivalent area with the same layout and treatments, and Rhodesgrass (Chloris gayana) was also planted, but fenced in a slightly modified layout which excluded the fixed stocked continuous grazing treatment (Fig. 2.1 and 2.2). The years in which each grass was assessed under grazing are indicated in Table 2.2.

Herbage availability was measured weekly with the disc meter by taking a total of 50 readings on the two diagonals across each paddock and subsequently estimating the mean disc height in centimetres. For rotational grazing treatments 25 readings were taken on each sub-paddock, and the herbage availability on each sub-paddock as well as mean disc height of the whole rotational grazing treatment was estimated. The disc meter was calibrated by means of 50 paired observations of disc height and dry weight of





C = Coastcross

K = Kikuyu

R = Rhodesgrass

1. Heavy continuous grazing, put-and-take
2. Medium continuous grazing, put-and-take
3. Light continuous grazing, put-and-take
4. Continuous grazing, fixed stocked
5. Heavy rotational grazing, put-and-take
6. Lenient rotational grazing, put-and-take

Fig. 2.1. Schematic plan illustrating the layout of treatments on the experimental site.



Fig. 2.2. An aerial photograph of the experimental site.

TABLE 2.2 The seasons in which the different grass species were evaluated and total annual rainfall for each year.

| Year    | Coastcross | Kikuyu | Rhodesgrass | Rainfall (mm) |
|---------|------------|--------|-------------|---------------|
| 1976/77 | X          |        |             | 662,7         |
| 1977/78 | X          |        |             | 989,9         |
| 1978/79 | X          | X      | X           | 843,1         |
| 1979/80 | X          | X      |             | 506,2         |
| 1980/81 |            | X      |             | 616,9         |
| 1981/82 |            | X      |             | 555,0         |



material beneath the disc. This was done for grazed and ungrazed swards on each species in early and late summer.

All paddocks received the same level of fertilizer. At establishment the soil P and K levels were raised to 15 and 120 ppm respectively. Nitrogen was applied at 225 kg N/ha as limestone ammonium nitrate. This was done in three equal dressings in October, December and February.

### 2.3 Experimental animals

Young growing animals were used for the trial. However, the age and weight of animals varied between seasons and the breed/type also varied (Table 2.3). For the first four seasons steers only were used but both heifers and steers were used in the last two seasons. The respective groups all had a high proportion of half siblings but these could not be identified. Animals were overwintered on silage and hay to maintain weight and in some cases to gain very slightly. Tester animals were blocked according to weight, type, sex and overwinter performance on the recommendation of Matches (1970). Three testers were allocated to each paddock on a random basis from each block.

Animal numbers were adjusted on the basis of the mean disc height for each variable stocking treatment in an effort to maintain the disc height of a treatment constant throughout the grazing season. The aim was to establish a range of herbage availability. This was done in the first two seasons by starting grazing in each paddock as it reached the desired disc height and thereafter maintaining the height by adding or removing filler animals. In the following seasons, however, the paddocks were initially allowed to grow out and then mob-grazed to establish the

TABLE 2.3. Average age, weight and type of animals used in different seasons.

| Season  | Type of animal                          | Average age at start of grazing | Average weight at start of grazing (kg) |
|---------|-----------------------------------------|---------------------------------|-----------------------------------------|
| 1976/77 | Afrikander cross                        | 24 months                       | 237                                     |
| 1977/78 | Santa Gertrudis                         | 12 months                       | 186                                     |
| 1978/79 | Santa Gertrudis and Drakensberger cross | 24 months                       | 268                                     |
| 1979/80 | Drakensberger cross                     | 12 months                       | 192                                     |
| 1980/81 | Drakensberger cross                     | 24 months                       | 225                                     |
| 1981/82 | Drakensberger cross                     | 12 months                       | 158                                     |

desired disc heights at the beginning of the grazing season. At the end of the grazing season animals were removed from treatments if they lost weight during two consecutive weighing intervals, or if the paddock was so heavily grazed that there was a danger of damaging the pasture.

According to Hughes (1976) animals on grazing trials in which herbage intake differs between treatments should be starved before weighing. Assuming that differences in herbage availability would cause differences in gut-fill between treatments, animals in this trial were starved overnight for 16 hours before weighing. Weighing took place at 2 to 3 week intervals. All animals were put through a spray race once a week to control ticks and they were usually dosed for worms three times during the summer.

#### 2.4 Analysis

Initially it was intended to analyse the results by means of analysis of variance for six treatments with two replications in a randomized blocks design. Treatments had been defined in terms of herbage availability, where the intention was to maintain similar levels of herbage availability across replicates and to maintain availability constant within a treatment over time by means of the put-and-take technique. However, in practice herbage availability varied between replicates and in a few cases was of a similar order to the variation between treatments. In effect, then, the replicates of each treatment were too dissimilar to be considered as replicates. In view of this, results were analysed by the analysis of covariance described by Riewe (1961; 1965) and Bransby (1982). Since the interest was in trends as availability increased, rather than differences between levels of availability,



this analysis was appropriate. Continuous and rotational grazing were therefore the treatments which were applied at eight and four levels of herbage availability on Coastcross and kikuyu. While the presence of blocks in the layout of the trial constituted a minor infringement of statistical method, results are not likely to have been different if blocks had not been incorporated into the design and treatments had been allocated entirely at random. Initially, results for the two blocks on each grass were considered separately and compared statistically only within blocks. Since treatments within blocks had been randomly allocated, this was a valid procedure. However, subsequent comparisons between blocks showed no statistical differences, which implied that pooling results from the two blocks for covariance analysis was permissible for each grass.

The analysis was therefore concentrated on comparing relationships between liveweight gain, herbage availability and stocking rate for continuous and rotational grazing on Coastcross and kikuyu. This was a relatively simple procedure with the analysis of covariance because all these relationships were fairly well described by linear functions.

For comparing linear functions which had been fitted by the method of least squares (Rayner, 1967), the analysis of covariance sub-routine of the GENSTAT computer programme developed at Rothamstead, UK was used on the UNIVAC computer, initially to test whether a difference in slopes existed. In the event of the difference between slopes being statistically significant, no further analysis was valid. However, if there was no difference in slopes, then parallel lines were fitted and the statistical significance of the difference in the location of these lines was

tested. The raw data was processed with the Stocking Rate Trial Programme developed by Lyle, Bartholomew and Brockett (1982) at the Cedara research section of the Department of Agriculture.

The statistic which appears most frequently in this thesis is the correlation coefficient ( $r$ ). Unless the level of significance is indicated,  $r$  values are non-significant.

### 3. AN EVALUATION OF THE PUT-AND-TAKE TECHNIQUE

#### 3.1 Introduction

In conducting a grazing trial either fixed or variable stocking (put-and-take) may be used. Fixed stocking involves keeping the same number of animals on a treatment for the entire grazing period. This method has been preferred in countries such as Australia, New Zealand, the U K and South Africa. To apply variable stocking a certain number of "tester" animals remain on each treatment permanently while "filler" or "grazer" animals are introduced to or removed from the treatment, depending on its growth rate. This method has been most commonly used in North America.

The value of each technique has been strongly debated in the past and the philosophy and principles of put-and-take have therefore been widely documented (Mott & Lucas, 1952; Mott, 1960; Matches & Mott, 1973; Wheeler, Burns, Mochrie & Gross, 1973). However, although these principles appear to be sound, little detail has been published on how to implement put-and-take. It appears, then, that the practical feasibility of put-and-take and the degree to which it achieves its goals have not been tested.

In addition to the primary objective listed in Chapter 2, the grazing trials described in this thesis offered an opportunity to assess the put-and-take technique in relation to certain of its goals. Treatments in the trials from which data will be used to assess the technique were different levels of utilization. Put-and-take was therefore used to maintain differences in herbage availability between treatments, and in this sense it was



different to other trials which may make use of the technique to maintain herbage availability constant between treatments, such as different levels of nitrogen fertilizer. However, it was hoped that put-and-take would maintain herbage availability constant between intended replicates and within replicates over time, and the success in attaining these goals is examined. Furthermore, herbage availability as measured by the disc meter is assessed as a basis for adjusting animal numbers in put-and-take grazing trials.

Another difficulty experienced in the application of grazing treatments in these trials was the commencement of grazing on each treatment at the start of the growing season. Although this is not related to the put-and-take technique, it seemed appropriate to discuss it in this chapter since it was an issue of experimental procedure. Essentially, the question was whether to start each treatment independently when it reached its goal disc height i.e. in sequence, or to start grazing all treatments at the same time and establish different grazing heights by "mob grazing".

### 3.2 Philosophy of put-and-take

In order to measure treatment effects with animals in grazing trials, animal potential must exceed pasture potential (Matches & Mott, 1973). This concept is important with respect to both quantity of herbage produced and herbage quality: if the quantity of feed is in excess supply but quality limits animal production, then the potential of the pasture can be measured only in terms of its quality. In other words, if for example a number of pasture species were being compared by grazing them with high producing

dairy cows, but all pastures were understocked, then any differences in milk production would result from differences between species in herbage quality. However, if the quality of feed is so high that animals are genetically incapable of responding to it, but quantity of feed is limiting animal performance, then the potential of the pasture can be measured only in terms of its quantity. An example of such a case would be when genetically inferior beef steers graze on ryegrass and clover pastures stocked so that intake per head is limited. The third possibility would be for quality and quantity of feed to be so high that no differences between treatments can be detected. An example of this situation would be genetically inferior beef steers grazing at very low stocking rates on ryegrass and clover pastures.

It is therefore essential that the potential of the animal exceeds that of the pasture with respect to quality and quantity at all times, if animals are to be used to measure the potential of the pasture in terms of both these components of production simultaneously. In addition, except where direct effects of utilization intensity are being investigated, it is important that non-treatment variables (particularly those which may influence animal performance, whether directly or indirectly) be kept near constant between and within treatments, and between replicates, for the whole experimental period. Examples of such non-treatment variables are herbage consumption per animal, accessibility of herbage and physiological condition of the pasture. Examples of the latter include factors such as herbage maturity and quality, carbohydrate status and leaf area index.

Growth rates of pastures often vary substantially over the duration of a growing season. Under fixed stocking, however, animal numbers remain constant. This means that forage supply fluctuates in relation to demand; non-treatment variables will also vary and there may be times when pasture potential exceeds animal potential. Consequently, the main objection to the use of fixed stocking in grazing trials that make use of animals to measure output, is that treatment effects cannot be effectively isolated due to introduced bias in the results. The put-and-take method was designed to overcome such difficulties inherent in the use of fixed stocking. In this technique, as pasture growth rate fluctuates, animal numbers are adjusted in an effort to keep non-treatment variables relatively constant, and to ensure that animal potential remains above pasture potential so that realistic interpretation of results is possible.

Wheeler et al. (1973) listed a number of situations in which the put-and-take method would be particularly useful. These were (a) if the pattern of forage growth is markedly periodic and herbage quality and quantity cannot be maintained if the pasture is left uneaten, (b) if results are to be applied to a farm enterprise in which there is a high degree of flexibility to accommodate changes in animal numbers, (c) when the animal production potential of a pasture species cannot be well predicted at the design stage, (d) if results are to be extrapolated to farm practice and not directly applied, and (e) if the forage is to be used in a complex type of farm enterprise. In general, therefore, the put-and-take method should be viewed mainly as a research tool for evaluating pastures in terms of animal products, although for certain flexible livestock enterprises such as



growing out steers on pastures, it may have direct application to farm practice. However, in this respect put-and-take of land (Harkess, de Battista & Dickson, 1972; Brockett, 1978) would probably have greater value than put-and-take of animals.

### 3.3 The basis for adjusting animal numbers

Mott (1960) defined grazing pressure as the number of animals per unit of available forage. Subsequent to this, he stated that, "In comparisons between plant species, fertility treatments, grazing management systems and other trials of a similar nature in which animals are being used to measure output, it is imperative that the grazing pressure imposed on each of the treatments should be equal". However, it is doubtful that the objectives of put-and-take can best be achieved by using grazing pressure as a basis for adjusting animal numbers.

As an illustration, a situation might be visualized in which there is a sharp increase in pasture growth rate. In such a case animal numbers would be increased, but available forage would inevitably have to be allowed to increase as well, in order to maintain constant grazing pressure. However, if the total amount of available forage were allowed to fluctuate, a similar situation to that which may occur under fixed stocking could prevail viz. the non-treatment variables that were listed in section 3.2 would still vary - although not to quite the same extent - and there might still be times when pasture potential exceeded animal potential, particularly if the pasture were to fluctuate widely in growth rate. Therefore, on the basis of constant or equal grazing pressure the objectives of the put-and-take philosophy would not necessarily be achieved.

As an alternative basis for the adjustment of animal numbers on put-and-take trials Bransby et al. (1977) suggested available herbage in kg/ha, or as measured by the disc meter instead of grazing pressure. If either of these factors is kept constant or equal within and among treatments, the non-treatment variables such as herbage consumption, acceptability of forage, herbage maturity etc. would be likely to remain within narrow limits and animal potential should, therefore, remain above pasture potential at all times. This means that the ratio of the number of animals : pasture growth rate is kept constant and that the ratio between feed supply and demand remains constant. Stated in a more practical way, sufficient animals are kept on the pasture to consume the same amount of forage as is produced each day at a given availability.

An additional advantage of using availability as a basis for adjusting animal numbers is that it is an objective index and the overall principle can be more easily conveyed to the farmer than can an abstract concept like grazing pressure.

### 3.4 Procedure

The results from the 1977/78 season for Coastcross were used for most of the following discussion because this was the season which provided the longest grazing period as a result of receiving the highest total rainfall (Table 2.2). The success of put-and-take to achieve equivalent levels of herbage availability between replicates was assessed by comparing the variation in the average disc meter height over time for replicates, with that for treatments. In other words, the difference in disc meter height between replicates was compared to the difference between

treatments.

In order to assess to what extent put-and-take was able to keep herbage availability constant within a paddock over time, the standard deviation of the mean weekly disc meter readings for put-and-take paddocks was examined in relation to that for fixed stocked paddocks. In addition, the variation in stocking rate of a put-and-take paddock was studied in relation to the pattern of rainfall.

The disc meter was calibrated in early and late summer on the ungrazed regrowth in sub-paddocks of the rotational grazing systems which were in their period of absence (Booyesen, 1967) or recovery period, and on continuously grazed paddocks that were under grazing. This was done by taking 50 paired samples of disc meter height and dry weight of herbage beneath the disc (Bransby & Tainton, 1977) for each grass species in the first season.

### 3.5 The success of the disc meter in determining herbage availability

The success of the disc meter in assessing herbage availability has been reported on previously (Bransby et al. 1977; Bransby & Tainton 1977). This investigation confirmed previous findings in that it showed that the linear correlation between disc height and dry matter beneath the disc was in most cases fairly good (Table 3.1) but that the nature of the relationships depended on the season, and whether the material measured was recovery growth in a rotational grazing system or from a continuously grazed paddock (Fig. 3.1).

The implication of this is that if availability is to be expressed in terms of kg DM/ha, it would then be necessary to



TABLE 3.1. Linear regression equations and correlation coefficients (r) for disc meter height in cm (x) and DM of herbage beneath the disc in kg/ha (y) on various pasture swards.

| Treatment                          | Equation           | r       |
|------------------------------------|--------------------|---------|
| Coastcross, early summer, grazed   | $y = -536 + 335x$  | 0,77 ** |
| Coastcross, early summer, ungrazed | $y = -159 + 285x$  | 0,96 ** |
| Coastcross, late summer, grazed    | $y = 784 + 309x$   | 0,92 ** |
| Coastcross, late summer, ungrazed  | $y = 929 + 251x$   | 0,91 ** |
| Kikuyu, early summer, grazed       | $y = -768 + 339x$  | 0,94 ** |
| Kikuyu, early summer, ungrazed     | $y = -1068 + 308x$ | 0,95 ** |
| Kikuyu, late summer, grazed        | $y = 77 + 364x$    | 0,81 ** |
| Kikuyu, late summer, ungrazed      | $y = -314 + 349x$  | 0,93 ** |

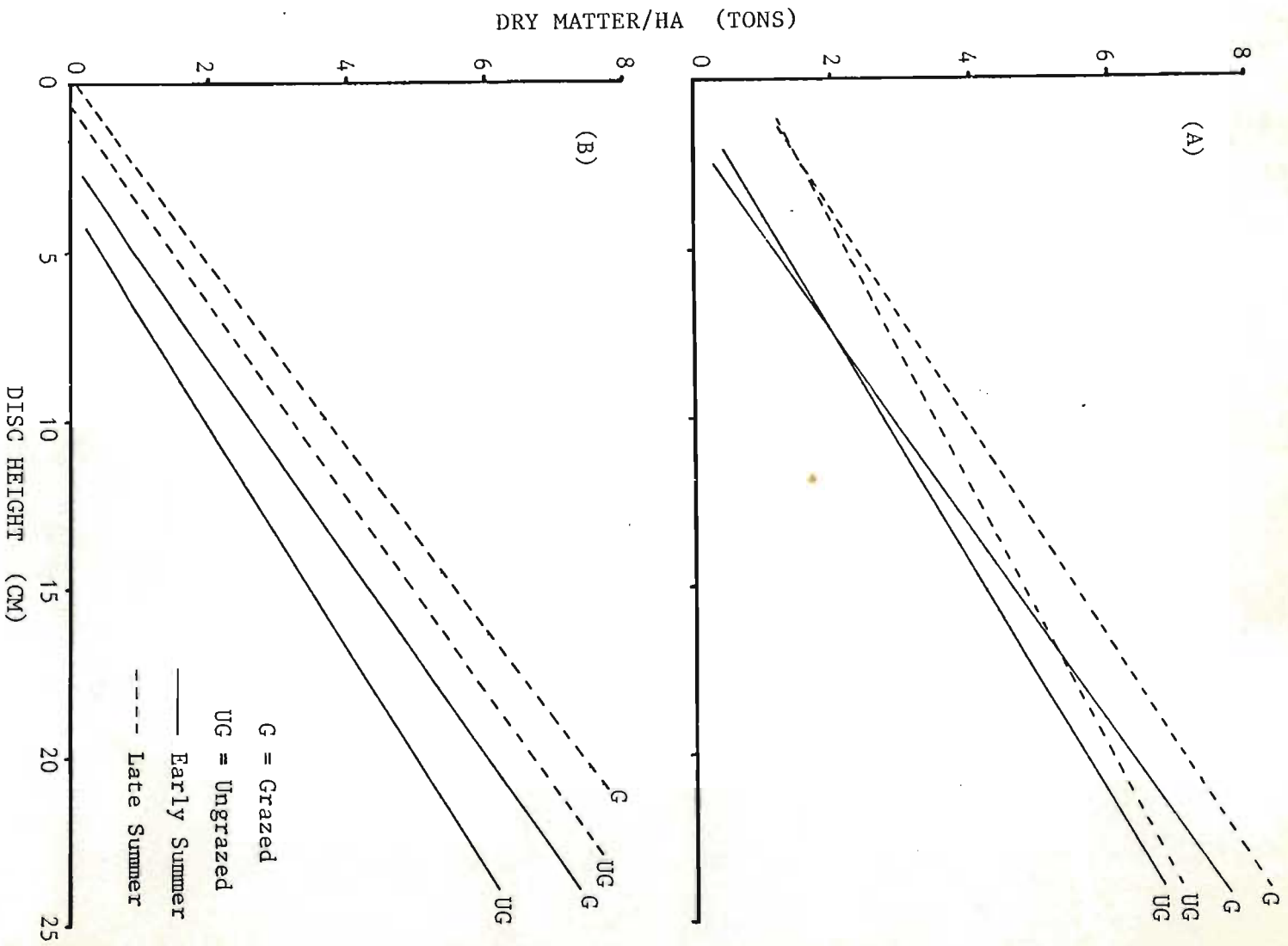


Fig. 3.1. Regression lines for dry matter/ha and disc height from Coastcross II (A) and kikyuu (B) in early and late summer.

calibrate the disc meter at fairly regular intervals throughout the experimental period. This being the case, the disc meter method would be extremely labour intensive and could no longer be regarded as a rapid technique (Bransby et al. 1977).

However, Bransby et al. (1977) suggested that for the purpose of adjusting animal numbers in put-and-take trials, it may not be necessary to calibrate the disc meter. In other words, instead of maintaining herbage availability in terms of DM/ha constant between replicates and within treatments over time, disc meter height would become the factor which would be kept constant. The assumption would therefore be that all the non-treatment variables which were listed in section 3.1, and animal performance in particular, are related to disc meter height.

Given careful consideration, this assumption is probably just as valid as the assumption that non-treatment variables are related to yield of DM/ha. For example, two paddocks may have the same yield of DM/ha but the herbage in one of these paddocks may be severely lodged (giving a low disc meter height) while the herbage in the other may remain erect (giving a high disc meter height). In such a case disc meter height would have no relation to yield of DM/ha. However, animal consumption is likely to be different on the two paddocks and more closely related to disc meter height than to the yield of DM/ha.

On the other hand it could well be argued that two swards could have the same disc meter height but one might contain mainly stem material and the other mainly leaf material. Herbage consumption on two such plots would differ even though disc meter heights were equal.



Despite these opposing arguments, disc meter height was chosen as the means to measure herbage availability mainly because it could be easily and rapidly measured, and because it was usually linearly related to liveweight gain per animal (Chapter 4). In the chapters which follow, the terms "disc meter height" and "disc height" are used interchangeably.

### 3.6 The practical application of the put-and-take technique.

From examining Table 3.2 it is clear that the difference in disc meter height between replicates was often greater than differences between treatments. This meant firstly, that the use of put-and-take had not been successful in maintaining disc meter height constant between replicates. Secondly, it meant that the intended replicates could not be regarded as replicates for the purpose of analysis, and that results would have to be analysed by means of regression analysis and the analysis of covariance (Riewe 1961, 1965). In addition, the author was not successful in using put-and-take to achieve goal heights set for each treatment, and the weekly disc meter heights of each paddock sometimes varied considerably around the mean over time (Table 3.3). In this respect the actual disc heights achieved tended to be above the goal for heavily utilized rotational grazing treatments in particular, and tended to be below the goal for continuous grazing, particularly when the objective was lenient utilization. Furthermore, the standard deviations of the mean of weekly disc heights for fixed stocked treatments were in the same range as those for put-and-take treatments. This fluctuation of disc meter height with time is presented graphically in Fig. 3.2. Here again

TABLE 3.2. Average disc meter height for the whole grazing period for all treatments in all seasons.

| Paddock | Replicate | Treatment<br>(utilization and<br>grazing method) | Average of weekly disc meter height (cm) for whole season |         |         |         |         |         |         |         |             |
|---------|-----------|--------------------------------------------------|-----------------------------------------------------------|---------|---------|---------|---------|---------|---------|---------|-------------|
|         |           |                                                  | Coastcross                                                |         |         |         | Kikuyu  |         |         |         | Rhodesgrass |
|         |           |                                                  | 1976/77                                                   | 1977/78 | 1978/79 | 1979/80 | 1978/79 | 1979/80 | 1980/81 | 1981/82 | 1978/79     |
| 3       | 1         | P & T Heavy                                      | 7,18                                                      | 7,44    | 5,61    | 5,60    | 6,62    | 5,80    | 6,15    | 5,78    | 4,25        |
| 12      | 2         | Continuous                                       | 6,34                                                      | 7,00    | 4,55    | 4,90    | 5,60    | 5,24    | 4,89    | 3,49    | 5,15        |
| 1       | 1         | P & T Medium                                     | 8,30                                                      | 9,07    | 6,56    | 6,01    | 8,44    | 7,66    | 7,07    | 4,45    | 7,84        |
| 11      | 2         | Continuous                                       | 8,72                                                      | 8,54    | 8,15    | 7,72    | 7,59    | 7,33    | 8,38    | 5,49    | 8,12        |
| 5       | 1         | P & T Light                                      | 10,03                                                     | 9,95    | 8,85    | 7,51    | 10,48   | 8,59    | 9,09    | 5,86    | 7,78        |
| 9       | 2         | Continuous                                       | 11,00                                                     | 10,04   | 9,14    | 10,18   | 10,29   | 6,64    | 8,77    | 5,50    | 7,66        |
| 6       | 1         | Fixed Light                                      | 10,75                                                     | 9,90    | 8,18    | 9,88    | 9,65    | 7,50    | 11,63   | 5,77    |             |
| 8       | 2         | Continuous                                       | 11,74                                                     | 9,19    | 10,96   | 9,39    | 11,54   | 9,36    | 8,60    | 5,77    |             |
| 4       | 1         | P & T Heavy                                      | 10,47                                                     | 10,59   | 10,13   | 9,85    | 12,73   | 9,28    | 8,52    | 6,66    | 8,35        |
| 7       | 2         | Rotation                                         | 11,36                                                     | 10,66   | 10,08   | 9,00    | 9,73    | 9,63    | 8,31    | 6,12    | 8,91        |
| 2       | 1         | P & T Light                                      | 12,96                                                     | 12,68   | 12,50   | 11,28   | 13,44   | 9,76    | 9,32    | 6,95    | 10,55       |
| 10      | 2         | Rotation                                         | 12,83                                                     | 12,55   | 12,70   | 11,56   | 13,88   | 10,55   | 9,68    | 7,58    | 12,10       |

TABLE 3.3. Goal disc meter heights and means of weekly disc meter heights with standard deviations for all treatments on Coastcross II in the 1977/78 season.

| Paddock number | Level of utilization and grazing method | Goal disc height (cm) | Mean of weekly disc heights achieved for the season (cm) | Standard deviation of weekly disc heights (cm) |
|----------------|-----------------------------------------|-----------------------|----------------------------------------------------------|------------------------------------------------|
| 3              | P & T Heavy                             | 7                     | 7,44                                                     | ± 1,24                                         |
| 12             | Continuous                              | 7                     | 7,00                                                     | ± 0,93                                         |
| 1              | P & T Medium                            | 9                     | 9,07                                                     | ± 1,01                                         |
| 11             | Continuous                              | 9                     | 8,54                                                     | ± 0,87                                         |
| 5              | P & T Light                             | 11                    | 9,95                                                     | ± 1,36                                         |
| 9              | Continuous                              | 11                    | 10,04                                                    | ± 1,27                                         |
| 6              | Fixed                                   | -                     | 9,90                                                     | ± 1,23                                         |
| 8              | Continuous                              | -                     | 9,19                                                     | ± 0,72                                         |
| 4              | P & T Heavy                             | 7                     | 10,59                                                    | ± 0,88                                         |
| 7              | Rotational                              | 7                     | 10,66                                                    | ± 0,73                                         |
| 2              | P & T Light                             | 11                    | 12,68                                                    | ± 1,09                                         |
| 10             | Rotational                              | 11                    | 12,55                                                    | ± 1,20                                         |



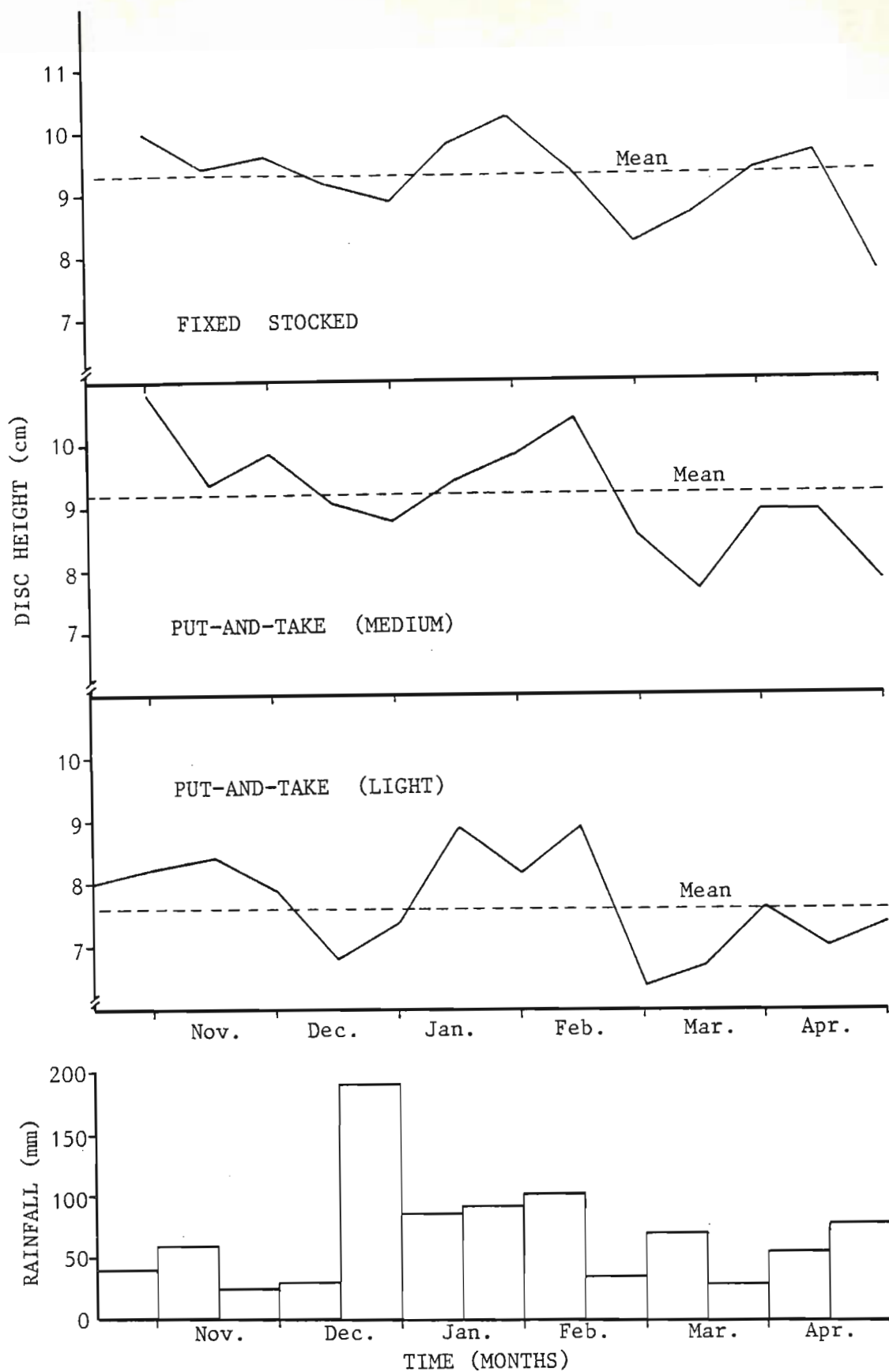


Fig. 3.2. Disc height plotted against time for a medium and a light put-and-take paddock and for fixed stocking, and rainfall plotted at 2-weekly intervals.

it is apparent that little success was achieved in reducing the variation in disc meter height with time by using the put-and-take technique as an alternative to fixed stocking.

The basis for adjusting animal numbers on rotational grazing treatments also presented difficulties. Initially it was intended to take the mean disc height of all the sub-paddocks in the rotation into account as well as the disc height to which paddocks were grazed and to which they were allowed to regrow. This proved to be practically unattainable and so the mean disc height of all the sub-paddocks only was used. However, the mean of the disc height in the last sub-paddock grazed and in the next paddock to be grazed in the rotation might well have been a more realistic criterion.

Other difficulties experienced with the application of the put-and-take technique are illustrated in Fig. 3.3. From examination of the fluctuation in disc height and the adjustment of animal numbers in each treatment with time, there appears to be evidence of a lag in the reaction of disc height to adjustments in animal numbers. When the disc meter height rose above the goal height animals were introduced, but it is clear that in a number of cases disc meter height continued to rise before it started to drop in reaction to the increase in animal numbers. Then, as the disc meter height decreased towards the goal height animals would be removed, but disc height would often continue to fall after this to a level well below the goal height. If the fluctuation of disc height with time and the patterns of adjustments to animal numbers are compared with the distribution of rainfall (Fig. 3.3) it seems possible that a greater measure of success may have been achieved by adjusting animal numbers according to rainfall rather than according to disc meter height.

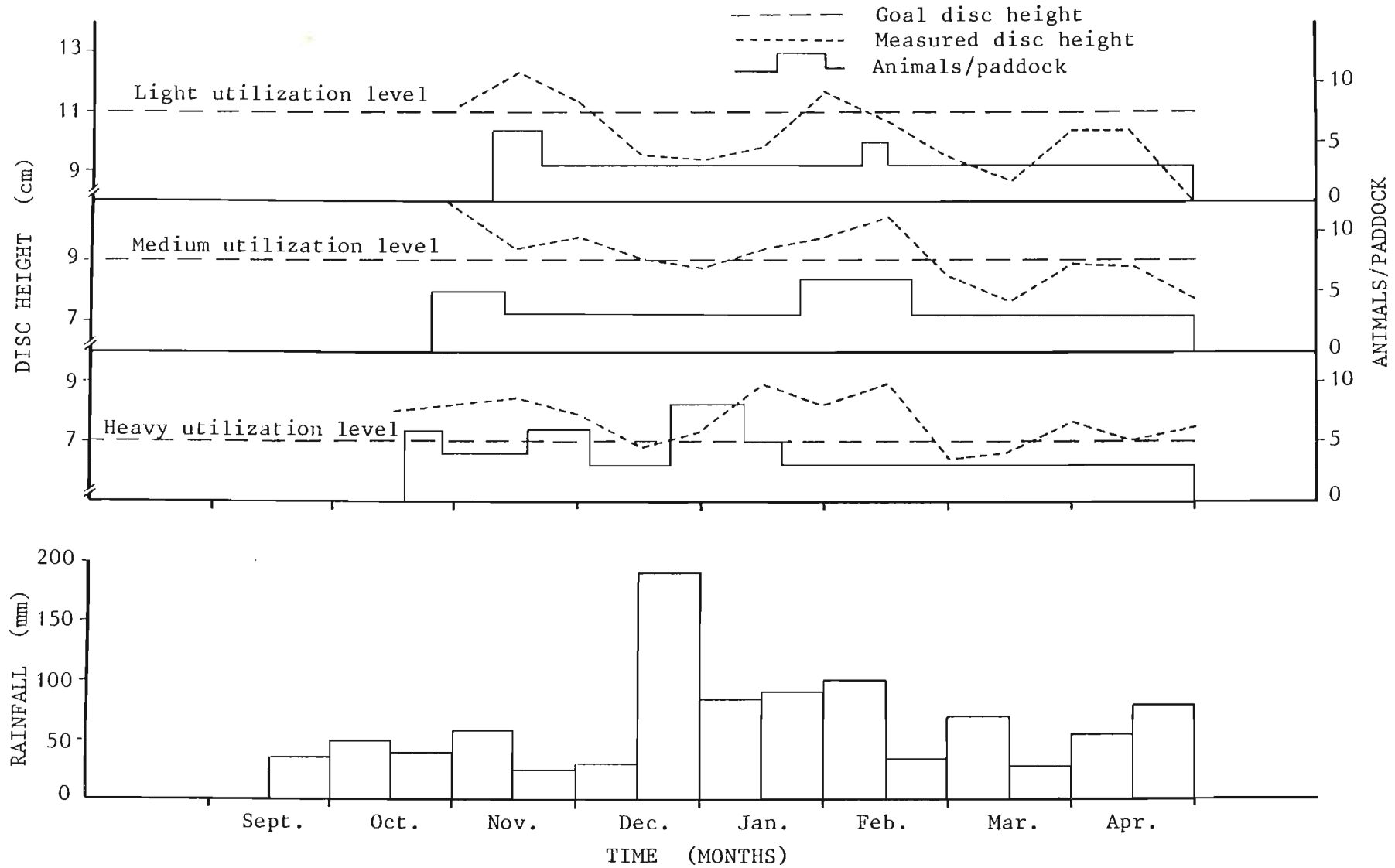


Fig. 3.3. Disc height and animal numbers on three put-and-take treatments in relation to rainfall for the 1977/78 season.



Another factor which seemed to make the application of put-and-take difficult was the large variation in rainfall between seasons. The size of the paddocks in these grazing trials was calculated on the basis of a minimum of three tester animals and the expected pasture yield for an average rainfall of 700 mm per annum. However, rainfall varied between 506,2 mm and 989,9 mm. Bearing in mind the minimum limit of three testers, the author was often reluctant to add fillers in case disc height was depressed below the goal height. This was definitely a problem in the seasons in which rainfall was low (1979/80, 1980/81 and 1981/82) and resulted in the range in stocking rates in these seasons being very narrow (Chapter 6). However, even during seasons of good rainfall the inclination was to be conservative with the introduction of fillers.

In other words, the suggestion is that if the restriction of a minimum of three testers was removed i.e. if it was permissible to remove all animals from the pasture when necessary, then greater success would probably have been achieved in keeping disc height constant over time. The implication here is that the size of paddocks in a put-and-take trial should be determined according to the number of testers to be used and the lowest rainfall expected rather than the average. This would then allow the researcher greater flexibility and freedom to put-and-take, but would require a larger area and more filler animals, thus probably limiting the number of possible treatments.

Despite the difficulties experienced in maintaining disc meter height constant over time, it is clear that a measure of success was achieved in maintaining differences between treatments (Fig. 3.2, Table 3.3). However, although a range in fixed stocking rates was not applied in these trials (which means that

comparison with put-and-take is not possible) it is likely that a range of fixed stocking rates would have been more or less equally successful.

Since it appears that accurate application of the put-and-take technique under the conditions of these trials was almost impossible, it is doubtful whether its use in preference to fixed stocking was justified. In view of the lower labour input, application of a range of fixed stocking rates should be preferred for future grazing trials at Ukulinga, provided disc meter height is still measured. However, in cases where patterns of forage production are not erratic but predictable, and fluctuations in forage production are large, the put-and-take technique is likely to be more appropriate than fixed stocking. The data of Blaser, Johnson, McLaugherty, Fontenot, Hammes, Bryant, Wolf and Mays (1981) seem to support this view.

### 3.7 Methods adopted in starting treatments at the beginning of each season

Since treatments in these trials were designed to compare different levels of herbage availability i.e. different disc meter heights, each treatment would therefore reach its goal disc height at a different point in time. Assuming that the whole experimental area had been mown off below the level of the lowest goal height in winter, treatments would become ready for grazing in sequence at the beginning of the summer growing period, starting with the lowest disc height (high utilization level) and ending with the highest disc height (low utilization level). This meant that grazing should perhaps have started sequentially on the treatments at the beginning of the summer. This method was

adopted in the 1976/77 and 1977/78 seasons. However, analysis of results became difficult because of the different length of the grazing period for each treatment. In these seasons only results from the period which was common to all treatments were therefore used to develop the Jones and Sandland model.

An alternative approach was to allow all treatments to grow out and then to "mob graze" them with relatively high stocking densities for a short period at the beginning of the season to establish goal heights. Thereafter, put-and-take could be applied normally. This approach was used in the 1978/79 and 1979/80 seasons. However, although it created a common grazing period for all treatments, it is likely to have created artificial conditions in the sward at the beginning of the season. These different approaches could well have been the cause of the differences in liveweight gain with time over these seasons. In the 1976/77 and 1977/78 seasons liveweight gain was high at the beginning of the season (Fig. 6.13a and b.) while in the 1978/79 and 1979/80 seasons it was low during this period (Fig. 6.13c and f ). This could possibly be explained by a relatively large amount of high quality, leafy material being available to animals when treatments were started sequentially (1976/77 and 1977/78) as opposed to low quality stemmy material being available after "mob grazing" (1978/79 and 1979/80).

Unfortunately it cannot be said that these were, without doubt, cause and effect relationships because the two approaches were not compared in the same season and confounding with animal and seasonal effects was possible. Nevertheless, in the last two seasons treatments were started simultaneously but without "mob grazing", the different disc meter heights thus being established more gradually. This approach, or the application of a range of



stocking rates simultaneously at the start of the season, would ensure a common grazing period for all treatments without creating an artificial type of sward. It may be argued that this method of starting treatments would mean that the period from the start of grazing to the point in time when the goal height was reached would have to be excluded from the analysis. However, in view of the apparently uncontrollable fluctuation of disc meter height with time, this argument would not carry much weight.

#### 4. THE EFFECT OF HERBAGE AVAILABILITY ON DAILY LIVWEIGHT GAIN PER ANIMAL

Daily liveweight gain per animal is a vital component of beef production from pastures and is influenced by stocking rate mainly through its effect on herbage availability. The emphasis in this chapter is therefore on the response of liveweight gain per animal to herbage availability as measured by the disc meter.

In view of the many possible interpretations of the term "herbage availability", its use is restricted to general discussion only, and in this context it can be considered to be an abbreviation for "herbage availability as measured by the disc meter". In the specific context herbage availability is referred to as disc meter height or disc height, dry matter per ha (DM/ha) and dry matter per animal (DM/animal). However, DM/ha and DM/animal were estimated by using appropriate calibrations of the disc meter.

For continuous grazing, disc meter height for the season was obtained by calculating the mean of the weekly disc meter heights which were in turn, means of 50 readings taken on each paddock. Disc meter height was then converted to available DM/ha by using the calibrations established on continuously grazed paddocks in early and late summer. However, for rotational grazing 25 disc meter readings were taken on each sub-paddock every week, giving a total of 150 readings from which a weekly mean was calculated. The average of these means over the whole season then represented the disc height for that season. The calibration of the disc meter for rotational grazing was established on all five

sub-paddocks in the system that were in their recovery period i.e. the one being grazed was not included.

The animals under rotational grazing were confronted with a continually changing sward, starting with ungrazed leafy regrowth at the beginning of the grazing period and ending with stalky material at the end. The most accurate method of measuring availability would therefore have been to take readings and calibrate the disc meter every day on the sub-paddock which was being grazed. Since this would have required a high labour input it was decided that all the paddocks not being grazed (including the one which had been grazed last and the one to be grazed next) would be measured for estimation of herbage availability.

Since the disc meter was used to measure DM/ha it might be argued that herbage availability should be expressed as kg DM/ha only, and not as disc height. However, disc meter height takes into account the vertical distribution of DM and as such constitutes a different measure of herbage availability to DM/ha. Herbage availability is therefore expressed as disc height, DM/ha and DM/animal, and daily liveweight gain per animal is related to each of these variables separately.

To calculate daily liveweight gain per animal the mean weight of testers at the beginning of the grazing period was subtracted from the mean weight of testers at the end of the grazing period, and this value was divided by the number of days in the period.



#### 4.1 Relationships developed for the whole season

In this section the relationships between daily liveweight gain per animal and herbage availability are presented for data from the whole season.

##### 4.1.1 Coastcross

In the 1976/77 season the correlation coefficient ( $r$ ) for the linear regression of daily liveweight gain per animal on disc meter height was significant for continuous grazing ( $P < 0,05$ ) but not for rotational grazing (Fig. 4.1). However, when parallel lines were fitted to the two sets of data there was a significant difference in their location ( $P < 0,01$ ). The implication is, therefore, that within the range of disc meter height covered in this season, liveweight gain per animal is higher under continuous grazing than under rotational grazing, the difference being approximately 0,20 kg.

While the hazard of extrapolating regression lines beyond the limits of the data from which they were derived is recognized, this has been done throughout this thesis to facilitate further speculation. In Fig. 4.1 extrapolation of the line for continuous grazing results in the interception of the vertical axis, thus implying that when disc height is zero animals will still gain weight. This, however, is clearly impossible and indicates that extrapolation beyond the limits of the data is not valid.

In the 1977/78 season the correlation coefficient for the regression between liveweight gain per animal and disc meter height was significant for rotational grazing ( $P < 0,05$ ) but not for continuous grazing (Fig. 4.2). However, when parallel lines were fitted to the two sets of data the location of the two lines was significantly different ( $P < 0,01$ ). This result was therefore

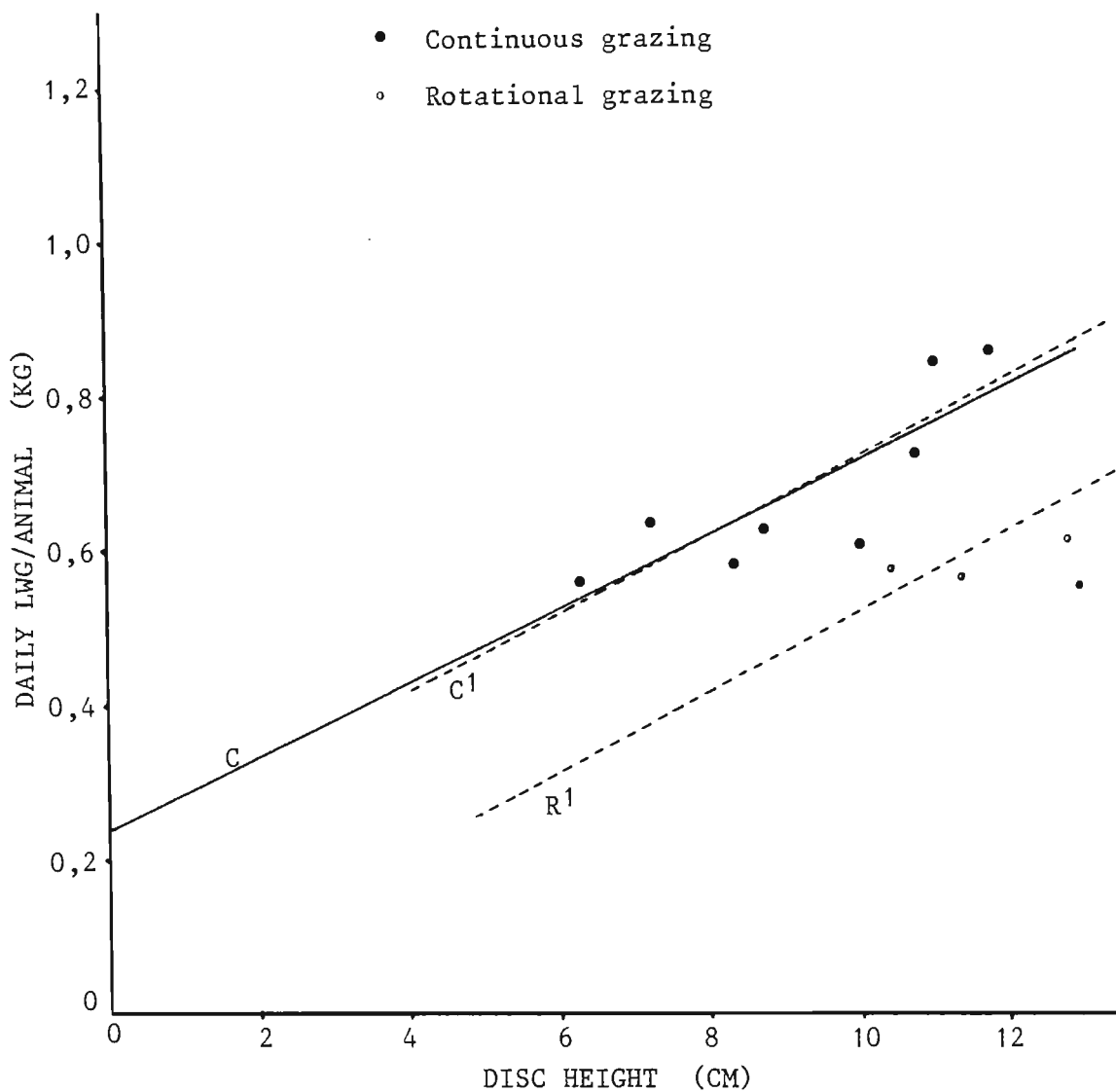


Fig. 4.1. The relation between liveweight gain per animal (y) and disc height (x) in the 1976/77 growing season for continuous grazing (C as  $y = 0,22 + 0,049x$ ,  $r = 0,82^*$ ) and parallel lines for continuous grazing (C<sup>1</sup>) and rotational grazing (R<sup>1</sup>) on Coastcross.

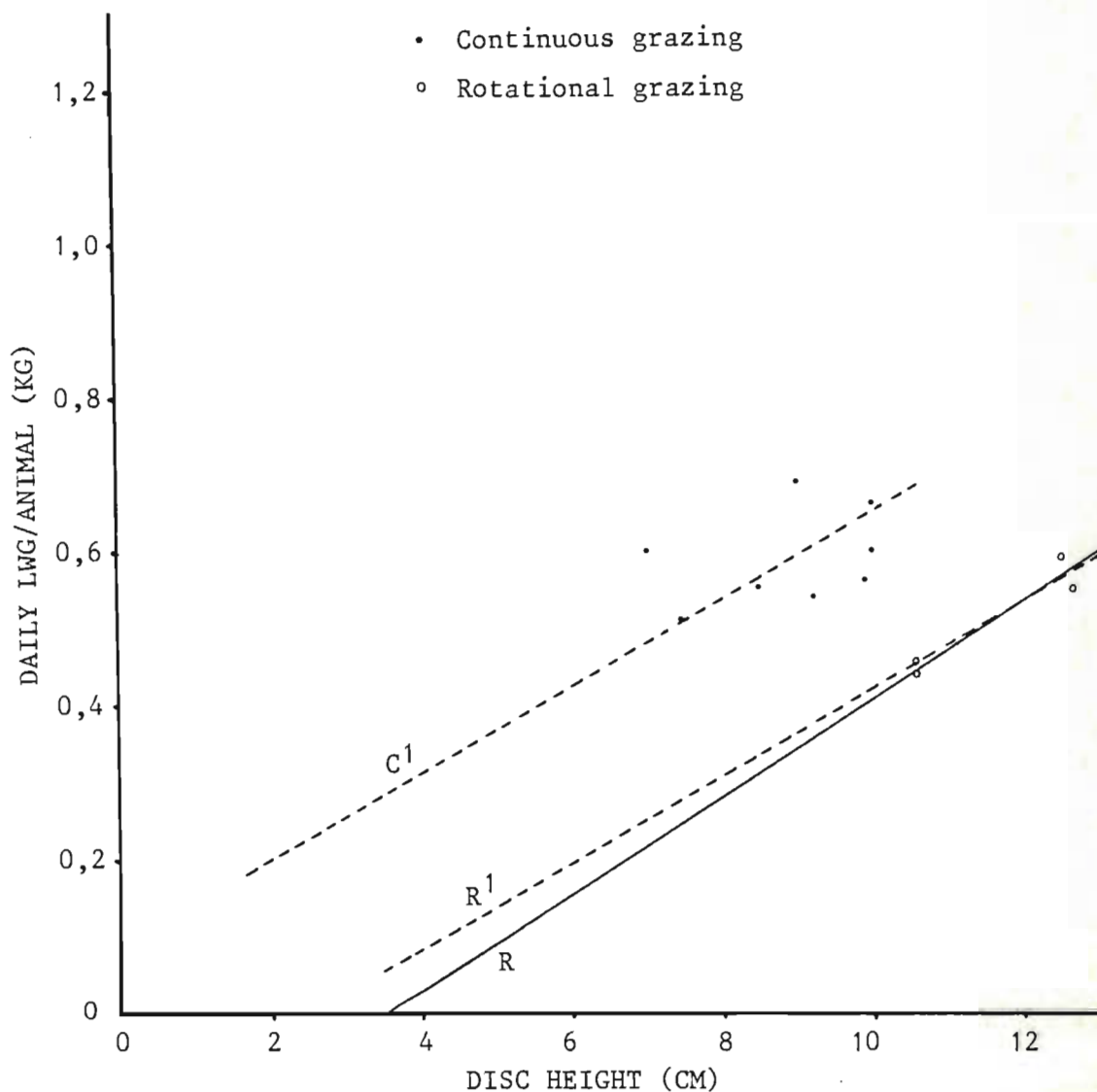


Fig. 4.2. The relationship between liveweight gain per animal ( $y$ ) and disc height ( $x$ ) in the 1977/78 season for rotational grazing ( $R$  as  $y = -0,22 + 0,627x$ ,  $r = 0,96^*$ ) and parallel lines for continuous grazing ( $C^1$ ) and rotational grazing ( $R^1$ ) on Coastcross.



in agreement with that of the first season, the difference between rotational and continuous grazing in this case being 0,22 kg over the range in disc height applied.

Correlation coefficients of the linear regressions for both continuous and rotational grazing were good in the 1978/79 season but only that for continuous grazing was significant ( $P < 0,05$ ) (Fig. 4.3). Despite the apparent difference between these lines, the slopes were not significantly different and neither was the location of fitted parallel lines. The points for rotational and continuous grazing therefore have to be regarded as members of the same population. However, their relative positions in the scatter diagrams suggest a tendency towards the superiority of continuous grazing in liveweight gain per animal at equivalent disc meter heights i.e. the results tended towards those of the first two seasons.

In the fourth and final season in which Coastcross was assessed (1979/80) there were relatively poor correlation coefficients for both regressions and there was no significant difference between the two methods of grazing (Fig. 4.4). However, when the data for each paddock were averaged for all four seasons, the difference between continuous and rotational grazing was still evident, and extrapolation of both lines resulted in the interception of the vertical axis (Fig. 4.5).

It is evident from comparisons of Fig. 4.6a, b, c and d with Fig. 4.1, 4.2, 4.3 and 4.4 respectively, that conversion of disc meter height to DM/ha did not result in any major changes in the pattern for continuous and rotational grazing in each season. In the 1976/77 and 1977/78 seasons continuous grazing still resulted in higher liveweight gain per animal at equivalent DM/ha, the difference within the limits of the data being 0,15 kg and 0,18 kg

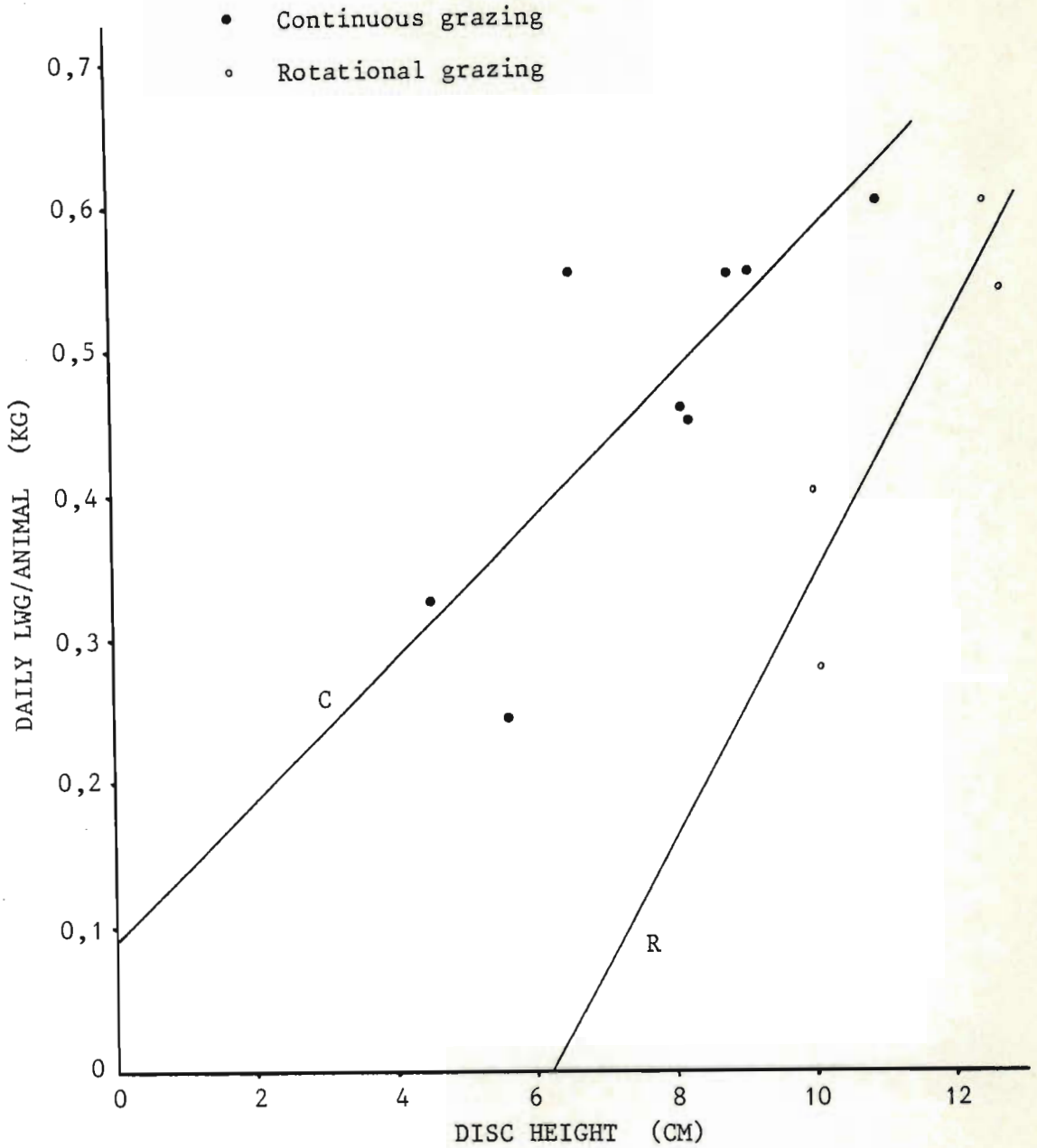


Fig. 4.3. Relationships between daily liveweight gain ( $y$ ) and disc height ( $x$ ) in the 1978/79 season for continuous grazing (C as  $y = 0,09 + 0,049x$ ,  $r = 0,81^*$ ) and rotational grazing (R as  $y = -0,56 + 0,090x$ ,  $r = 0,90$ ) on Coastcross.

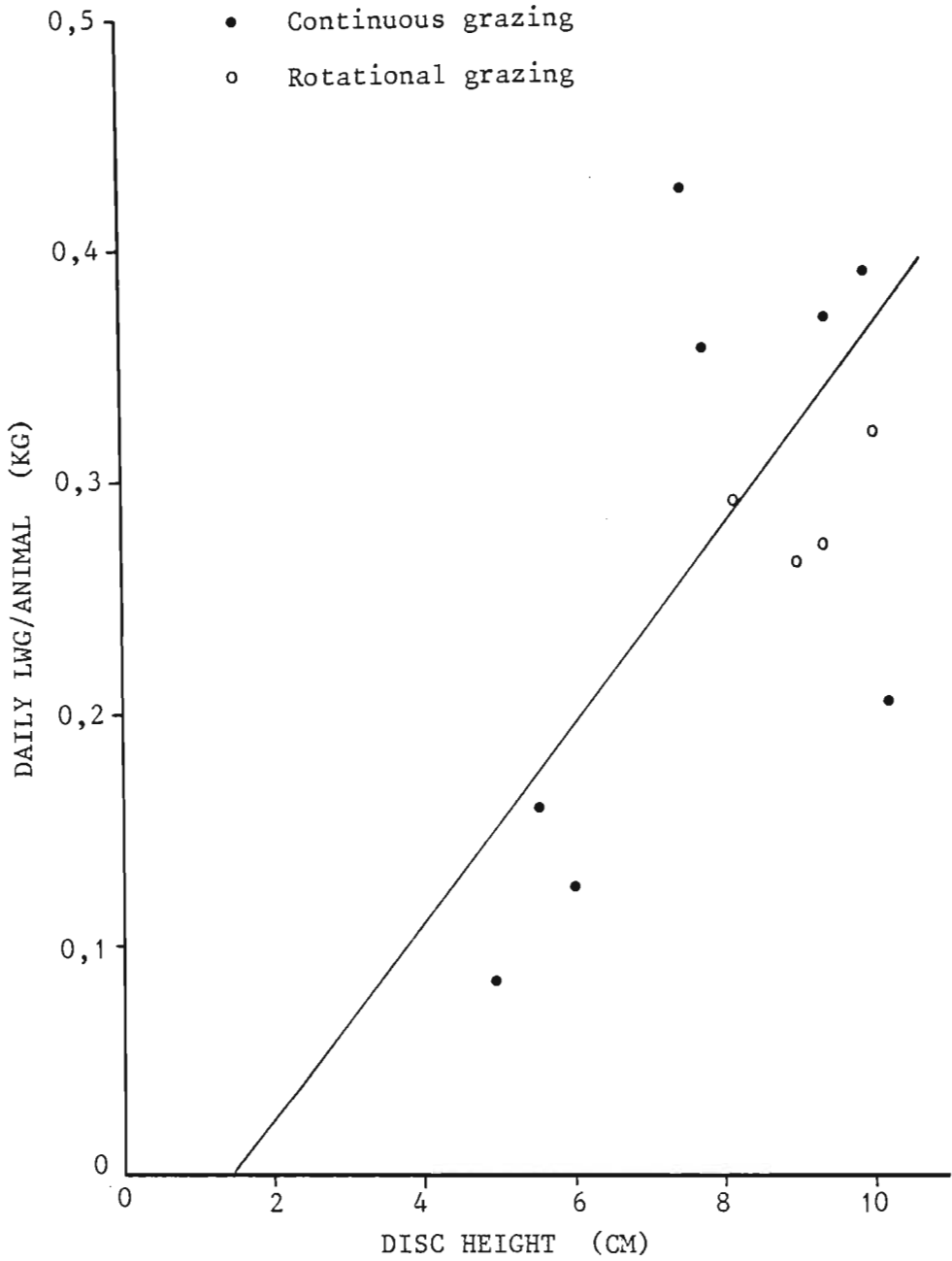


Fig. 4.4. The relationship between daily liveweight gain per animal (x) and disc height (y) in the 1979/80 season for continuous grazing (C as  $y = -0,0587 + 0,042x$ ,  $r = 0,64$ ) on Coastcross.



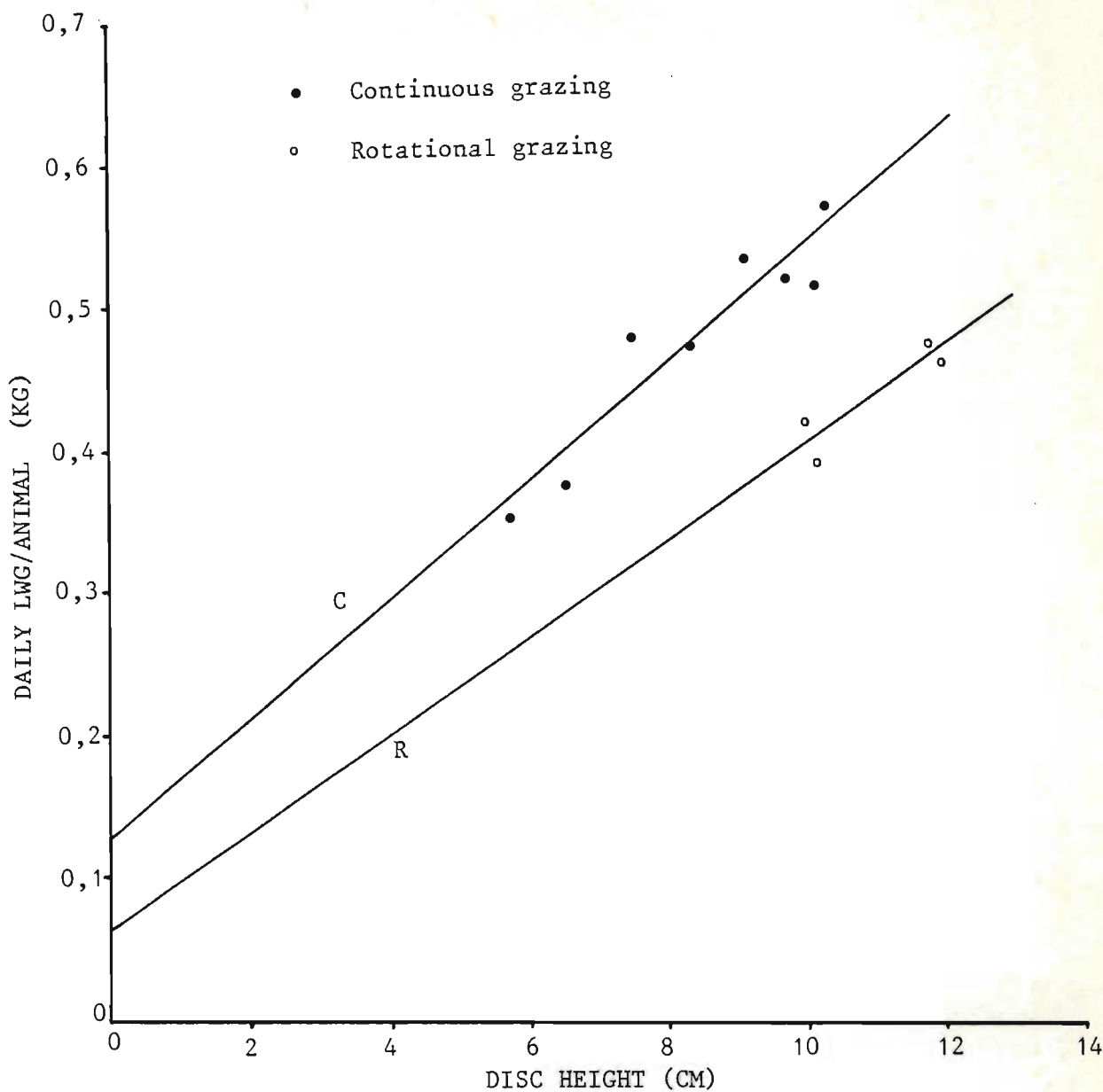


Fig. 4.5. The relationships between daily liveweight gain per animal ( $y$ ) and disc height ( $x$ ) derived from an average of all four seasons for continuous grazing (C as  $y = 0,127 + 0,042x$ ,  $r = 0,94^{**}$ ) and rotational grazing (R as  $y = 0,064 + 0,034x$ ,  $r = 0,93$ ) on Coastcross.

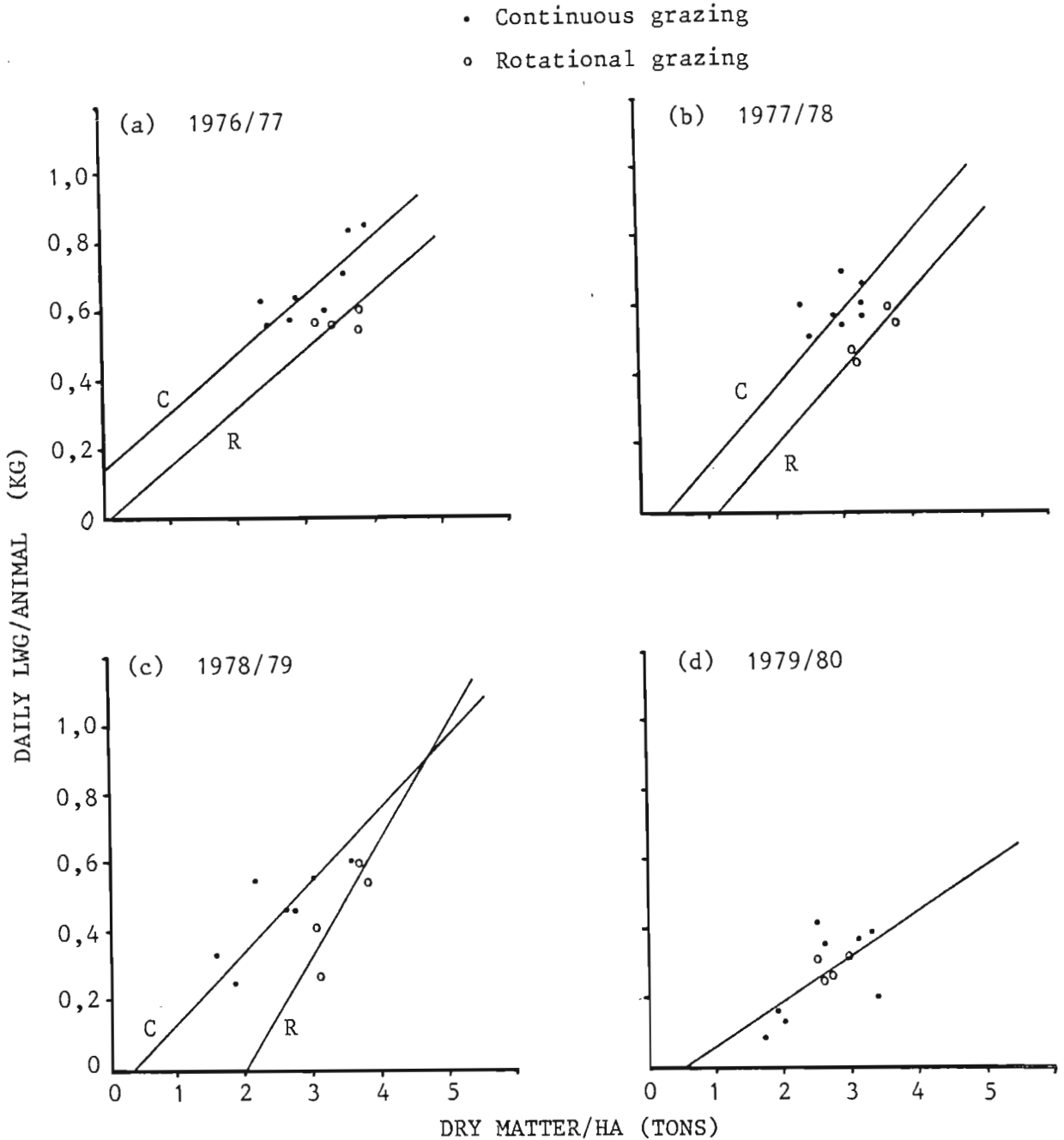


Fig. 4.6. Relationships between dry matter per ha and daily liveweight gain per ha on Coastcross for continuous grazing (C) and rotational grazing (R) in the first three seasons and for the pooled data from continuous and rotational grazing in the 1979/80 season.

respectively for the two seasons (Fig. 4.6a and b). No difference existed between the two methods of grazing in the 1978/79 and 1979/80 seasons (Fig. 4.6c and d) although there appeared to be a tendency towards higher liveweight gain under continuous grazing at equivalent DM/ha in the 1978/79 season (Fig. 4.6c). This pattern is very similar to that in Fig. 4.3.

For the average of all four seasons the location of parallel lines describing the relationships between liveweight gain per animal and DM/ha for rotational and continuous grazing was significantly different ( $P < 0,01$ ) (Fig. 4.7). This means continuous grazing resulted in a liveweight gain that was 0,1 kg per day higher than that for rotational grazing at equivalent DM/ha within the limits of the data.

Since the total number of animal grazing days for each paddock was recorded, it was possible to calculate an average stocking rate for each paddock in each season by dividing animal grazing days by the number of days in the grazing period. The estimated dry matter availability per animal could then be computed by dividing DM/ha by average stocking rate (in animals/ha). It was then possible to establish the relationships between DM/animal and liveweight gain per animal.

In the 1976/77 and 1977/78 seasons continuous grazing resulted in higher liveweight gain per animal than rotational grazing at similar levels of DM/animal (Fig. 4.8). However, in both seasons the difference was only 0,08 kg/animal ( $P < 0,05$ ). In the 1978/79 and 1979/80 seasons there was no difference between the two methods of grazing (Fig. 4.8). The pattern between seasons was therefore similar to that in Fig. 4.6, but the difference in liveweight gain per animal at equivalent DM/animal which occurred in the first two seasons was eliminated when the



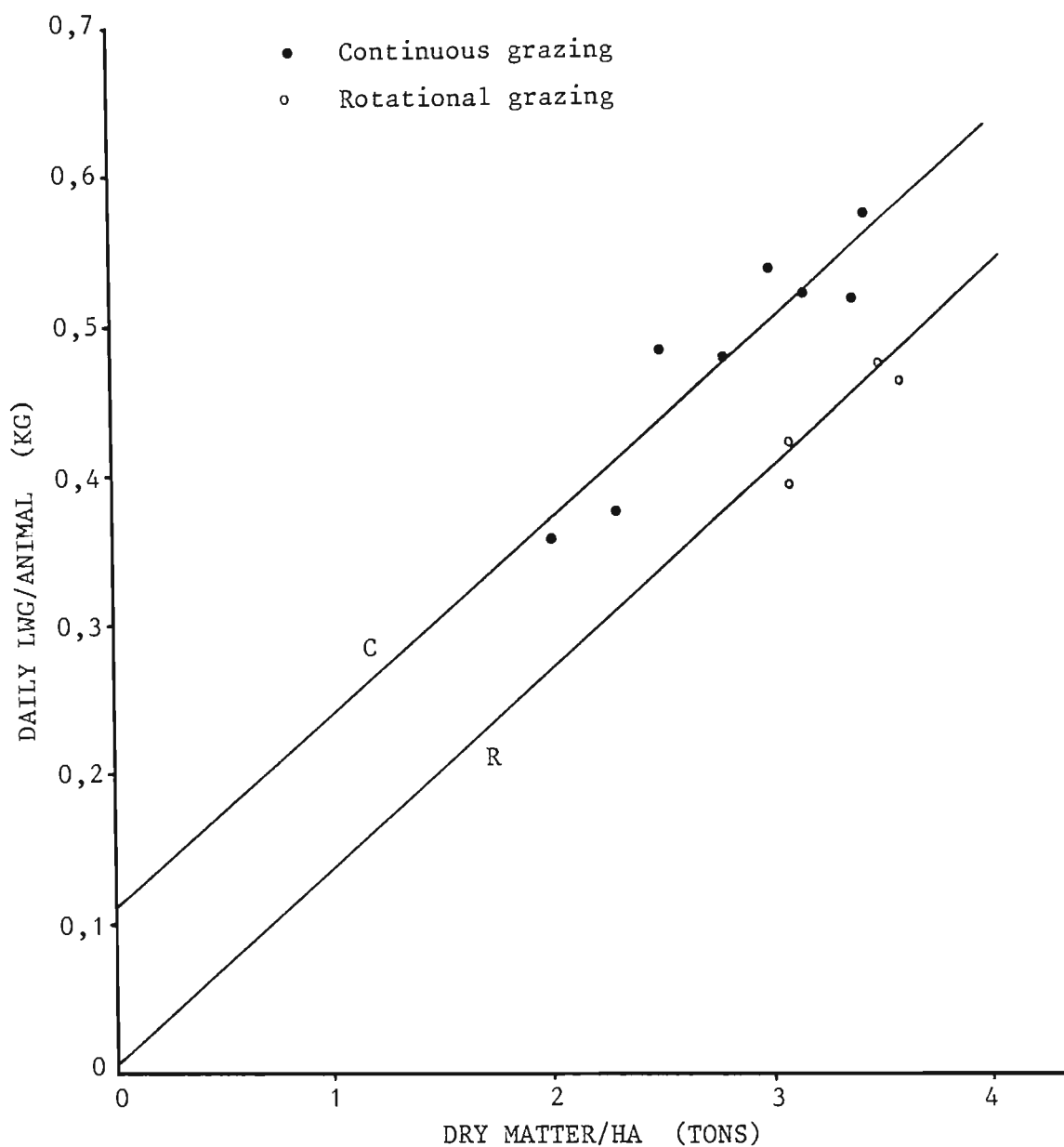


Fig. 4.7. The relationship between daily liveweight gain per animal ( $y$ ) and dry matter per ha ( $x$ ) from the average data from all four seasons for continuous grazing (C as  $y = 0,111 + 0,130x$ ,  $r = 0,94^{**}$ ) and rotational grazing (R as  $y = 0,006 + 0,130x$ ,  $r = 0,93$ ) on Coastcross

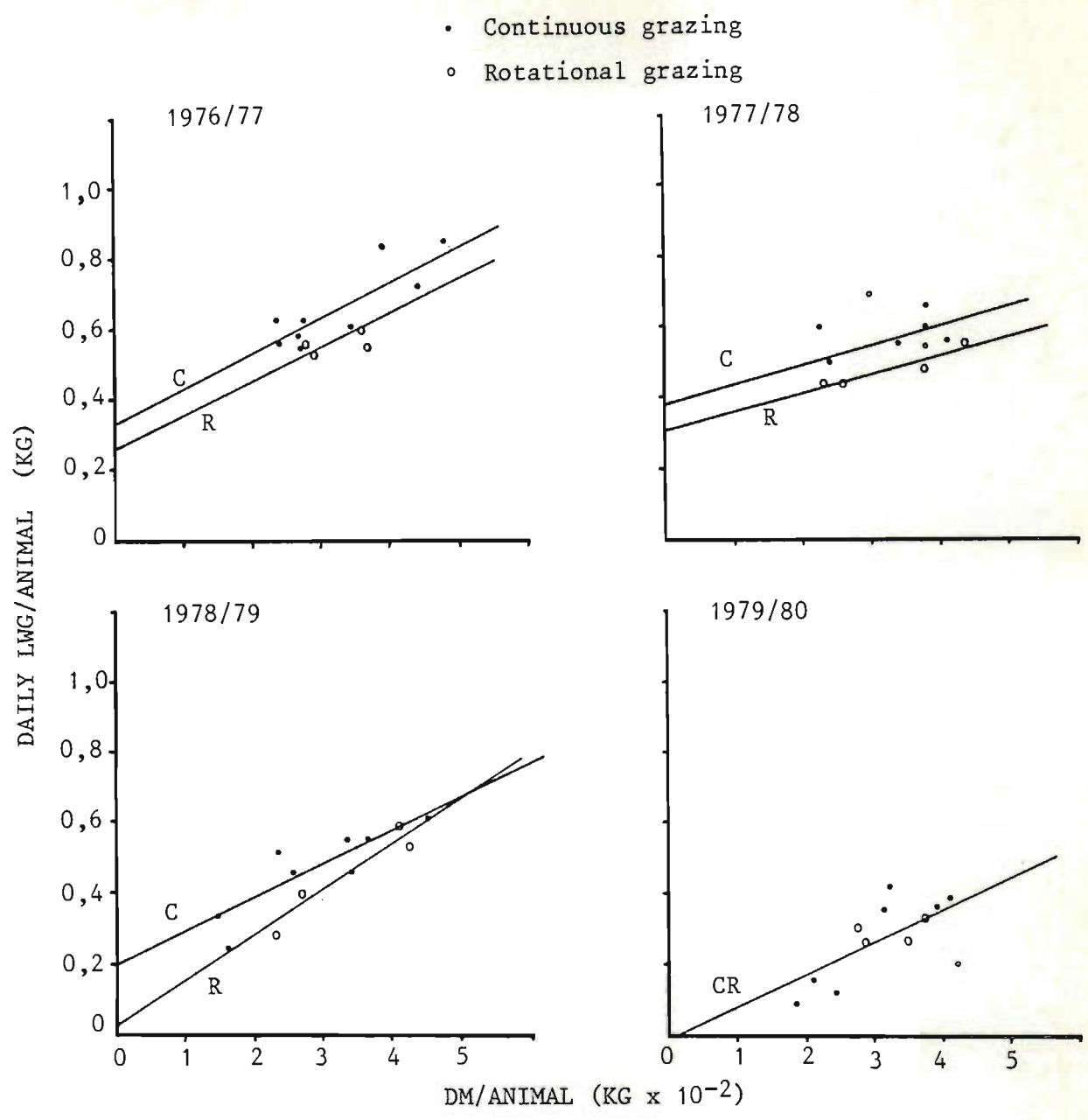


Fig. 4.8. Relationships between dry matter per animal and daily liveweight gain per animal on Coastcross under continuous grazing (C) and rotational grazing (R) for the first three seasons and for the pooled data from rotational and continuous grazing (CR) in the 1979/80 season.

average from the four years was used for regression (Fig. 4.9). Despite no difference between the two methods of grazing, correlation coefficients for each were good and separate regressions were therefore presented.

#### 4.1.2 Kikuyu and Rhodesgrass

In the first season in which kikuyu was evaluated (1978/79) there was no difference between continuous and rotational grazing in liveweight gain per animal at equivalent disc heights. The regression for the pooled data from both methods is therefore presented in Fig. 4.10. Extrapolation of this line again resulted in an intercept of the vertical axis.

In the 1979/80 season much the same result occurred, but in this case extrapolation was minimal, the intercept being on the horizontal axis at a disc meter height of 3,85 cm (Fig. 4.11). The implication is, therefore, that at a disc meter height of 3,85 cm the expected liveweight gain per animal is zero.

There was no significant difference between continuous and rotational grazing in the 1980/81 season, although there seemed to be a tendency for continuous grazing to result in slightly better liveweight gain per animal than rotational grazing when disc meter height was below 9 cm (Fig. 4.12). Finally, in the last season (1981/82) the correlation coefficient for the regression of daily liveweight gain per animal on disc meter height was significant for continuous grazing ( $P < 0,01$ ) but not for rotational grazing (Fig. 4.13). However, all the points for rotational grazing were located below the regression line for continuous grazing, again suggesting a possible tendency towards the superiority of continuous grazing.



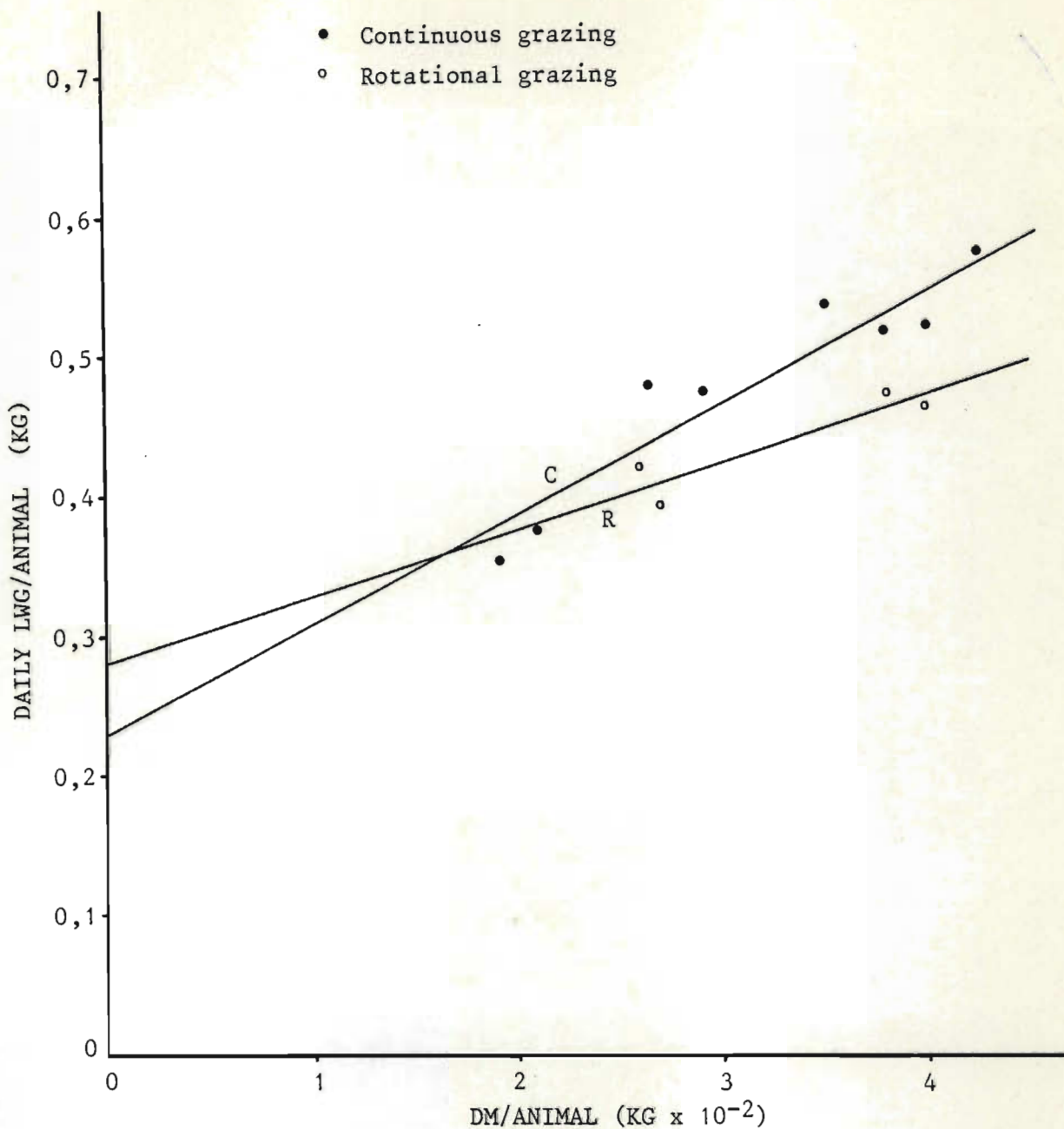


Fig. 4.9. The relationships between liveweight gain per animal and DM/animal derived from the average of four seasons for continuous grazing (C as  $y = 0,23 + 0,00080x$ ,  $r = 0,94^{**}$ ) and rotational grazing (R as  $y = 0,28 + 0,00048x$ ,  $r = 0,92$ ) on Coastcross.

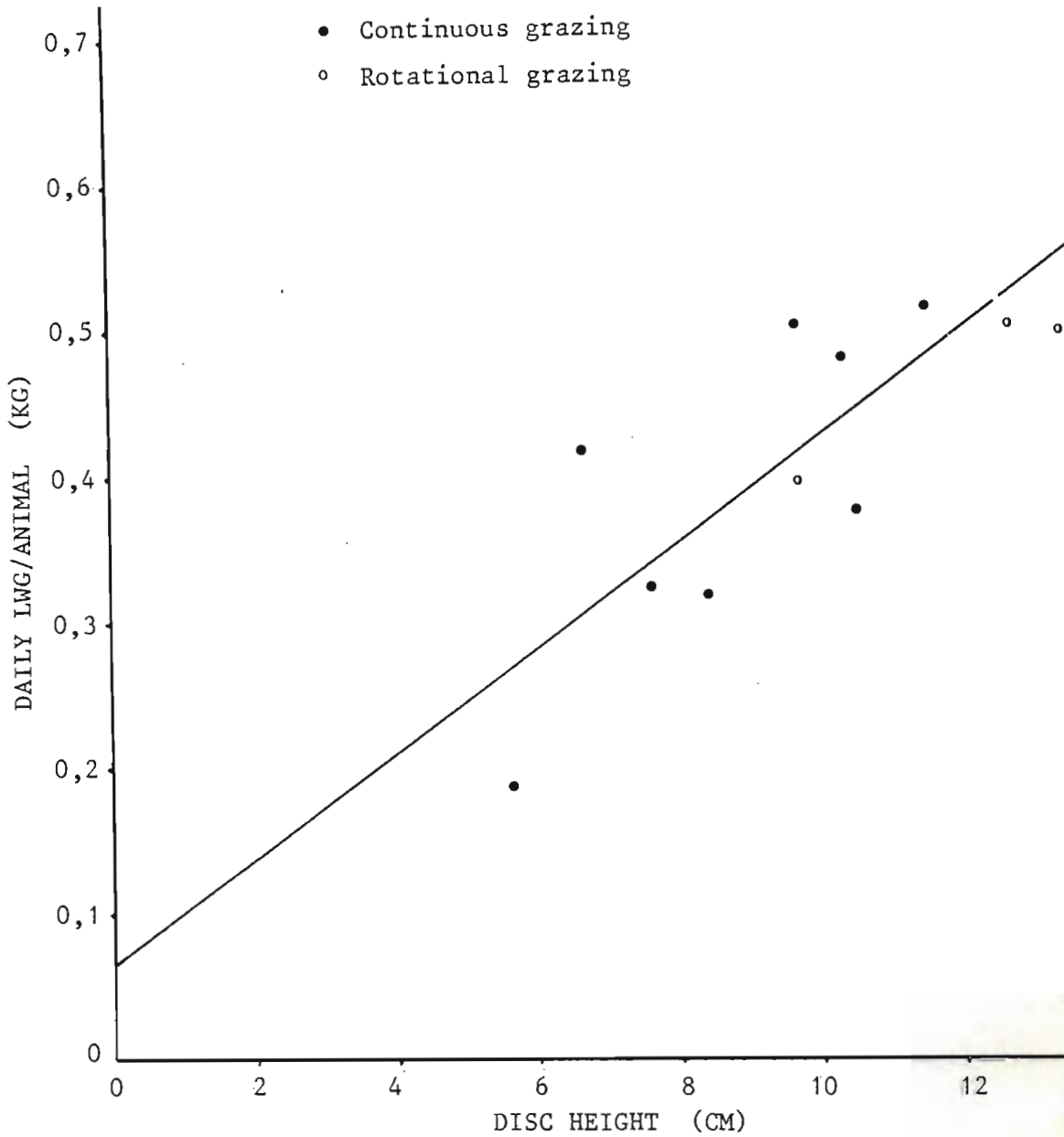


Fig. 4.10. The relationship between daily liveweight gain per animal ( $y$ ) and disc height ( $x$ ) in the 1978/79 season for the pooled data from both continuous and rotational grazing ( $y = 0,07 + 0,036x$   $r = 0,83^{**}$ ) on kikuyu.

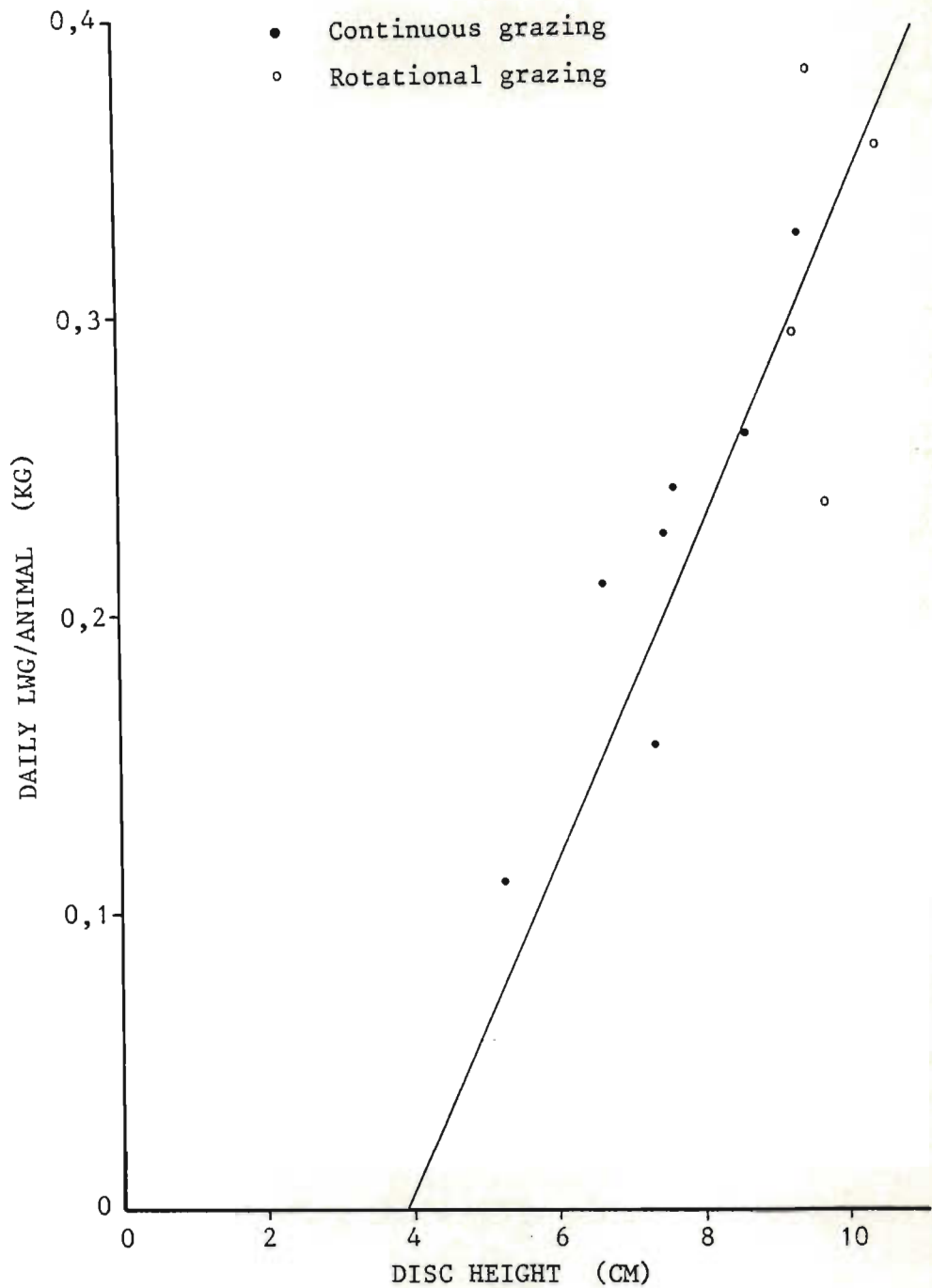


Fig. 4.11. The relationship between daily liveweight gain per animal (y) and disc height (x) in the 1979/80 season for the pooled data from both continuous and rotational grazing on kikuyu. ( $y = -0,22 + 0,055x$ ,  $r = 0,87^{**}$ ).

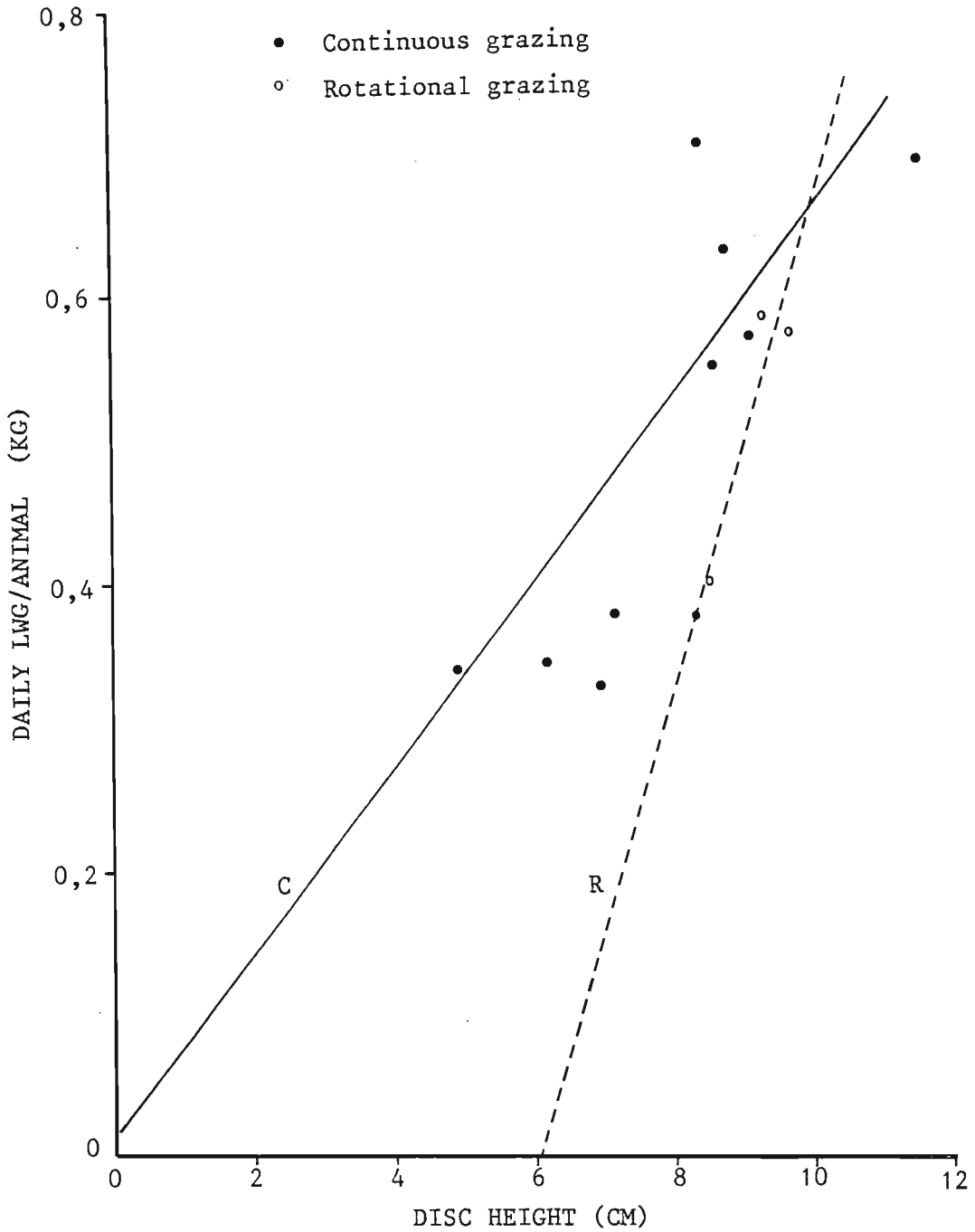


Fig. 4.12. Relationships between liveweight gain per animal ( $y$ ) and disc height ( $x$ ) in the 1980/81 season for continuous grazing (C as  $y = 0,015 + 0,06x$   $r = 0,76^*$ ) and rotational grazing (R as  $y = -0,99 + 0,16x$ ,  $r = 0,97^*$ ) on kikuyu.



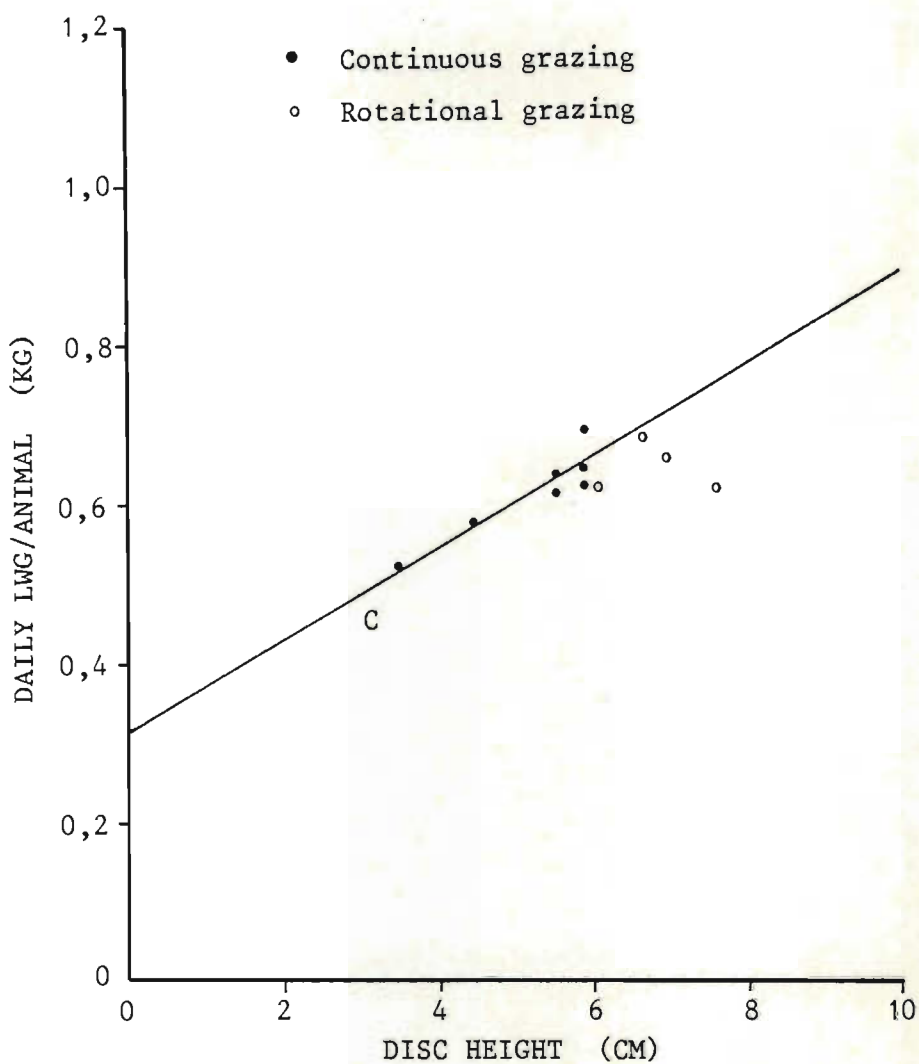


Fig. 4.13. The relationship between daily liveweight gain per animal (y) and disc height (x) in the 1981/82 season for continuous grazing (C as  $y = 0,32 + 0,058x$ ,  $r = 0,92^{**}$ ) on kikuyu.

When the four year average of data from each paddock was used for regression, significant correlation coefficients were obtained for both continuous grazing ( $P < 0,01$ ) and rotational grazing ( $P < 0,05$ ) but the lines were not significantly different (Fig. 4.14).

Results for Rhodesgrass in the 1978/79 season showed poor correlation and no significant difference between continuous and rotational grazing in terms of liveweight gain per animal at equivalent disc meter height (Fig. 4.15).

When disc meter data for kikuyu was converted to DM/ha by means of appropriate regression equations, there was no difference between regressions for continuous and rotational grazing in each season. The regressions for the pooled data from both methods of grazing are presented for all seasons in Fig. 4.16. In view of the similarity of results between seasons, it followed that there was no difference between continuous and rotational grazing when regressions were derived from the averages of all four seasons (Fig. 4.17).

Relationships between liveweight gain per animal and DM/animal also showed no difference between the two grazing methods in each season, nor for the averages of all four seasons.

#### 4.1.3 A comparison between Coastcross and kikuyu

Coastcross and kikuyu were evaluated concurrently in the 1978/79 and 1979/80 seasons. Only the data from these two seasons could therefore be used for comparison of the two grass species.

In terms of the relationship between liveweight gain per animal and disc meter height there was no difference between the two pasture species. Neither

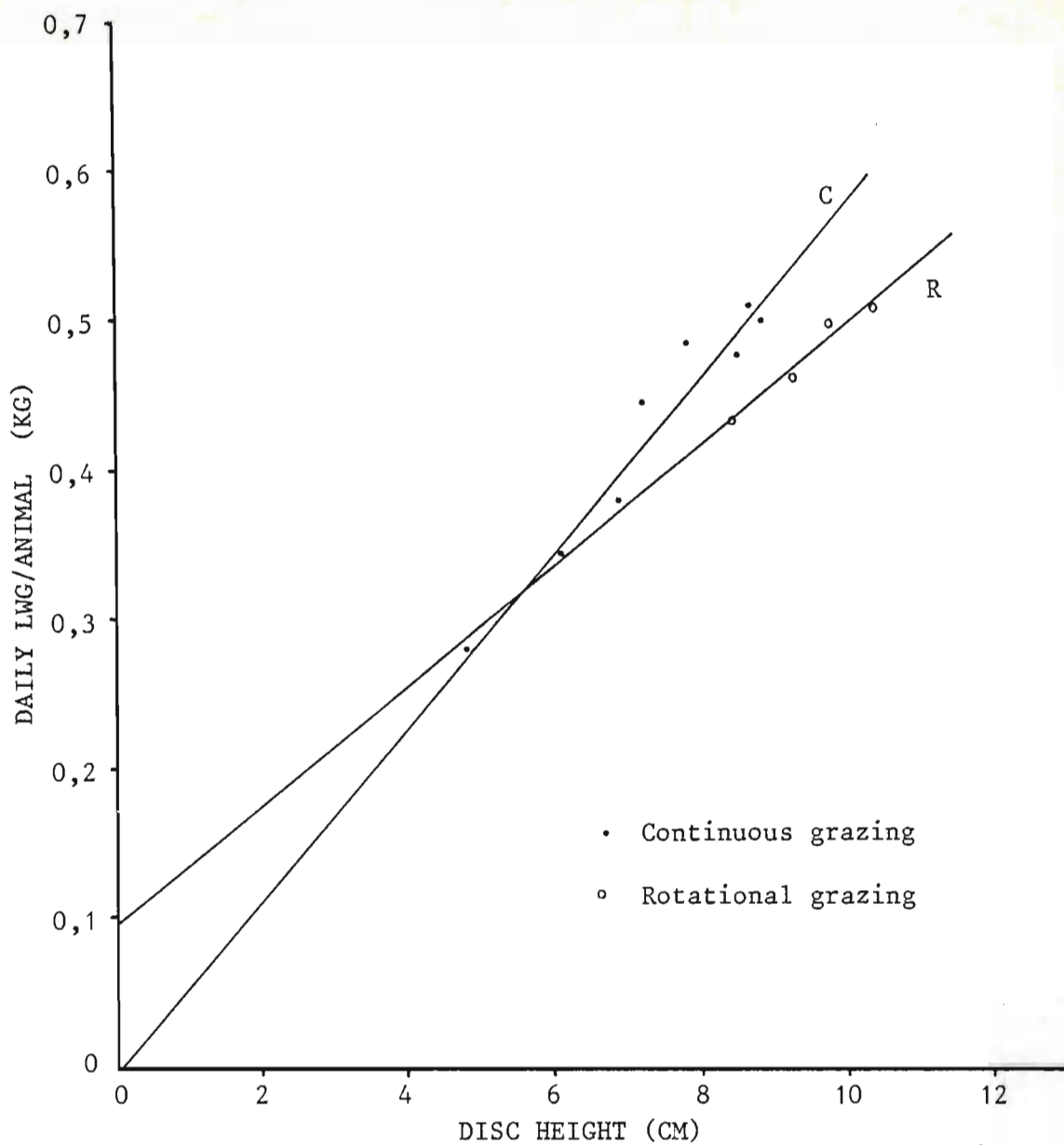


Fig. 4.14. The relationships between daily liveweight gain per animal (y) and disc meter height (x) derived from an average of all four seasons for continuous grazing (C as  $y = -0,004 + 0,058x$ ,  $r = 0,97^{**}$ ) and rotational grazing (R as  $y = 0,098 + 0,040x$ ,  $r = 0,098^{*}$ ) on kikuyu.

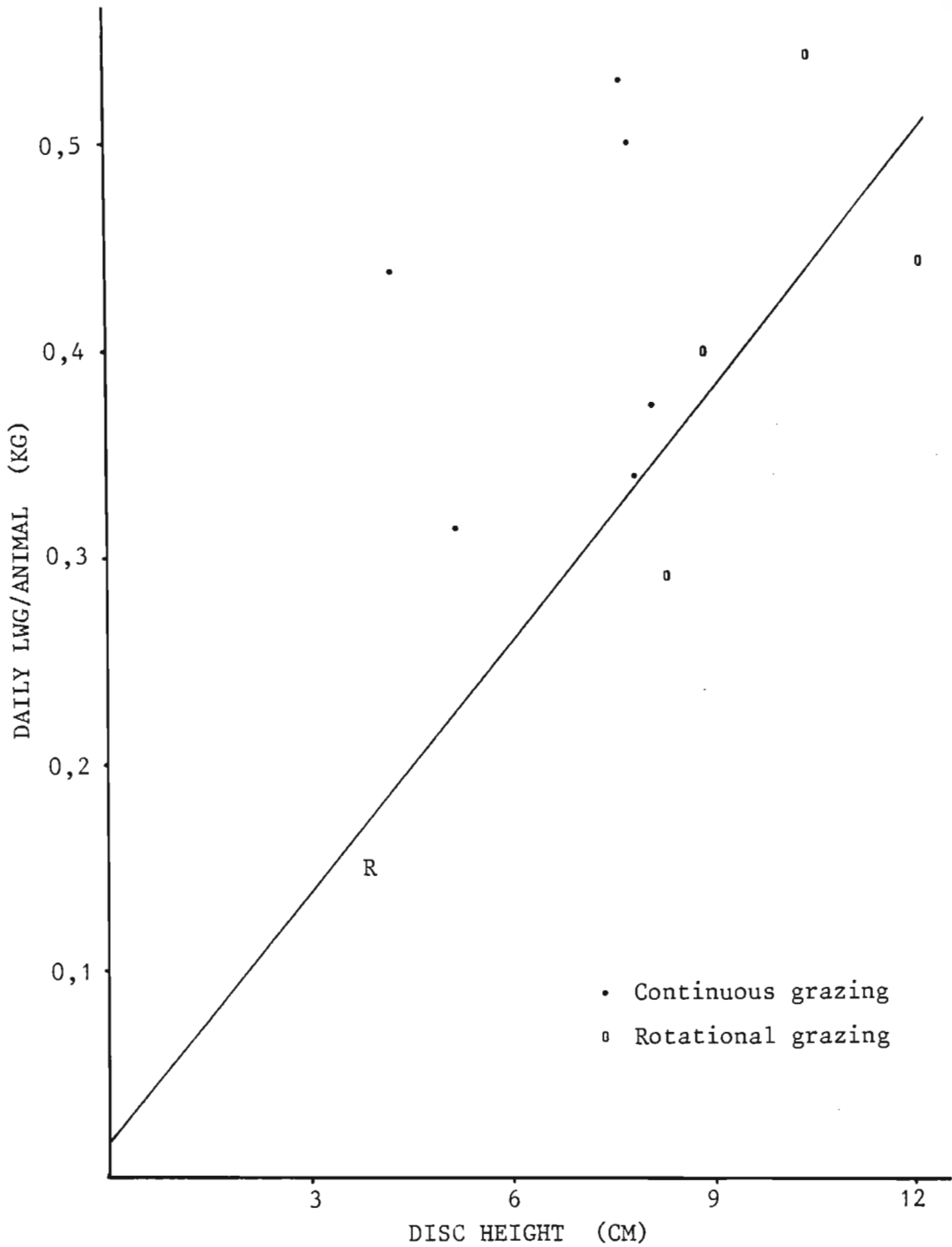


Fig. 4.15. The relationship between daily liveweight gain per animal (y) and disc height (x) in the 1978/79 season for rotational grazing (R as  $y = 0,02 + 0,04x$ ,  $r = 0,65$ ) on Rhodesgrass.



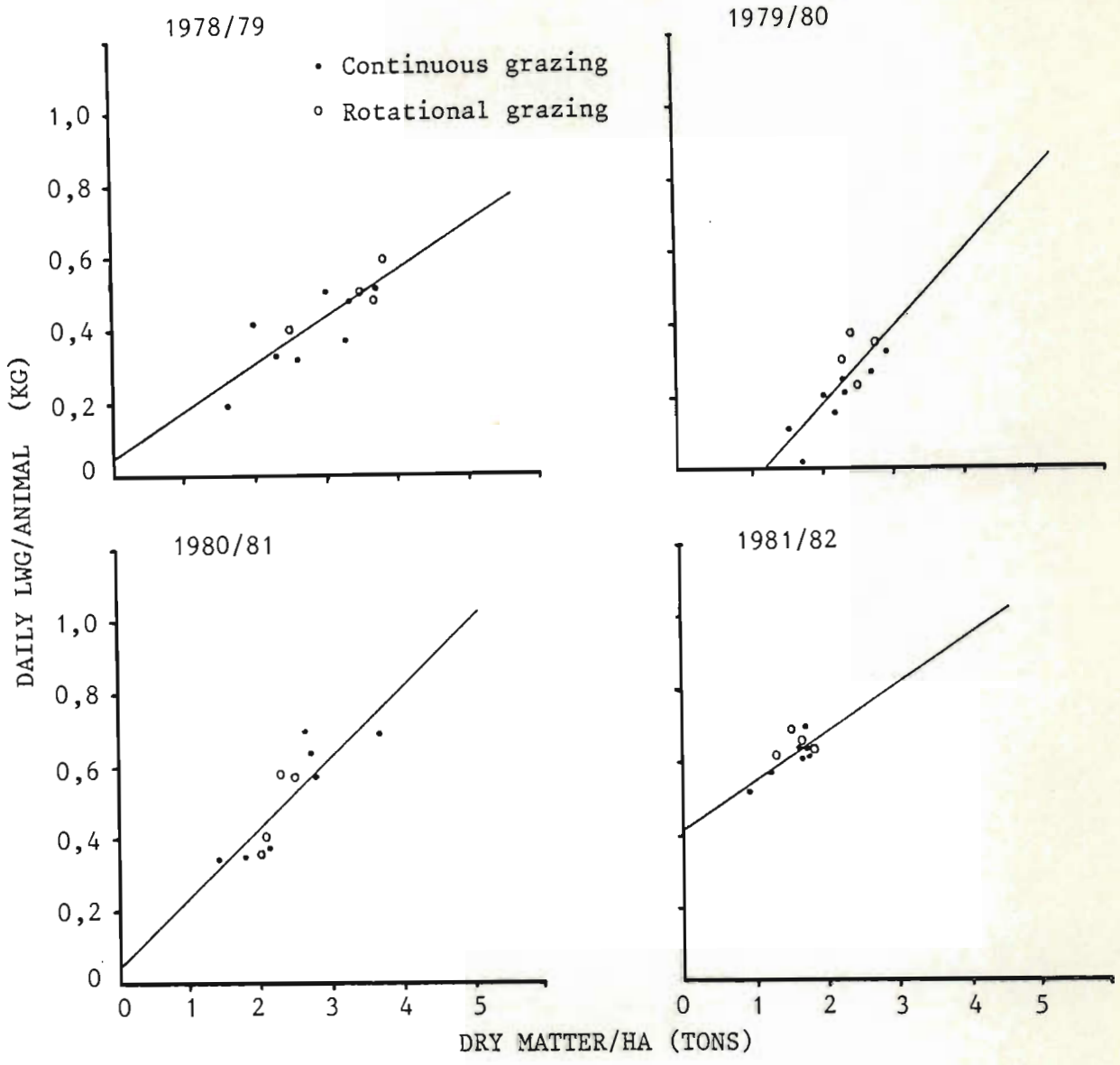


Fig. 4.16. The relationship between liveweight gain per animal and dry matter per ha on kikuyu derived from the pooled data for rotational and continuous grazing in each of the four seasons in which kikuyu was evaluated.

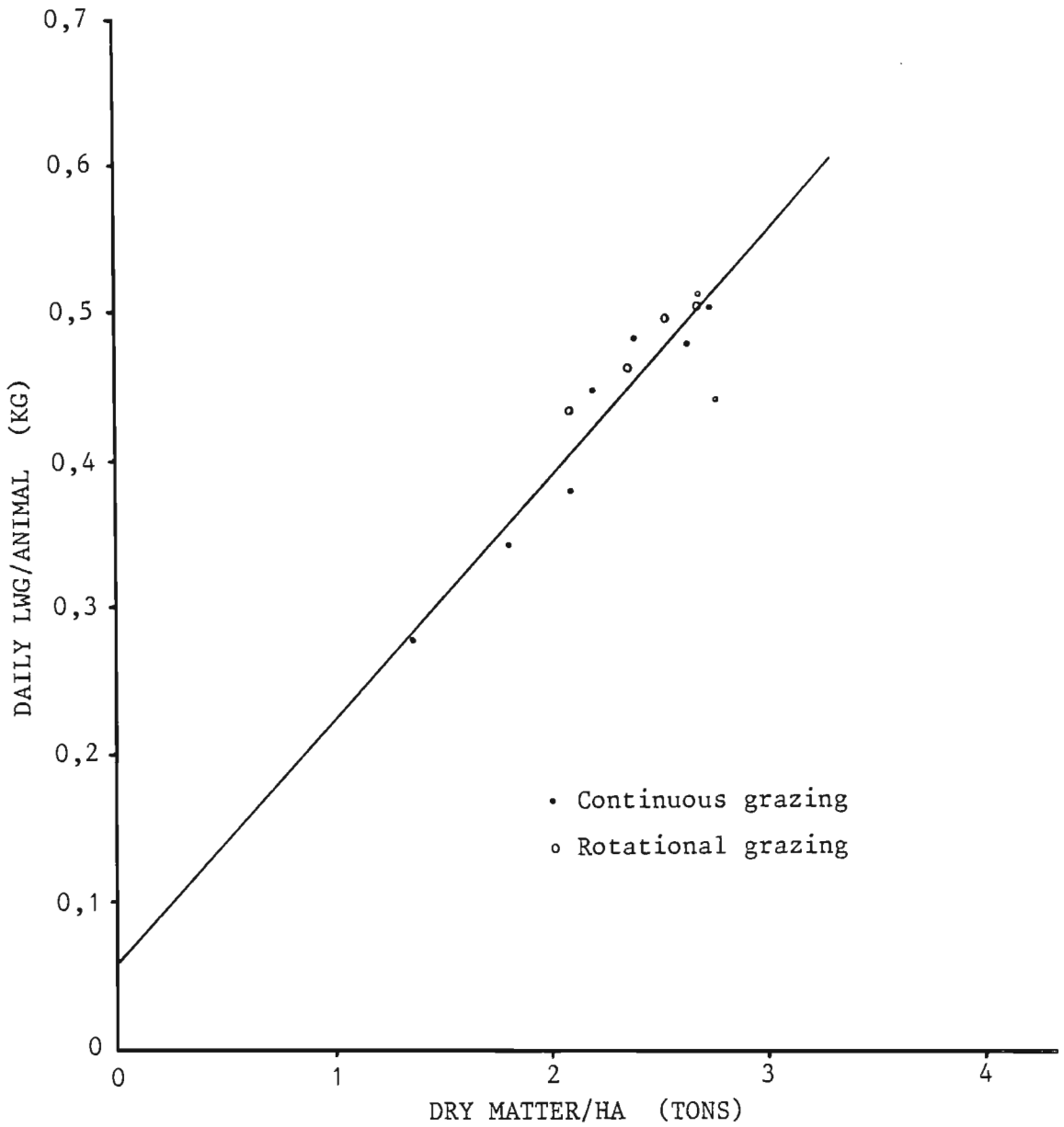


Fig. 4.17. The relationship between liveweight gain per animal (y) and dry matter per ha (x) for the pooled data for both rotational and continuous grazing on kikuyu averaged over all four seasons ( $y = 0,058 + 0,166x$ ,  $r = 0,97^{**}$ )

was there any significant difference between Coastcross and kikuyu in terms of liveweight gain per animal at equal DM/ha or at equal DM/animal.

#### 4.2 Changes within seasons

A change in the relationships between liveweight gain per animal and available herbage within seasons could have management implications. For example, if a period existed in which liveweight gain per animal was low in relation to other periods, then concentrate supplementation could be considered. The relationships between liveweight gain per animal and herbage availability was therefore examined in the first and second half of the grazing period.

The grazing periods in the first three seasons (1976/77, 1977/78 and 1978/79) were relatively long due to high and well distributed rainfall. This facilitated the division of these seasons into early and late summer periods which were then compared. However, the grazing periods in the subsequent three seasons were relatively short due to low rainfall. Subdivision of these seasons was therefore not warranted.

From examination of the grazing periods for the first three seasons it was evident that the mid-point of each was in January. Early summer was therefore defined as the period from the start of grazing until the weighing date closest to 15 January in each season. Similarly, late summer was defined as the period from the weighing date closest to 15 January to the termination of grazing.

In the 1976/77 season correlation between daily liveweight gain per animal and disc height was poor in early summer (Fig. 4.18). However, in late summer it was better and the locations of

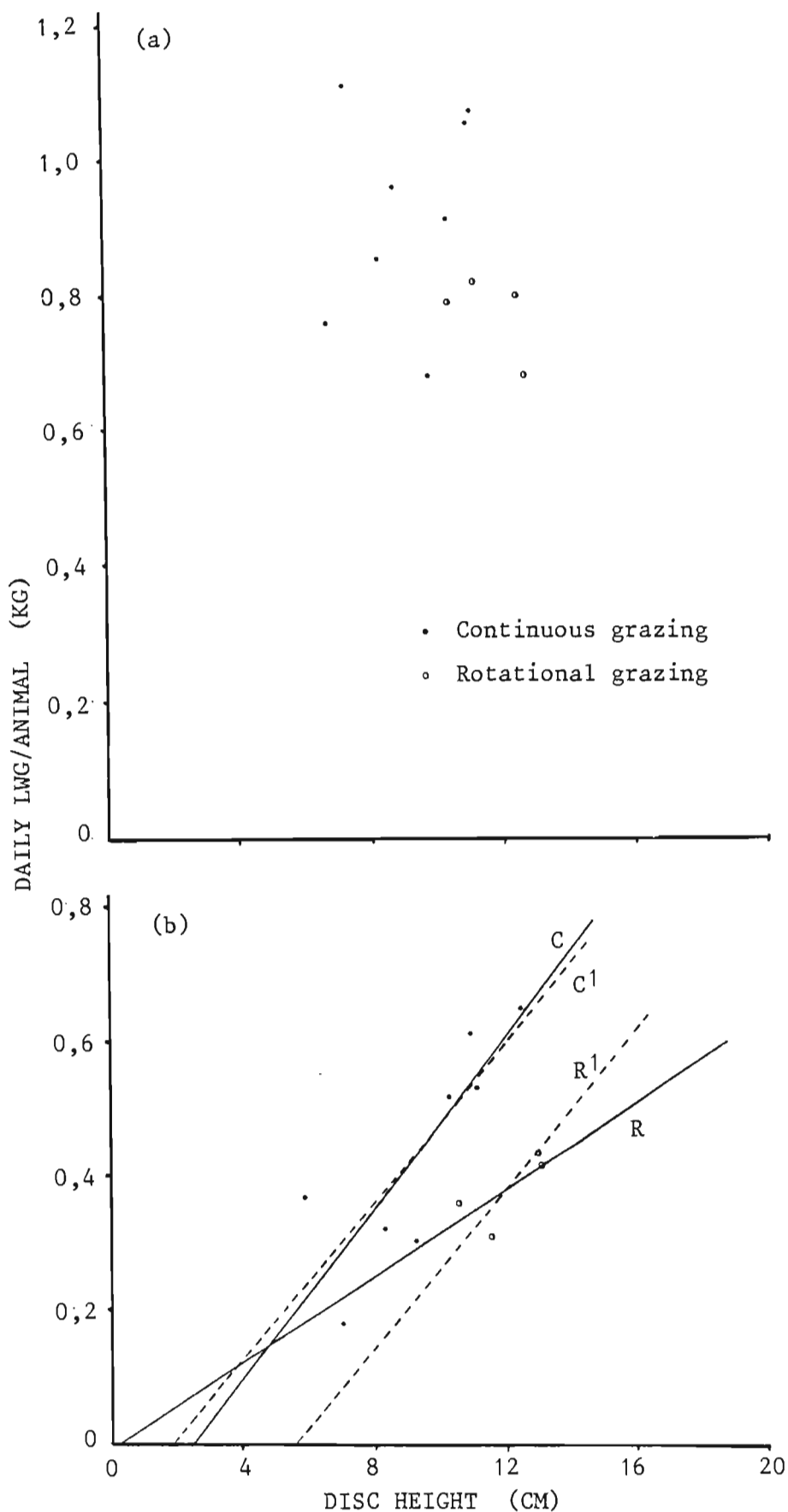


Fig. 4.18. A scatter diagram for daily liveweight gain per animal and disc height in early summer (a) and relationships for continuous grazing (C and C1) and rotational grazing (R and R1) on Coastercross in late summer (b) of the 1976/77 season.



the parallel lines fitted to these data were significantly different ( $P < 0,01$ ).

Conversion of disc meter height to kg DM/ha did not improve correlation in early summer and eliminated the difference between continuous and rotational grazing which existed in late summer (Fig. 4.19). However, a significant difference between continuous and rotational grazing existed in terms of the relationship between liveweight gain per animal and DM/ha for the whole season (Fig. 4.6a). This suggests, therefore, that continuous grazing tends towards higher liveweight gain per animal at equal DM/ha in early and late summer, but that the relatively short periods considered here resulted in high experimental error.

The relation between liveweight gain per animal and DM/animal was similar to that between liveweight gain per animal and disc height, showing no difference between continuous and rotational grazing in early and late summer (Fig. 4.20) despite the existence of a significant difference for the season as a whole (Fig. 4.8). In addition, at equivalent disc meter height, DM/ha and DM/animal, there appeared to be a tendency towards lower liveweight gain per animal in late summer, but the difference between early and late summer was not significant.

In the 1977/78 season the location of parallel lines fitted to liveweight gain per animal and disc height for continuous and rotational grazing was significantly different ( $P < 0,01$ ) in early summer (Fig. 4.21). However, in late summer there was no significant difference between the two methods of grazing. This pattern was maintained when liveweight gain per animal was related to DM/ha and DM/animal. These data therefore suggest that the significant differences observed between rotational and continuous grazing for the whole season (Fig. 4.2, 4.6b and 4.8) were due

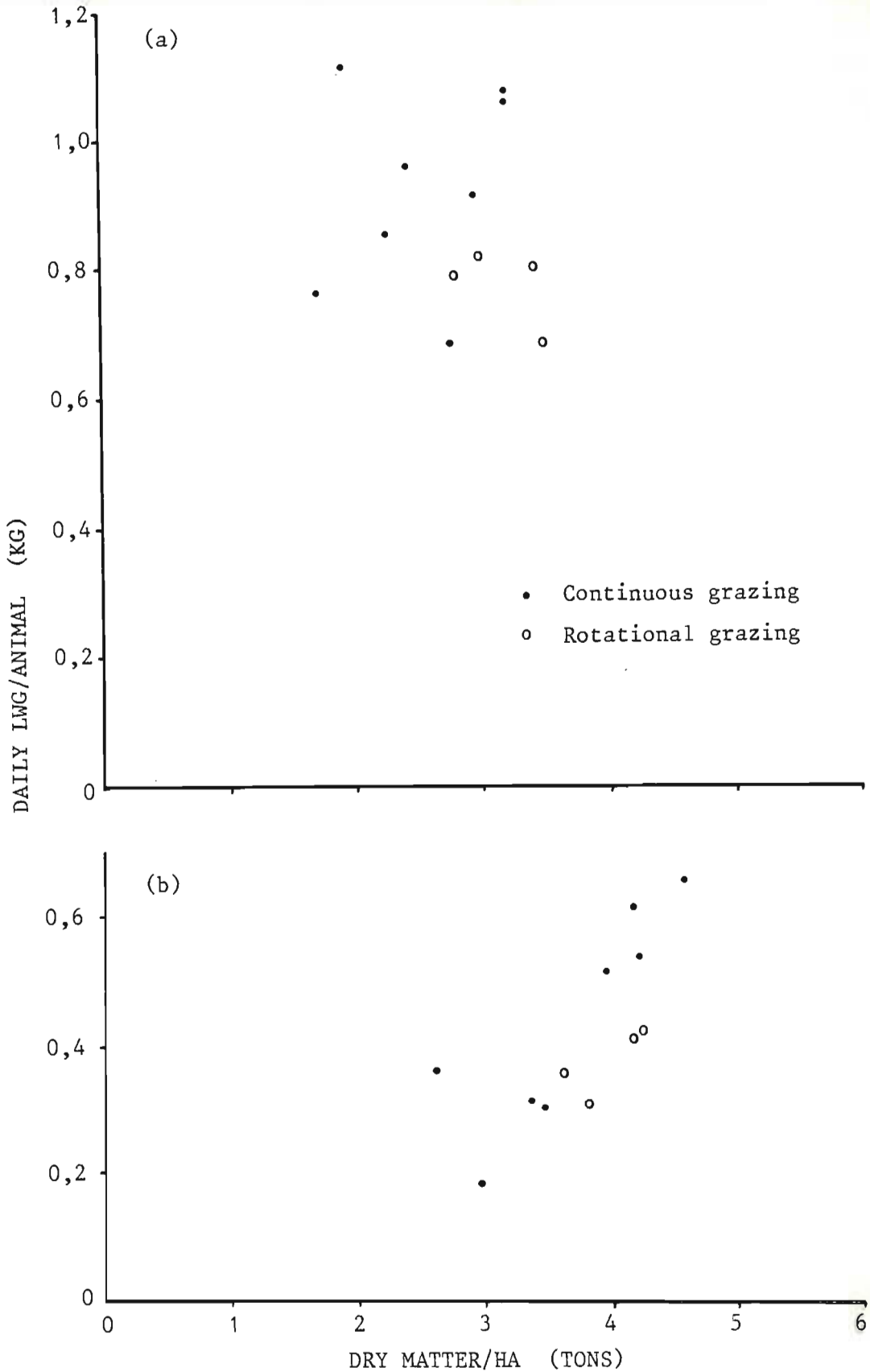


Fig. 4.19. Scatter diagrams of daily liveweight gain per animal and DM/ha for continuous and rotational grazing on Coastcross in early summer (a) and late summer (b) of the 1976/77 season.

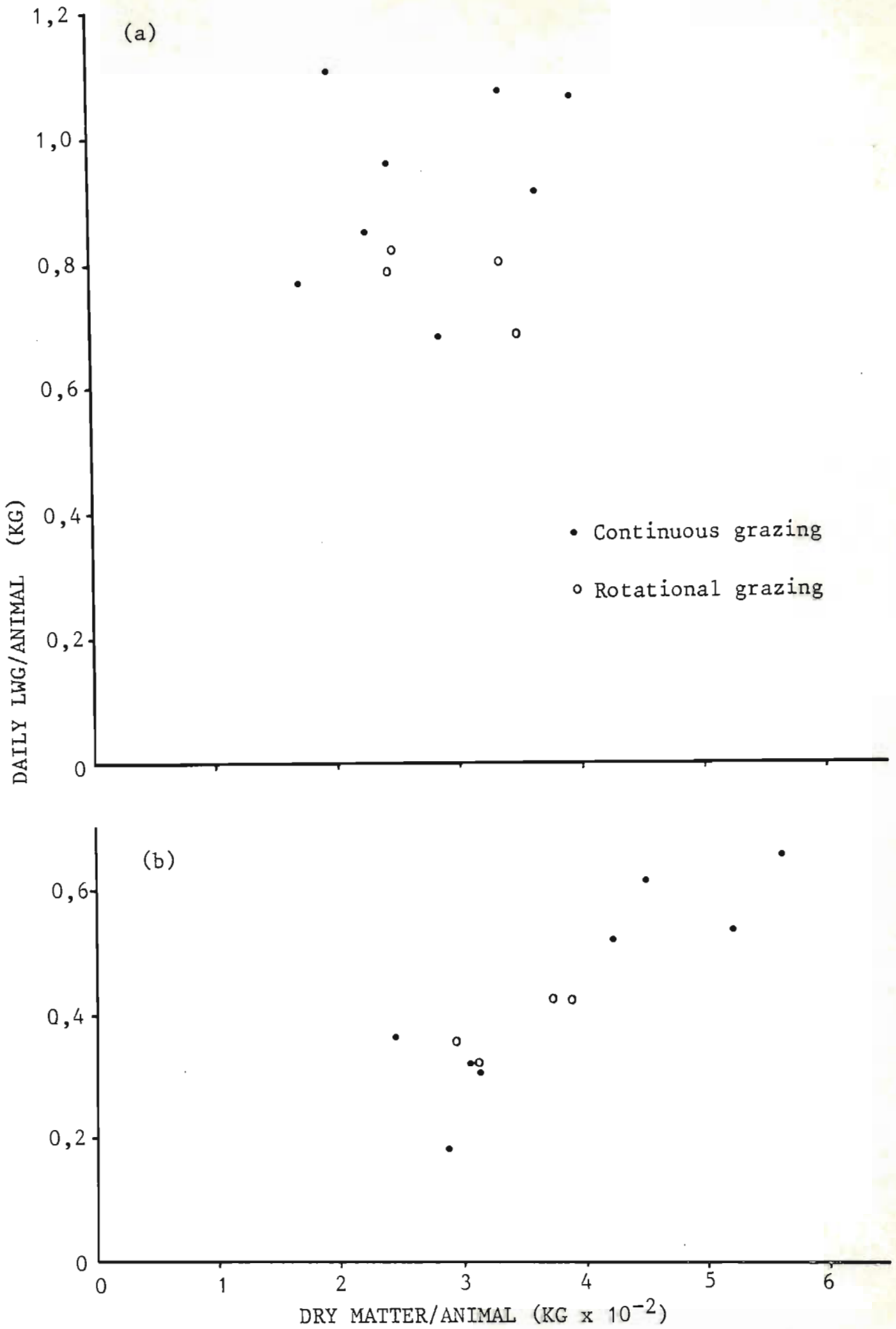


Fig. 4.20. Scatter diagrams of daily liveweight gain and DM/animal for continuous and rotational grazing on Coastcross in early summer (a) and late summer (b) of the 1976/77 season.





mainly to the difference which occurred in early summer.

Liveweight gain per animal was again higher in early summer at equivalent disc height, DM/ha or DM/animal than in late summer. In the case of rotational grazing this difference (which was estimated in terms of the location of parallel lines) was significant ( $P < 0,01$ ) but poor correlation resulted in no significant difference for continuous grazing (Fig. 4.21).

Continuous grazing on Coastcross in the 1978/79 season resulted in significantly higher ( $P < 0,01$ ) liveweight gain per animal than rotational grazing at equivalent disc heights in early summer, but there was no significant difference between the two methods of grazing in late summer (Fig. 4.22). This is to a certain extent surprising in view of no significant difference existing between rotational and continuous grazing for the whole season (Fig. 4.3). The pattern was again maintained for liveweight gain per animal at equal DM/ha and equal DM/animal and in general, liveweight gain was higher in early summer than in late summer.

On kikuyu there was no difference in liveweight gain per animal between rotational and continuous grazing in early or late summer at equal disc meter heights (Fig. 4.23), DM/ha and DM/animal. However, in each case liveweight gain was higher in the early summer than in late summer.

#### 4.3 Discussion

The data presented in this chapter may initially appear to be unsuitable for statistical analysis due to poor correlation which resulted from relatively high experimental error and narrow ranges

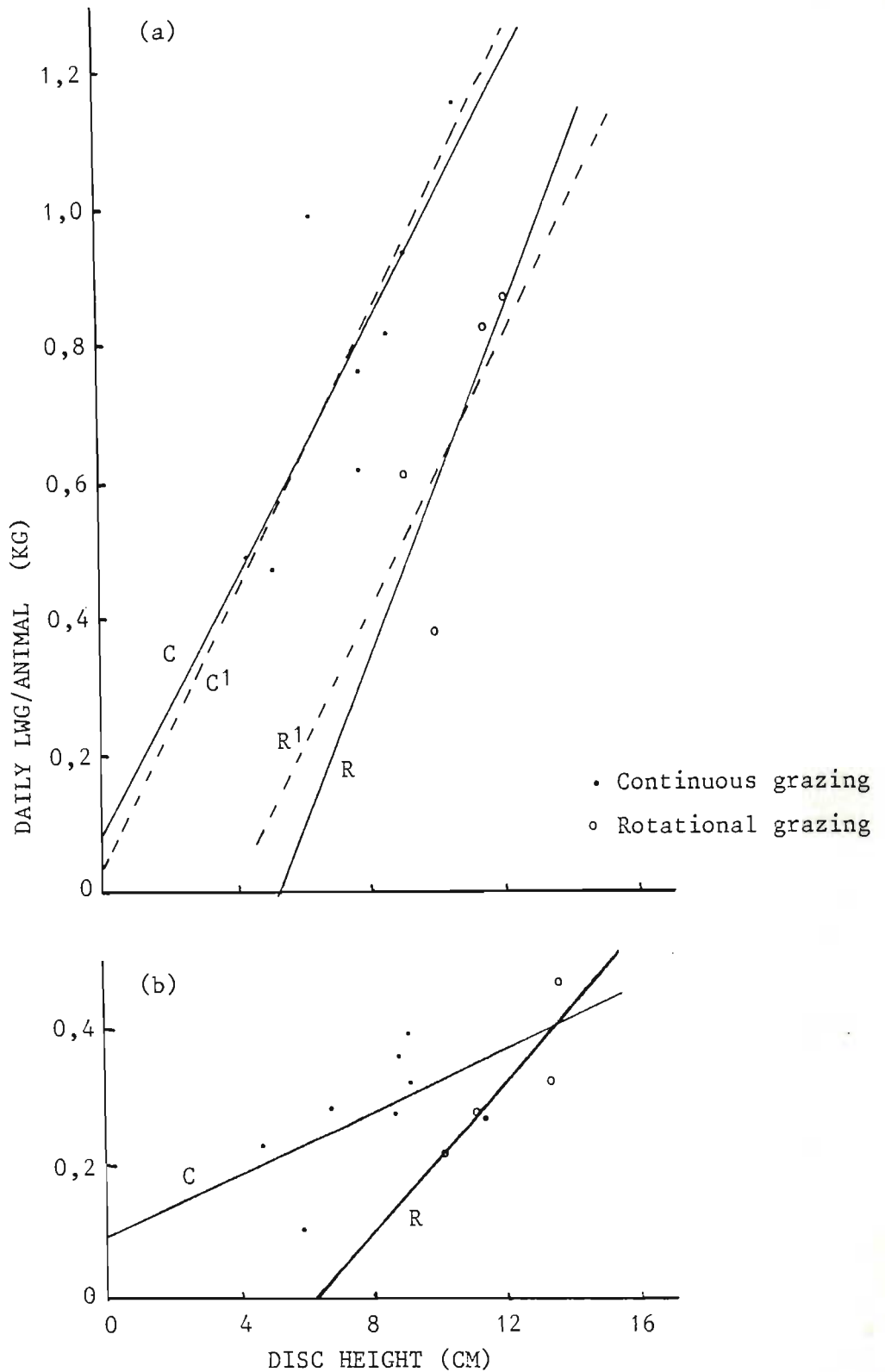


Fig. 4.22. Relationships between daily liveweight gain per animal and disc meter height for continuous grazing (C and C<sup>1</sup>) and rotational grazing (R and R<sup>1</sup>) on Coastcross in early summer (a) and late summer (b) of the 1978/79 season.

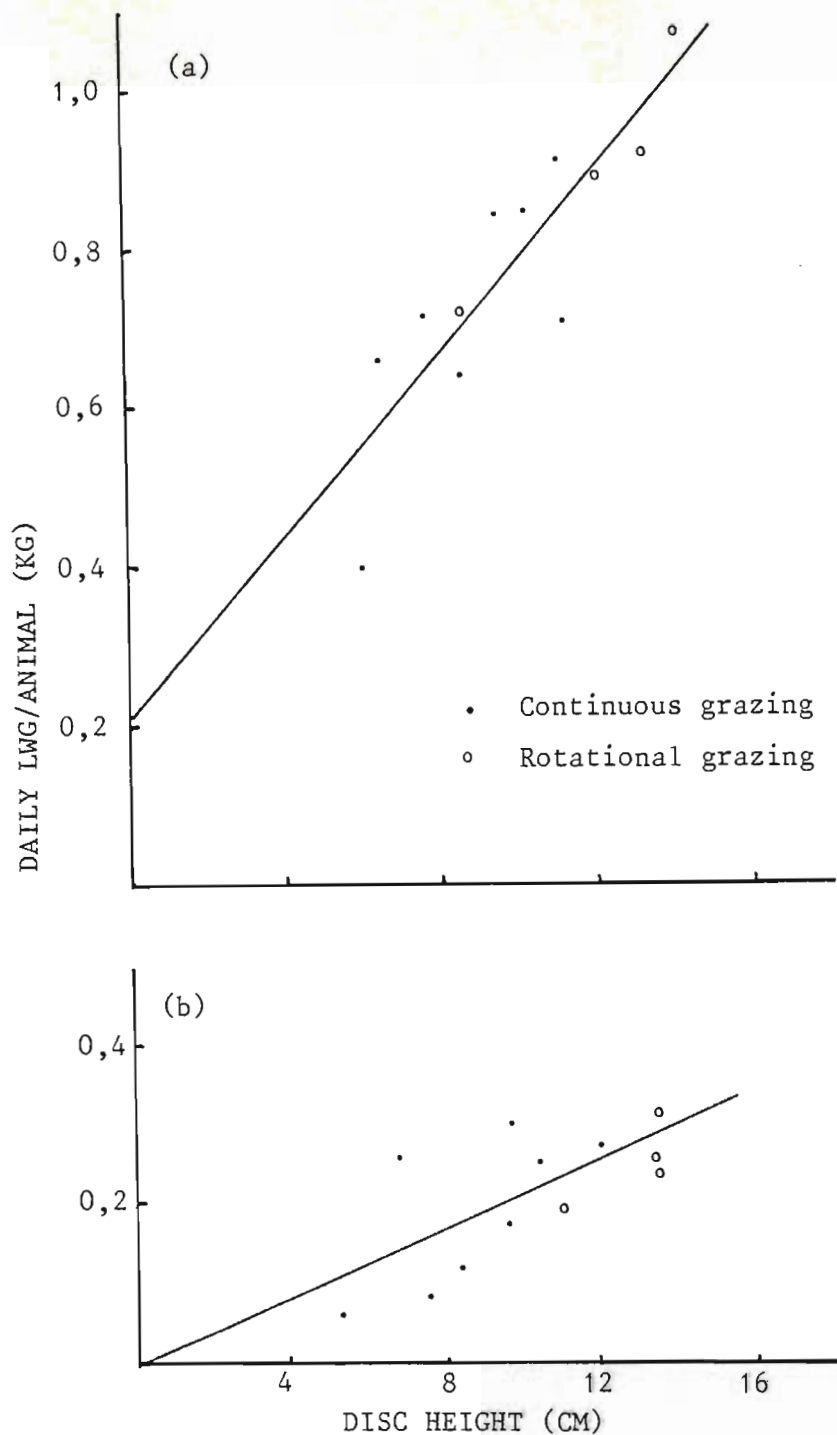


Fig. 4.23. Relationships between daily liveweight gain and disc height derived from the pooled data for continuous and rotational grazing on kikuyu in early summer (a) and late summer (b) of the 1978/79 season.

in herbage availability. However, the covariance method of analysis described in section 2.4 allowed comparison of daily liveweight gain per animal under rotational and continuous grazing after making an adjustment for herbage availability. This was done by fitting parallel lines to the two sets of data which then represented the location of the points from the two methods of grazing. Hence, despite poor correlation for individual regressions in some cases (such as for rotational grazing in Fig. 4.1 and continuous grazing in Fig. 4.2) the location of these points could be compared statistically. The slope of the fitted parallel lines was influenced most by the set of data for which correlation was good. For example, in Fig. 4.1 the data from continuous grazing had the stronger effect on the slope while in Fig. 4.2 the slope of the parallel lines was influenced more by the points for rotational grazing.

In general, liveweight gain per animal was linearly related to disc meter height, DM/ha and DM/animal within the limits of the data. This result was in agreement with Edwards and Mappledoram (1979). However, extrapolation of the fitted lines usually resulted in interception of the vertical (liveweight gain per animal) axis which was clearly unrealistic. This suggests that the true relationship is probably non-linear with a plateau or even a peak, and that it intercepts the horizontal axis (Fig. 4.24). Such relationships were obtained by Mears and Humphreys (1974b) and by Parkin and Boulwood (1981). The reason for the non-linear relationship would be that liveweight gain per animal is probably limited initially by herbage availability which affects herbage intake (Pattinson, 1981; Pattinson, Bransby & Tainton, 1981a; 1981b). However, at high herbage availability it would eventually be limited by the potential of the animal,



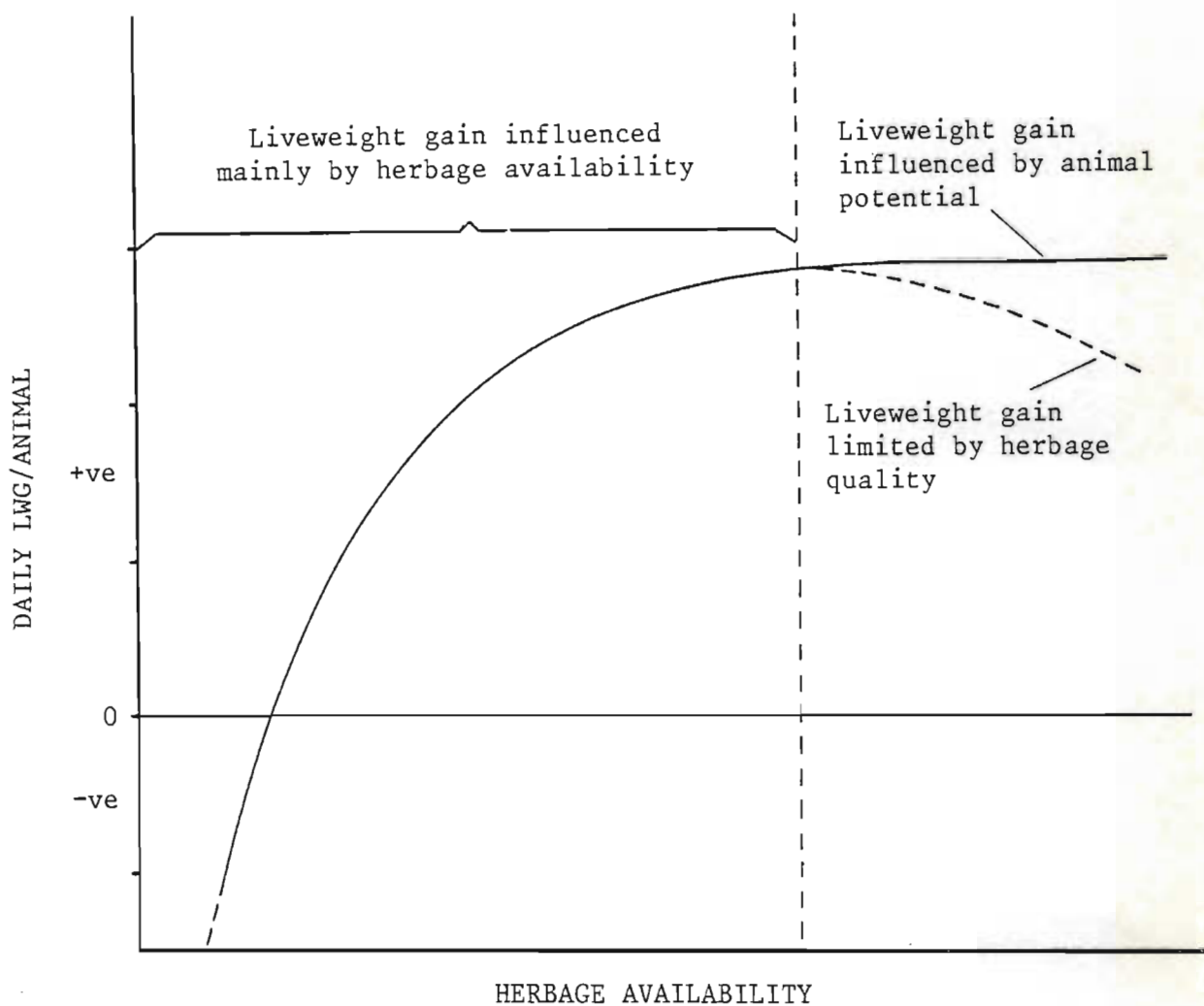


Fig. 4.24. The hypothetical relation between daily liveweight gain per animal and herbage availability.

resulting in a plateau, or by the quality of herbage, resulting in a peak.

From results presented in this chapter it would seem that disc meter height, DM/ha or DM/animal could be used as a basis for adjusting animal numbers in put-and-take trials, since each is linearly related to liveweight gain per animal. However, it is possible that the use of the disc meter could lead to incorrect conclusions when comparing liveweight gain per animal under continuous and rotational grazing at equal levels of herbage availability. In fact, it would seem that herbage availability under continuous grazing is strictly speaking, not comparable with herbage availability under rotational grazing. Despite this problem, it is unlikely that a better basis than that used in this study could be found for comparison of liveweight gain per animal under continuous and rotational grazing at equal levels of herbage availability. In experiments that are being continuously grazed and in which treatments are for example, levels of fertilizer or pasture species, disc meter height across treatments would be more meaningful. However, because of the variation in calibrations, the disc meter should be calibrated regularly and herbage availability should be expressed in terms of both DM/ha and disc height.

In view of no difference being observed between continuous and rotational grazing on kikuyu and Coastcross in the 1978/79 and 1979/80 seasons, it is unlikely that the difference in liveweight gain between continuous and rotational grazing on Coastcross in the 1976/77 and 1977/78 seasons was dependent on pasture species. A possible reason for such a difference occurring between rotational and continuous grazing is that under continuous grazing a higher proportion of leaf material might have been consumed by

animals whereas under rotational grazing the proportion of stem in the material consumed might have been higher. However, since the leaf:stem ratio of material consumed was not measured, this hypothesis cannot be tested. Another possible reason for the difference between the two methods of grazing was that herbage intake under rotational grazing may have been severely restricted for prolonged periods at the end of each grazing period in each paddock (Jones, 1971; Bransby, 1980).

In early summer there appeared to be a tendency towards higher liveweight gain per animal at equivalent levels of herbage availability under continuous grazing than under rotational grazing. However, in late summer little difference between the two methods of grazing was evident. This result could again be due to a higher proportion of leaf material being consumed under continuous grazing than under rotational grazing in the early summer, but little difference existing in the ratio of leaf to stem consumed in late summer under the two grazing methods.

The generally higher liveweight gain per animal at equivalent levels of herbage availability in early summer compared to late summer was probably related to a decrease in herbage quality with time, as well as compensatory growth of animals in early summer after relatively low growth rates in winter. This suggests that research into supplementary feeding of concentrates after mid-summer is warranted.

## 5. THE INFLUENCE OF STOCKING RATE ON HERBAGE AVAILABILITY

Results presented in Chapter 4 showed that herbage availability affected liveweight gain per animal. However, herbage availability was varied by adjusting animal numbers. It is therefore important to establish the relation between average stocking rate (animal grazing days divided by the number of days in the grazing season) and herbage availability. In particular, the patterns in this chapter will be used in Chapter 6 to interpret the relationships between liveweight gain per head and stocking rate.

### 5.1 Whole season relationships

#### 5.1.1 Coastcross

In general, the relation between stocking rate and DM/ha for Coastcross was fairly well described by linear functions which had negative slopes (Fig. 5.1). However, these relationships differed between seasons and between methods of grazing.

In the 1976 season the slopes of the lines for continuous and rotational grazing were not significantly different, but there was a significant difference ( $P < 0,01$ ) between the location of parallel lines which were fitted to these data (Fig. 5.1a). This implied, therefore, that for the range of stocking rates applied in this season, rotational grazing resulted in higher herbage availability in terms of kg DM/ha than continuous grazing.

The slopes of the lines for rotational and continuous grazing were significantly different ( $P < 0,01$ ) in the 1977/78 season (Fig. 5.1b). This suggests that as stocking rate increased the



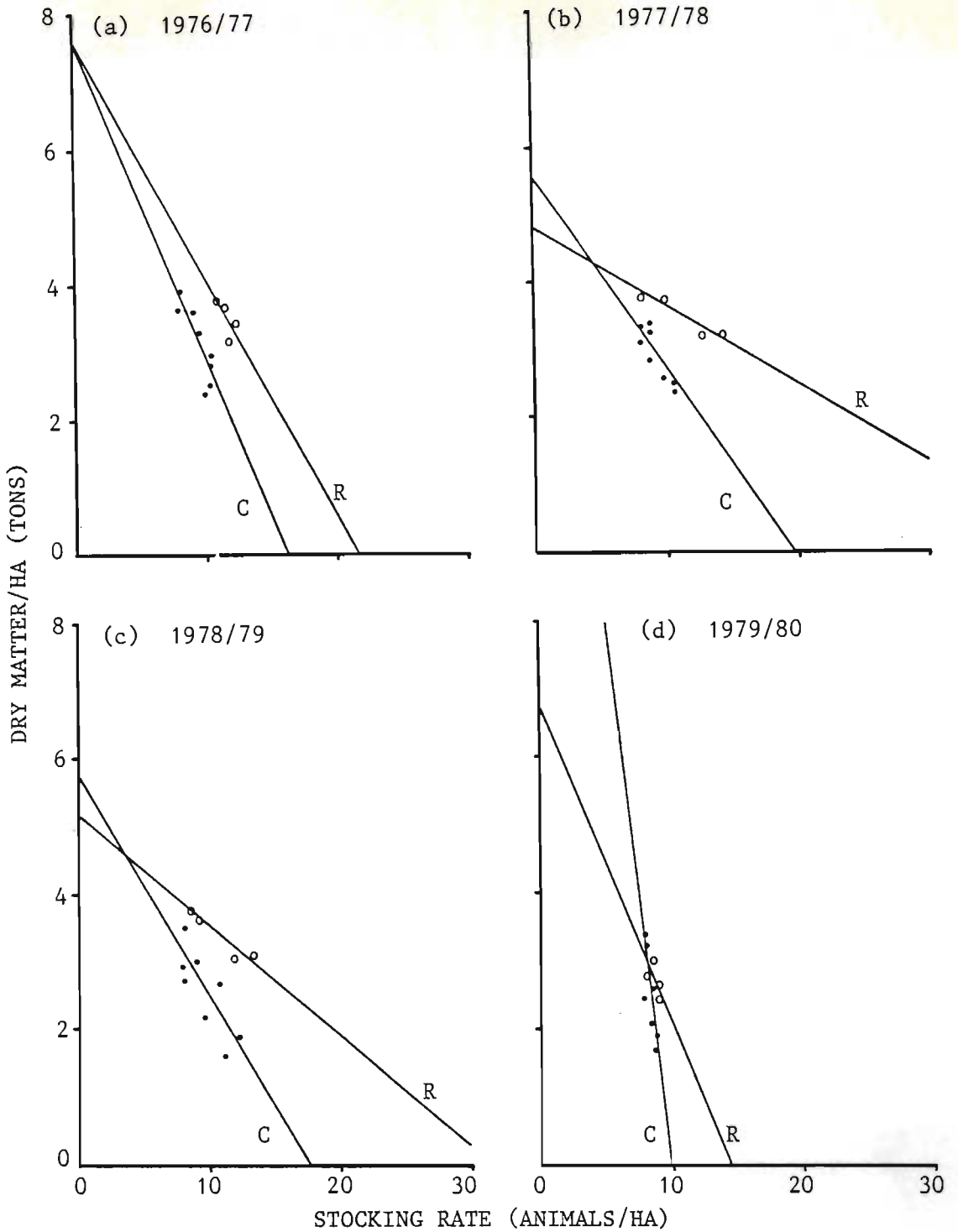


Fig. 5.1. The relationships between DM/ha and stocking rate for continuous grazing (C) and rotational grazing (R) on Coastcross in (a) the 1976/77, (b) 1977/78, (c) 1978/79 and (d) 1979/80 seasons.

advantage of rotational grazing over continuous grazing in terms of available DM/ha increased within the limits of the data. In the 1978/79 season there was no difference in the slopes of the lines but there was a significant difference ( $P < 0,01$ ) between the location of parallel lines fitted to data from the two methods of grazing (Fig. 5.1c). This result was therefore similar to that of the 1976/77 season. In the 1978/79 season there was no difference between the two methods of grazing (Fig. 5.1d).

When the data from all four seasons was averaged for each paddock, there was a significant difference ( $P < 0,01$ ) between the slopes of the lines for the two methods of grazing (Fig. 5.2). On average, therefore, as stocking rate increased rotational grazing resulted in increasingly greater DM/ha than continuous grazing within the limits of the data.

Since the disc meter calibrations for rotational and continuous grazing were different, there was a possibility that this difference would not have occurred if availability had been expressed in disc meter height. However, the pattern across seasons remained very similar and the relative positions of the lines for rotational and continuous grazing derived from four year averages also remained more or less unchanged (Fig. 5.3). The method of measuring availability therefore had less effect on the difference between the two methods of grazing in respect of the relationships between stocking rate and herbage availability than in terms of the relationships between liveweight gain per animal and herbage availability (Chapter 4).

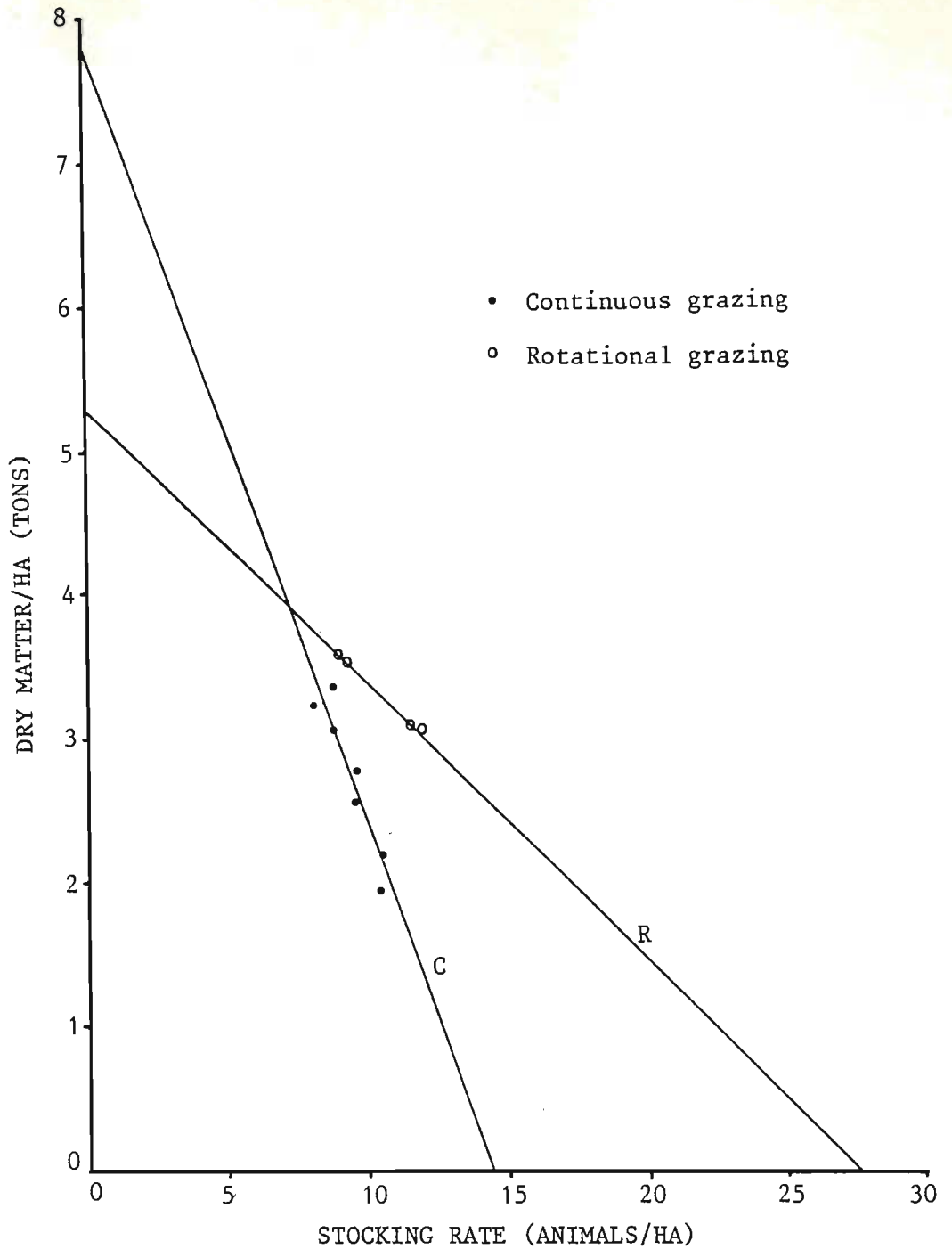


Fig. 5.2. The relationships between available DM/ha and stocking rate derived from four year averages for continuous grazing (C) and rotational grazing (R) on Coastcross.

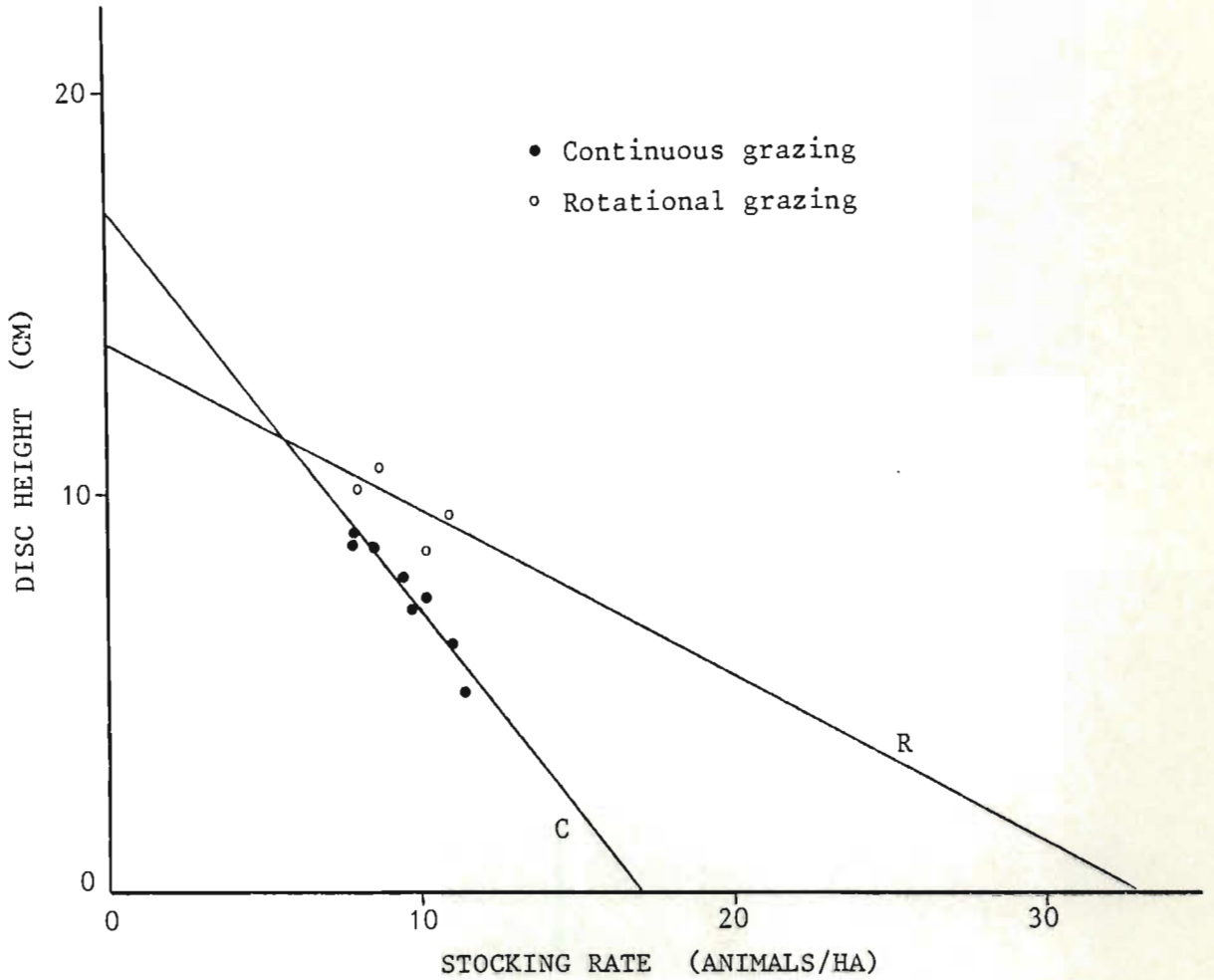


Fig. 5.3. The relationships between disc meter height and stocking rate derived from four year averages for continuous grazing (C) and rotational grazing (R) on Coastcross.



### 5.1.2 Kikuyu and Rhodesgrass

In the 1978/79 season correlation for rotational grazing was very poor on kikuyu (Fig. 5.4a). However, three out of four points indicated higher herbage availability under rotational grazing than under continuous grazing at equivalent stocking rates. There appeared to be a weak tendency towards different slopes for rotational and continuous grazing in the 1979/80 and 1980/81 seasons but these differences were not significant (Fig. 5.4b and c). The main limitation of these data is a narrow range in stocking rate as a result of very low rainfall. In the 1981/82 season an attempt was made to widen this range but low rainfall again caused a very short grazing period, resulting in poor correlation and no difference between the two methods of grazing.

The regressions derived from the four year average suggested a difference in the slopes of the lines for rotational and continuous grazing, but this difference was not significant (Fig. 5.5).

For Rhodesgrass in the 1978/79 season correlation was poor for continuous grazing but all the continuous grazing points were well below the line for rotational grazing (Fig. 5.6). The locations of parallel lines fitted to these data were significantly different ( $P < 0,05$ ).

## 5.2 Changes within seasons

There was no difference between the slopes of the lines for continuous and rotational grazing on Coastcross in early and late summer of the 1976/77 season (Fig. 5.7a and b). However, in both early and late summer there was a significant difference ( $P < 0,01$ ) in the location of parallel lines fitted to the data for the

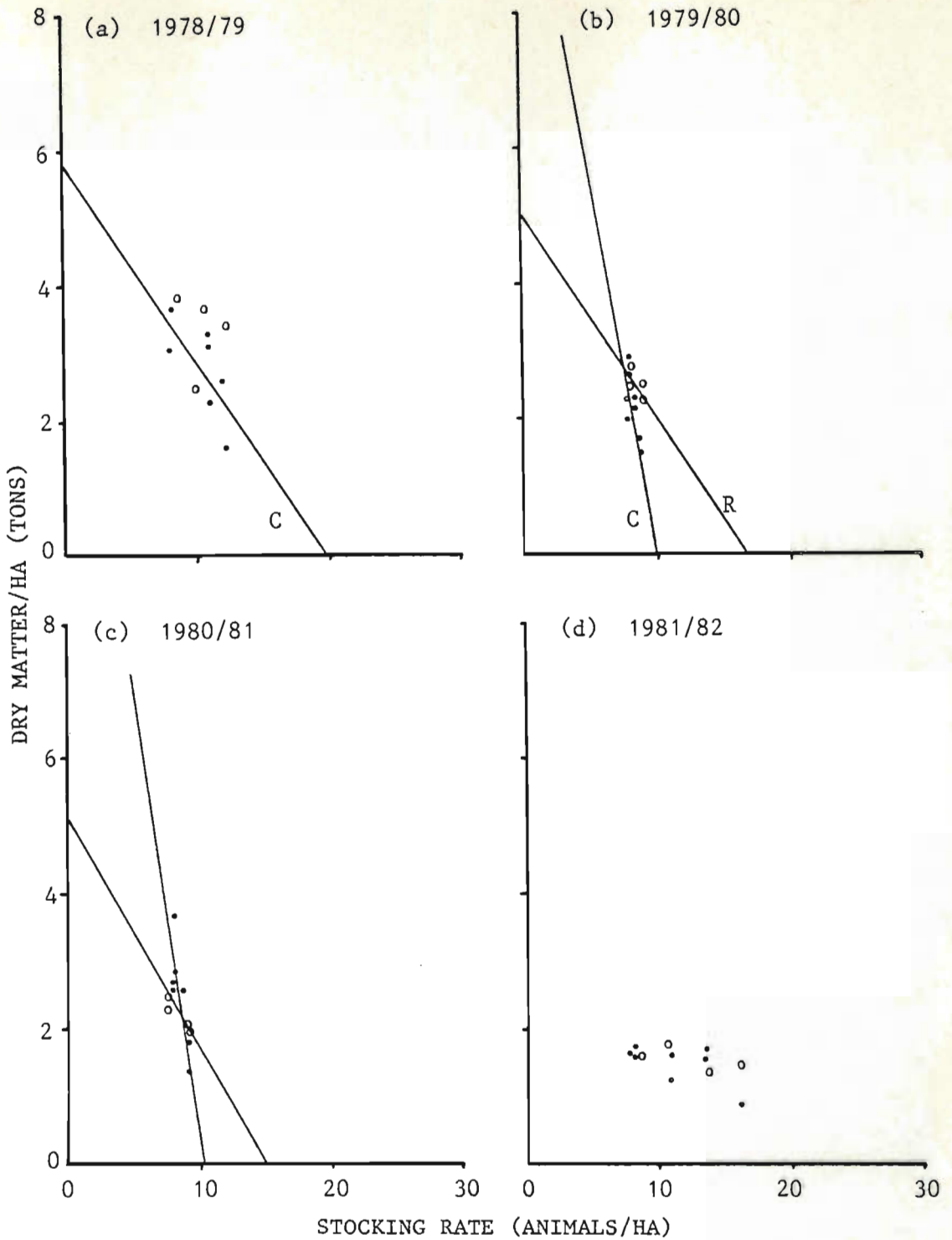


Fig. 5.4. The relation between available DM/ha and stocking rate for continuous grazing (C) and rotational grazing (R) on kikuyu in (a) the 1978/79, (b) 1979/80, (c) 1980/81 and (d) 1981/82 seasons.

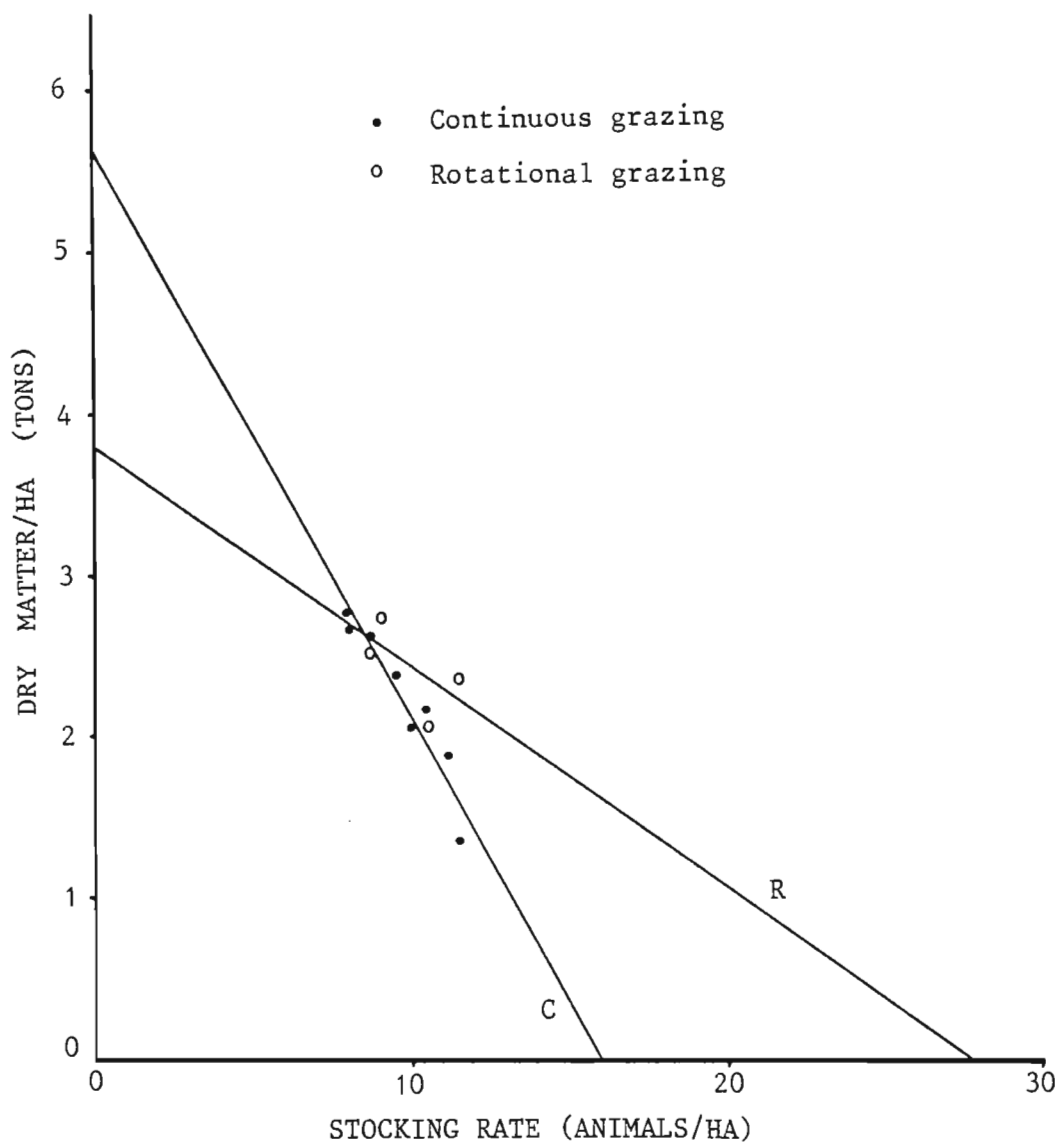


Fig. 5.5. The relationships between available DM/ha and stocking rate derived from the four year averages for continuous grazing (C) and rotational grazing (R) on kikuyu.

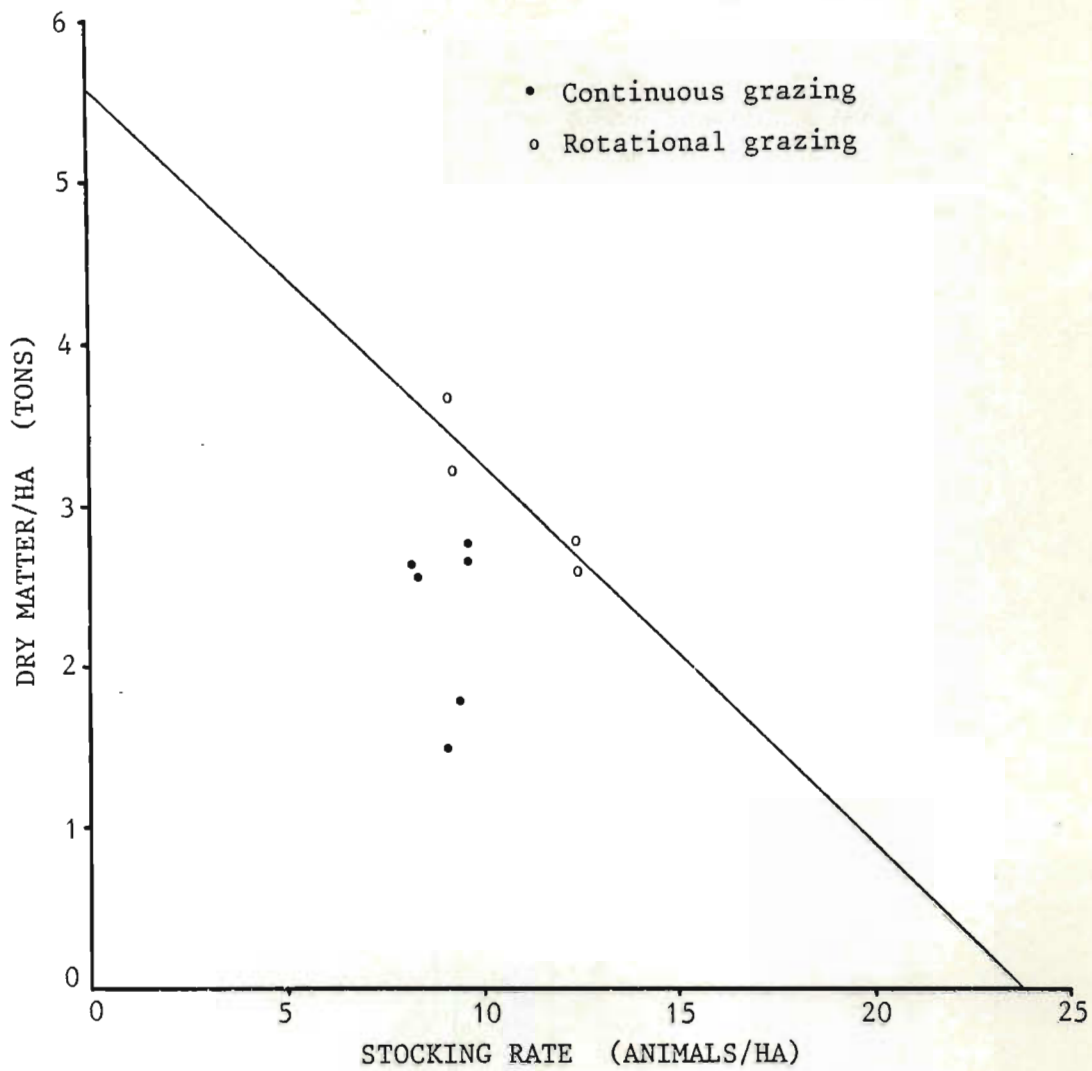


Fig. 5.6. The relation between DM/ha and stocking rate for continuous and rotational grazing on Rhodesgrass in the 1978/79 season.



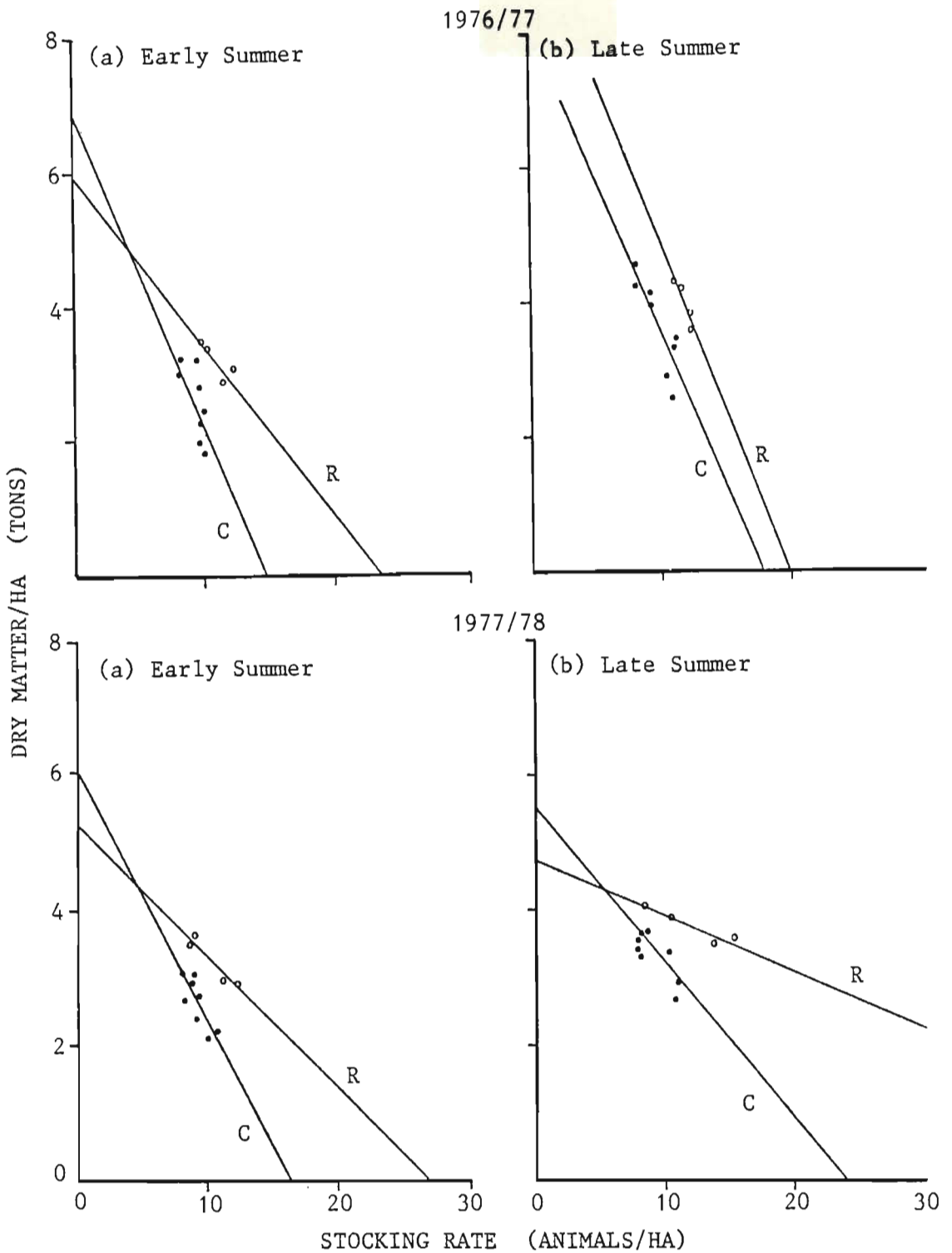


Fig. 5.7. The relationships between available DM/ha and stocking rate for continuous grazing (C) and rotational grazing (R) on Coastcross in early summer (a) and late summer (b) of the 1976/77 and 1977/78 seasons.

two grazing methods.

In the 1977/78 season there was no difference in the slopes of the lines for the two grazing methods in the early summer, but in late summer the slopes were significantly different ( $P < 0,01$ ). However, the locations of parallel lines fitted to the data from early summer were significantly different ( $P < 0,01$ ) (Fig. 5.7c and d).

There was again no difference in slopes of the regressions for the two grazing methods on Coastcross in early or late summer of the 1978/79 season (Fig. 5.8a and b) but the differences in locations of the parallel lines were significant ( $P < 0,01$ ). In the same season there was no statistical difference between the two methods of grazing on kikuyu. However, the location of the points for rotational grazing in relation to the regression for continuous grazing suggested that, on average, rotational grazing resulted in higher available DM/ha at equivalent stocking rates in early summer (Fig. 5.8c).

### 5.3 Discussion

On Coastcross, rotational grazing resulted in higher available DM/ha than continuous grazing at equivalent stocking rates in all but the 1979/80 season in which rainfall was well below average. However, on kikuyu there was no difference between the two methods of grazing. The difference between continuous and rotational grazing would therefore seem to be related to the grass species and/or rainfall.

Three out of the four seasons in which kikuyu was evaluated received below average rainfall and in none of these seasons was there a significant difference between methods of grazing. On the

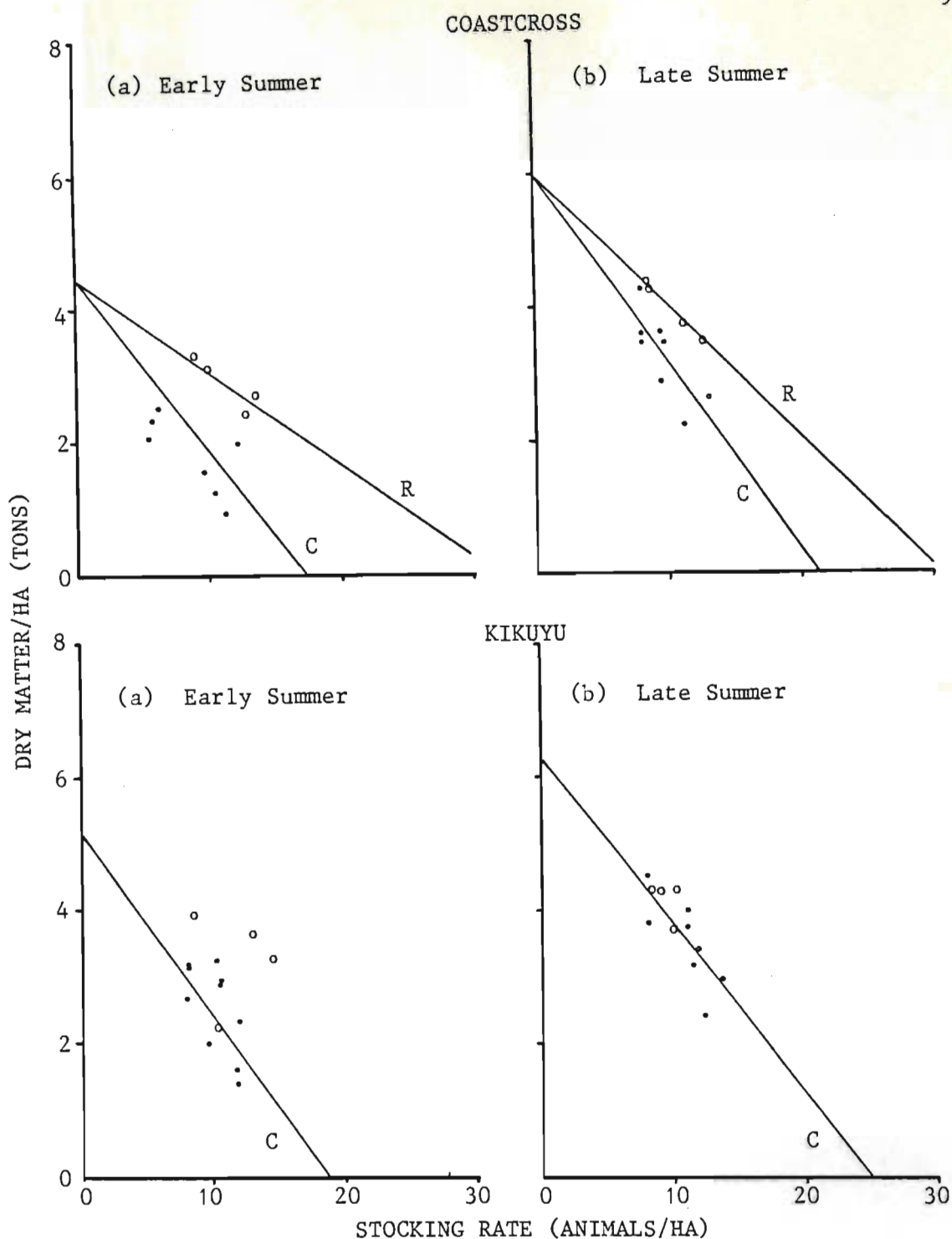


Fig. 5.8. The relationships between available DM/ha and stocking rate for continuous grazing (C) and rotational grazing (R) in early summer (a) and late summer (b) on Coastcross and kikuyu in the 1978/79 season.



other hand, three out of the four seasons in which Coastcross was evaluated received near or above average rainfall and in these three seasons there was a significant difference between continuous and rotational grazing. Since kikuyu is strongly rhizomatous while Coastcross tends to grow erect, it is possible that available DM/ha is reduced less by continuous grazing (in relation to rotational grazing) on kikuyu than on Coastcross. However, the difference between the two methods of grazing is more likely to be related to rainfall.

In the 1980/81 and 1981/82 seasons rainfall was well below average and no difference between continuous and rotational grazing was observed. Neither was there a difference between the methods of grazing on kikuyu or Coastcross in the 1979/80 season which also received well below average rainfall. In the 1978/79 season rainfall was above average and there was a significant difference between continuous and rotational grazing on Coastcross, but not on kikuyu. However, had it not been for high experimental error, the difference on kikuyu might well have been significant. Finally, on Coastcross in the 1976/77 and 1977/78 seasons which received just below and well above average rainfall respectively, the difference between the methods of grazing was significant.

Intuitively, rotational grazing might be expected to have a greater advantage over continuous grazing under stress conditions rather than under optimal conditions. However, these data suggest that the converse is true viz. that under high rainfall rotational grazing results in a higher available DM/ha relative to continuous grazing than under low rainfall. A possible explanation for this is that lack of moisture is such a strong limitation to production under low rainfall that the effects of grazing management are not



expressed.

In support of this suggestion is the relation between annual rainfall and the points at which the straight lines in Fig. 5.1 and 5.4 intercept the stocking rate axis. If the extrapolation of these straight lines is accepted, then these points represent the stocking rate at which available DM/ha is expected to be zero, and which is designated hereafter as SRO. The relation between annual rainfall and SRO was well described by a linear function for both methods of grazing and the slopes of these lines were significantly different ( $P < 0,05$ ) (Fig. 5.9). This suggests that SRO at low rainfall is similar for the two grazing methods, but has an increasing tendency to be higher for rotational grazing than for continuous grazing as rainfall increases.

Where differences between grazing methods were observed for data from the whole season, these differences were evident in both early and late summer. This result therefore contrasts that in Chapter 4 where differences between grazing methods established from analyses of whole-season data could be attributed to differences in response during the early summer only.

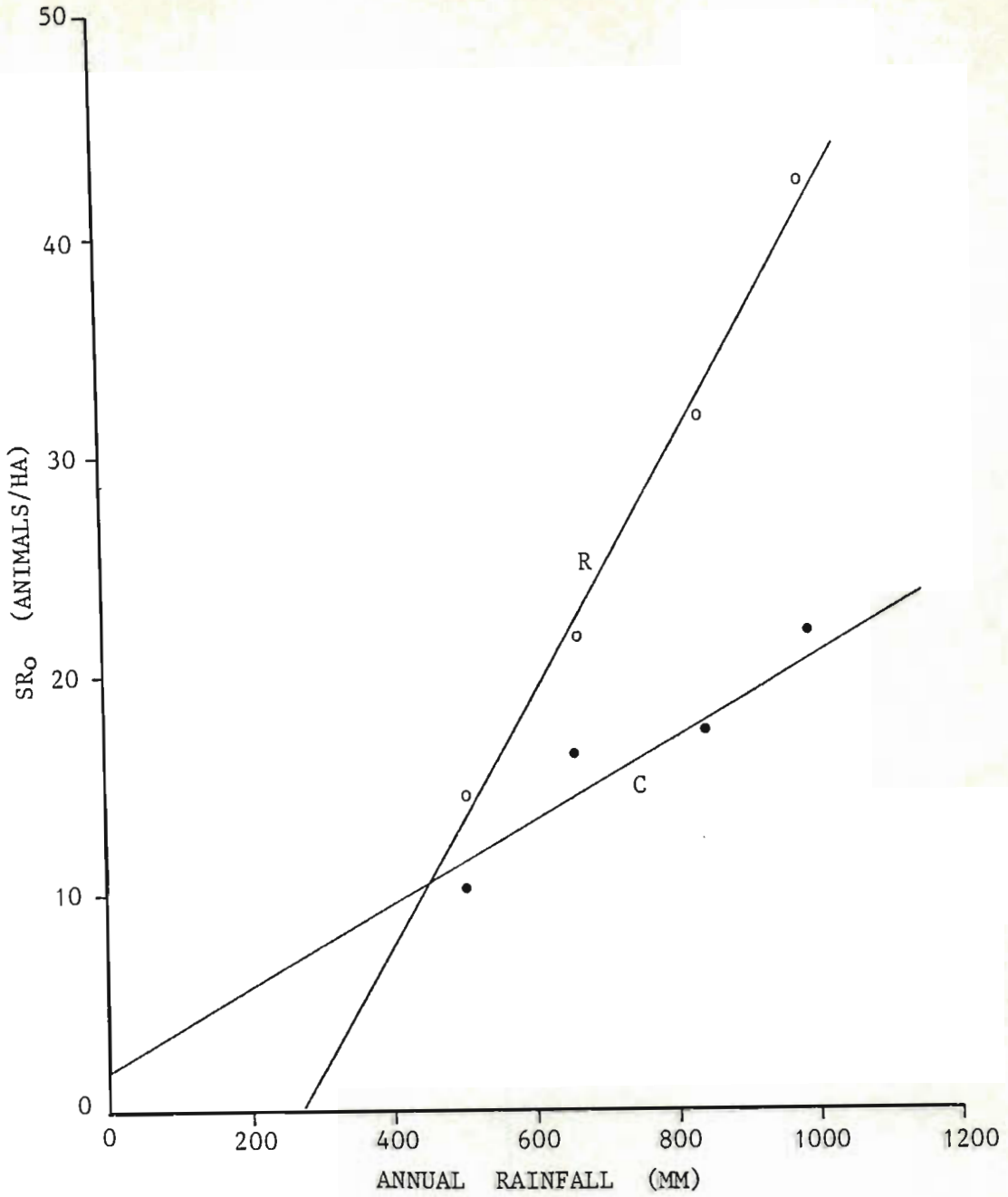


Fig. 5.9. The relationships between the stocking rate at which availability is expected to be zero ( $SR_0$ ) and annual rainfall for continuous grazing (C) and rotational grazing (R) on Coastcross.

## 6. RELATIONSHIPS BETWEEN LIVELWEIGHT GAIN AND STOCKING RATE

The relation between daily liveweight gain per animal and stocking rate is the basis for the establishment of the Jones and Sandland (1974) model. From this linear function the liveweight gain per ha curve is derived, thus facilitating an estimate of the stocking rate at which maximum liveweight gain per ha ( $SR_{max}$ ) occurs. This information then provides a basis for the economic analysis (Booyesen, 1975) which is described in Chapter 8.

Although the Jones and Sandland model should be derived from a fixed stocking trial, the relationships between daily liveweight gain per animal ( $y$ ) and average stocking rate ( $x$ ) for the trials described in this study were usually linear ( $y = a - bx$ ). It was therefore accepted that the Jones and Sandland model was applicable to these put-and-take trial data, but that extrapolation to fixed stocking would require caution. According to the Jones and Sandland model, therefore, the relationship between daily liveweight gain per ha ( $y$ ) and stocking rate ( $x$ ) was derived by means of the equation  $y = ax - bx^2$  with the same "a" and "b" constants as for the linear equation that describes the relation between liveweight gain per animal and stocking rate.

### 6.1 Whole season relationships

#### 6.1.1 Coastcross

In the 1976/77 season there was a significant ( $P < 0,05$ ) correlation between liveweight gain per animal and stocking rate for continuous grazing but not for rotational grazing (Fig. 6.1).

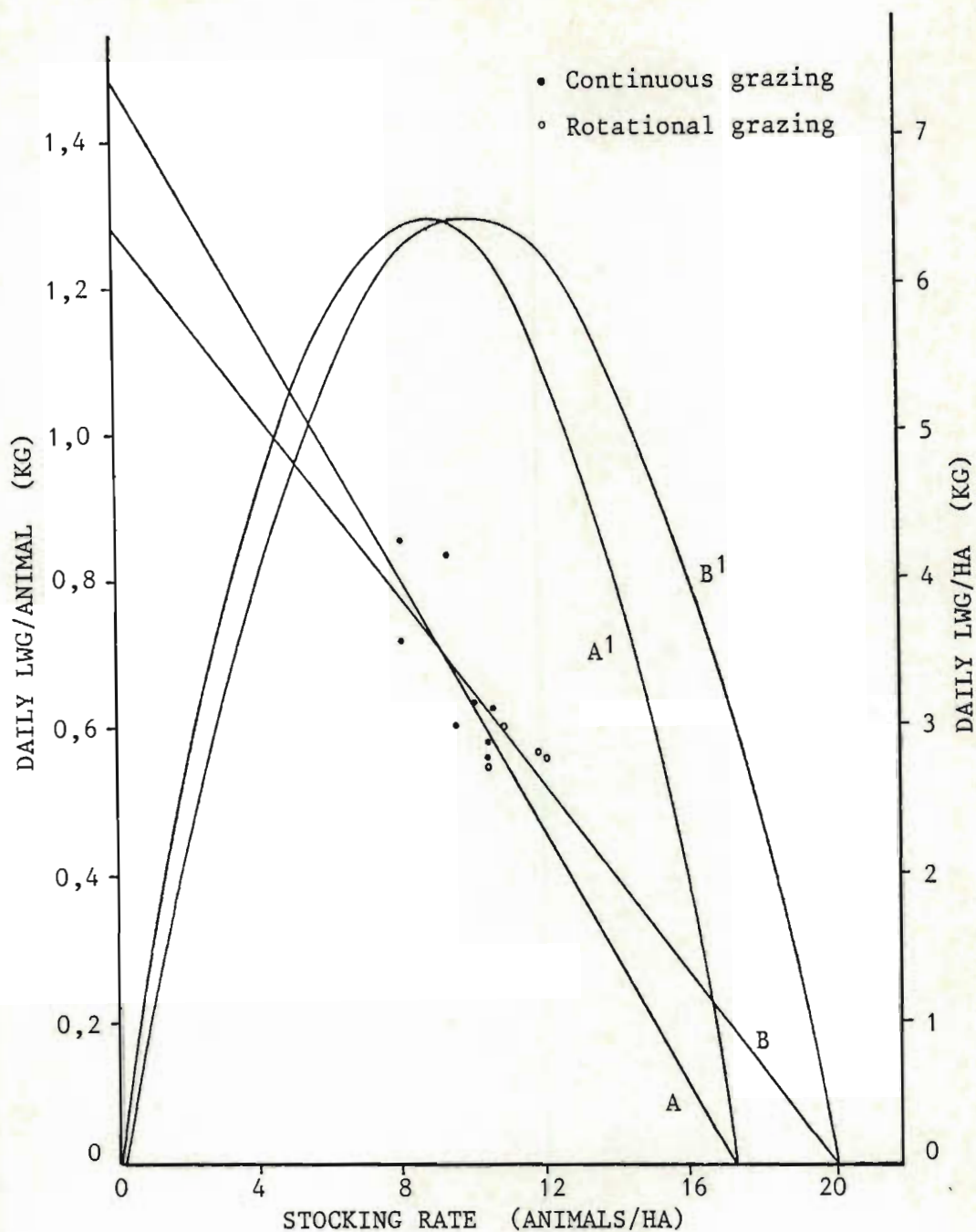


Fig. 6.1. The Jones and Sandland model for continuous grazing (A as  $y = 1,49 - 0,086x$ ,  $r = -0,76^*$  and A<sup>1</sup> as  $y = 1,49x - 0,086x^2$ ) and for the pooled data (B as  $y = 1,28 - 0,064x$ ,  $r = -0,76^{**}$  and B<sup>1</sup> as  $y = 1,28x - 0,064x^2$ ) on Coastcross in the 1976/77 season.



The reason for the poor correlation for rotational grazing is probably that the range in stocking rates was small. However, the points for rotational grazing appear to be members of the same population as those for continuous grazing, thus providing a significant correlation coefficient ( $P < 0,01$ ) for the pooled data. This regression was not significantly different from that for continuous grazing and the only conclusion that could therefore be drawn for this season was that the data indicated no difference between rotational and continuous grazing.

In the 1977/78 season there was poor correlation for continuous grazing but the correlation coefficient for the pooled data was significant ( $P < 0,01$ ) and that for rotational grazing was good although not significant (Fig. 6.2). The failure to develop a relationship for continuous grazing was again probably caused by the narrow range of stocking rates applied, which in turn might have been related to the high rainfall in this season. In this case too, there seemed to be no apparent difference between continuous and rotational grazing.

Although correlation coefficients were significant for continuous grazing ( $P < 0,01$ ) and rotational grazing ( $P < 0,05$ ) in the 1978/79 season, the two lines were very similar, with no significant difference in their slopes or the location of fitted parallel lines (Fig. 6.3). Finally, in the 1979/80 season the correlation coefficient was significant for continuous grazing only ( $P < 0,05$ ) (Fig. 6.4). The low rainfall in this season reduced the use of filler animals to a minimum and this resulted in a very narrow range in stocking rates which did not straddle  $SR_{max}$ . The slope of the line for continuous grazing and, therefore, the daily liveweight gain per ha curve is probably subject to greater error than the intercept on the stocking rate

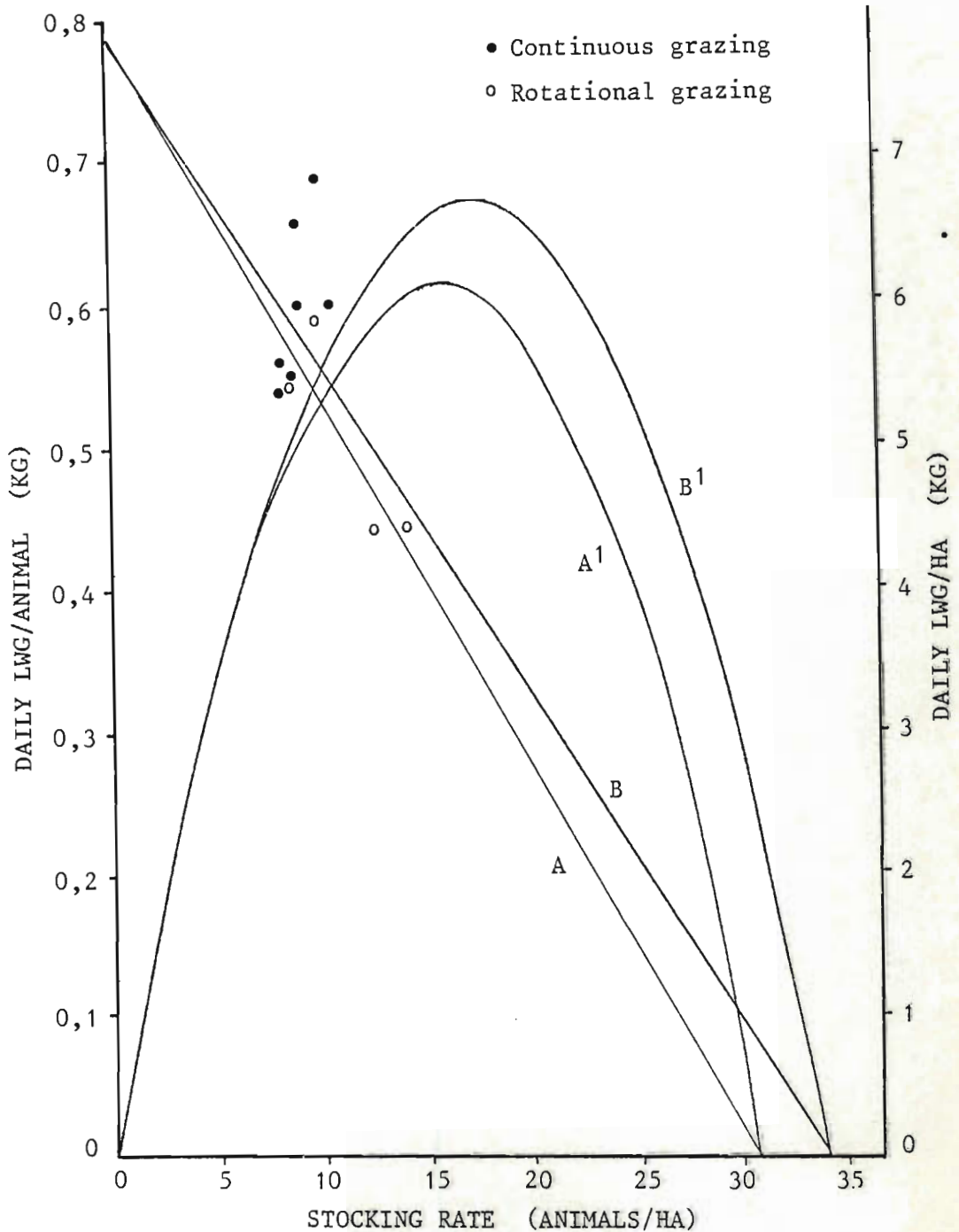


Fig. 6.2. The Jones and Sandland model for rotational grazing (A as  $y = 0,79 - 0,026x$ ,  $r = -0,86$  and A<sup>1</sup> as  $y = 0,79x - 0,026x^2$ ) and for the pooled data (B as  $y = 0,78 - 0,23x$ ,  $r = -0,79^{**}$  and B<sup>1</sup> as  $y = 0,78x - 0,23x^2$ ) on Coastcross in the 1977/78 season.

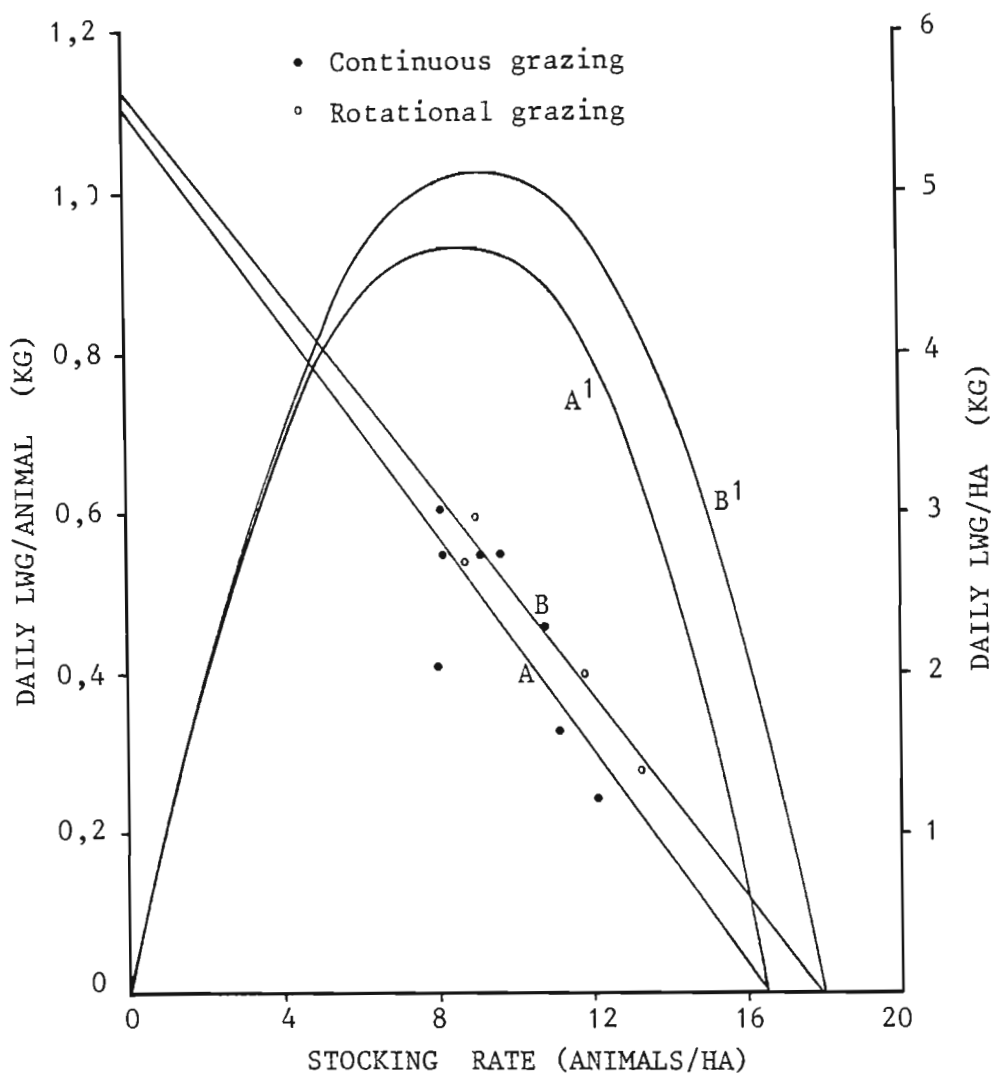


Fig. 6.3. The Jones and Sandland model for continuous grazing (A as  $y = 1,11 - 0,067x$ ,  $r = -0,84^{**}$  and A<sup>1</sup> as  $y = 1,11x - 0,067x^2$ ) and rotational grazing (B as  $y = 1,13 - 0,063x$ ,  $r = -0,97^*$  and B<sup>1</sup> as  $y = 1,13x - 0,063x^2$ ) on Coastcross for the 1978/79 season.

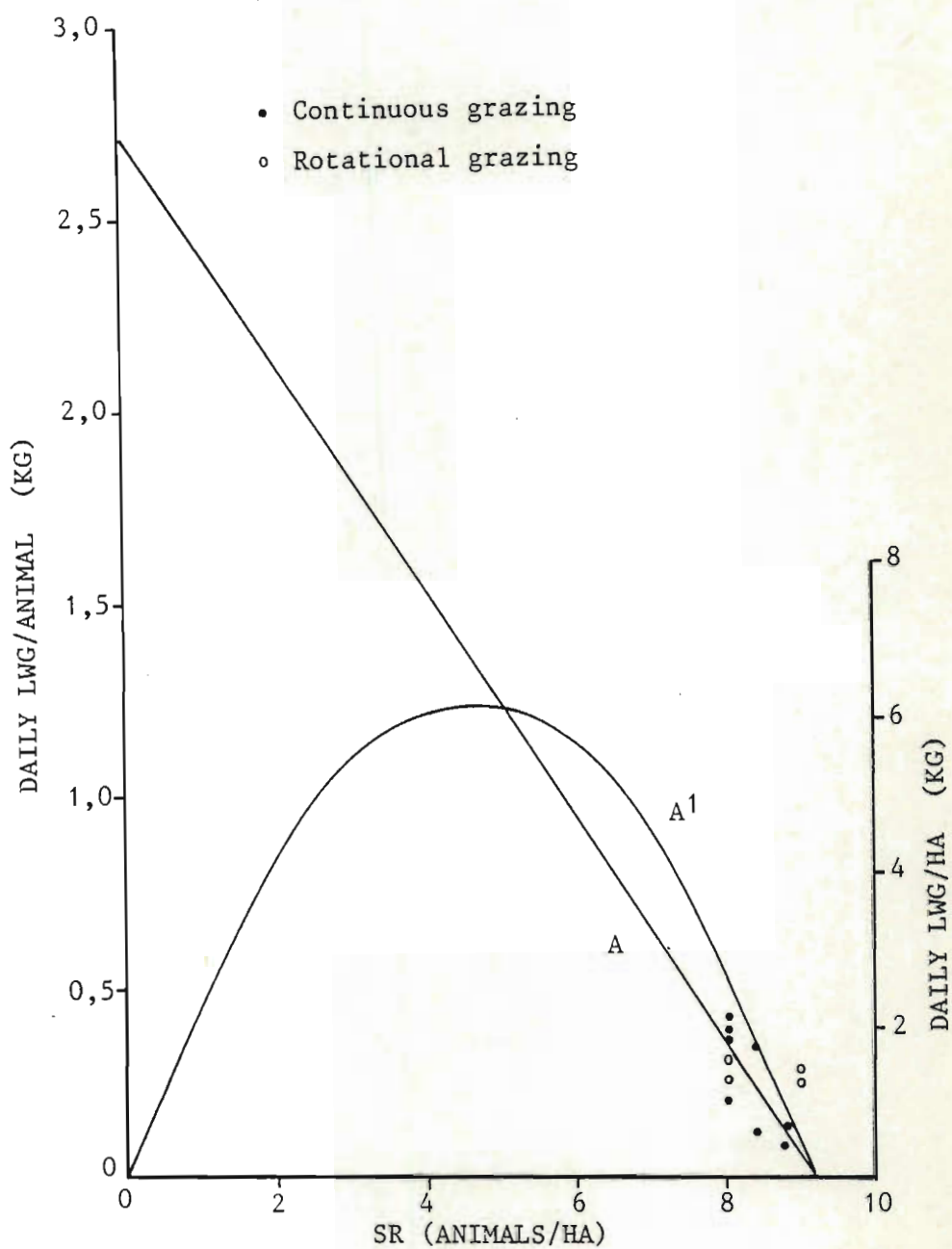


Fig. 6.4. The Jones and Sandland model for continuous grazing (A as  $y = 2,72 - 0,29x$ ,  $r = -0,73^*$  and  $A^1$  as  $y = 2,72x - 0,29x^2$ ) on Coastcross for the 1979/80 season.



axis and  $SR_{max}$  (Connolly, 1976). Despite no significant difference between the two grazing methods in this season, the relative position of the rotational grazing points suggests a higher  $SR_{max}$  for this method of grazing relative to continuous grazing.

From the analysis within each season it would appear that there was no difference between continuous and rotational grazing on Coastcross. However, when the Jones and Sandland model was established from four year averaged data, the slopes for the continuous and rotational grazing lines were significantly different ( $P < 0,01$ ) (Fig. 6.5). On average, therefore, it would seem that there is a difference between the two methods of grazing and that the narrow range in stocking rates and high experimental error were possibly responsible for the absence of significant differences within seasons.

The  $SR_{max}$  from the regressions established for the four year averages was 7,8 animals/ha for continuous grazing and 14,3 animals/ha for rotational grazing. Extrapolation of the lines resulted in interception of the stocking rate axis at 15,6 and 28.6 animals/ha, implying that at these stocking rates liveweight gain per animal would be zero. Comparison of Fig. 6.5 with Fig. 5.2 reveals very similar patterns, with expected herbage availability being zero ( $SR_0$ ) at 14,4 and 27,7 animals/ha for continuous and rotational grazing respectively. However,  $2 \times SR_{max}$  must permit intake for maintenance and this would be quite substantial. These data appear to confirm, therefore, that stocking rate affects liveweight gain per animal primarily through its effect on herbage availability.

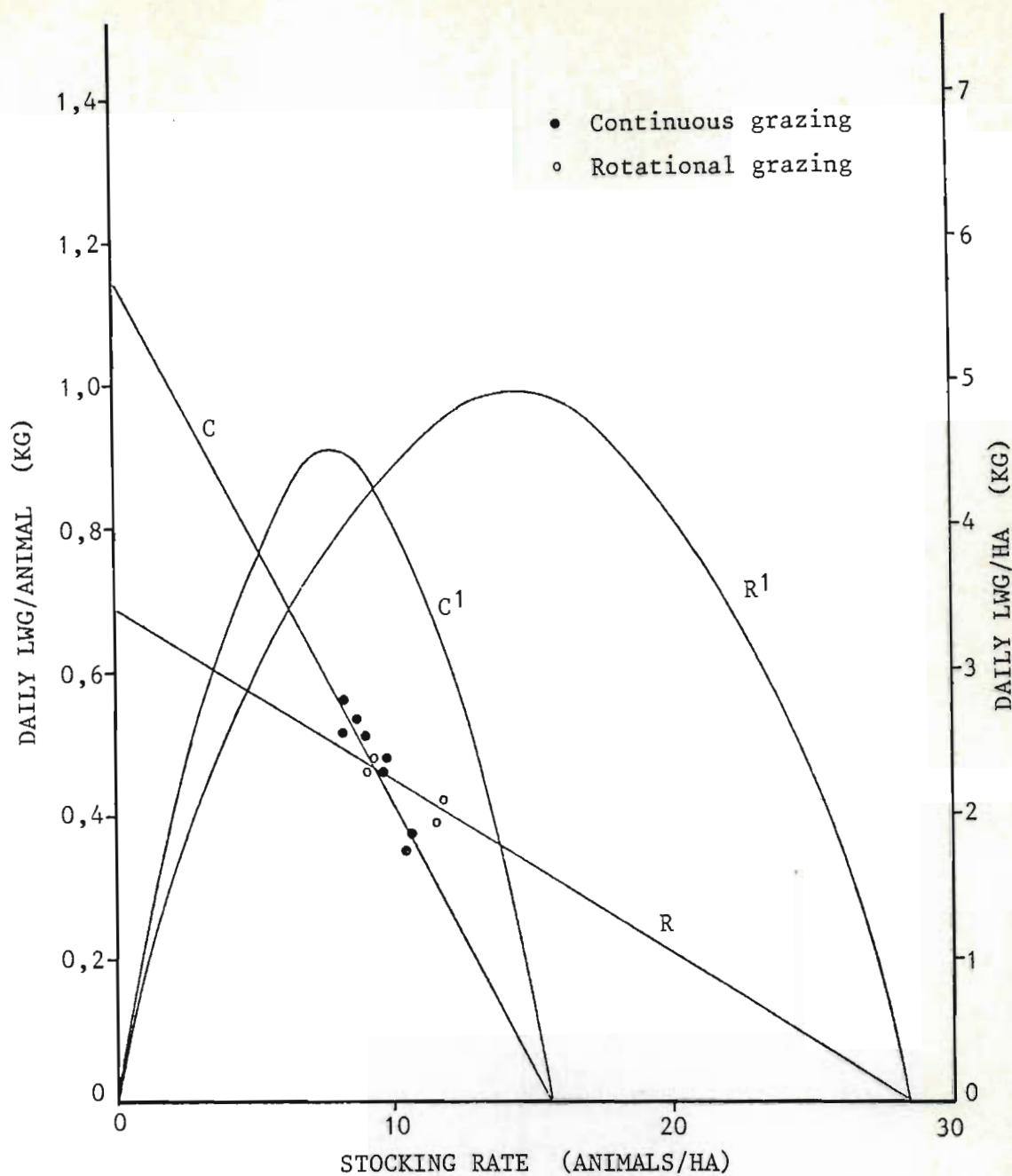


Fig. 6.5. The Jones and Sandland model for continuous grazing (C) and rotational grazing (R) on Coastcross, derived from the average of four years.

### 6.1.2 Kikuyu and Rhodesgrass

In the first season that treatments were applied to kikuyu (1978/79) animal variation appeared to be high, resulting in poor correlation (Fig. 6.6). However, although the correlation coefficient of the regression for the pooled data was low ( $r = 0,60$ ) it was nevertheless significant ( $P < 0,05$ ). This regression line was therefore plotted and used to derive the curve for daily liveweight gain per ha. The relative positions of the points in the scatter diagram suggest that, in general, rotational grazing resulted in slightly higher daily liveweight gain per animal than continuous grazing at equivalent stocking rates.

Results from the second season (1979/80) show a fairly good relationship between daily liveweight gain per animal and stocking rate for continuous grazing, but no correlation for rotational grazing (Fig. 6.7). Unfortunately, due to the low rainfall in this season and the minimum limit of three tester animals per treatment, the range of stocking rates was narrow and did not straddle  $SR_{max}$ . Since the actual points are close to the stocking rate axis, the position where the line intercepts this axis and, therefore,  $SR_{max}$  is likely to be fairly reliable. However, the slope of the line could well be subject to considerable error. Despite the absence of significant correlation for rotational grazing, the position of the rotational grazing points relative to the continuous grazing points suggests that rotational grazing provided superior liveweight gain per animal at the highest stocking rate i.e. 8,8 animals/ha.

In the 1980/81 season, fairly good relationships existed for both continuous and rotational grazing, but since this was also a season of low rainfall, the stocking rates which were applied did not straddle  $SR_{max}$  (Fig. 6.8). However, here again the intercept

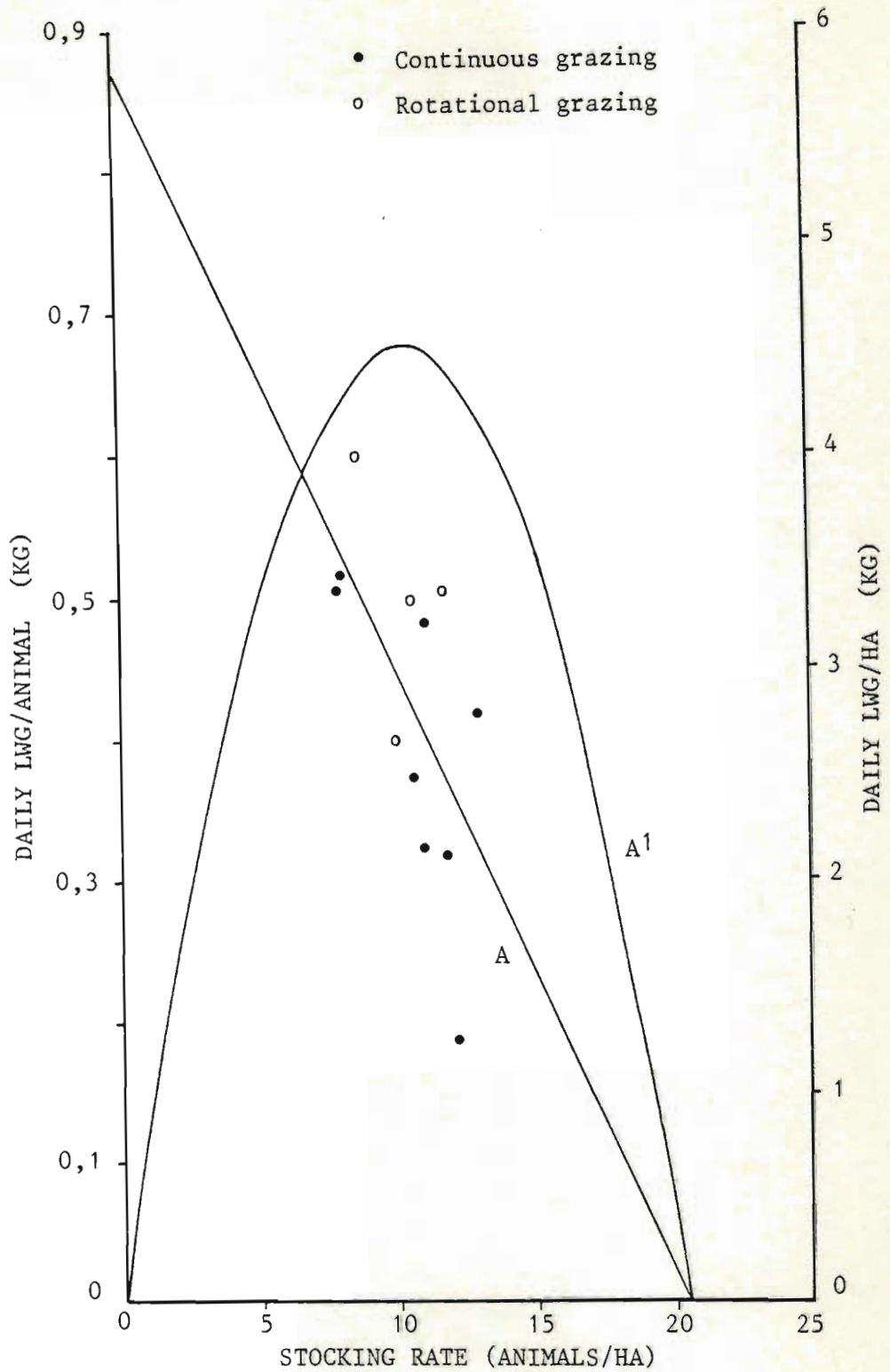


Fig. 6.6. The Jones and Sandland model for the pooled data (A as  $y = 0,87 - 0,043x$ ,  $r = -0,60^*$  and A<sup>1</sup> as  $y = 0,87x - 0,043x^2$ ) on kikuyu in the 1978/79 season.



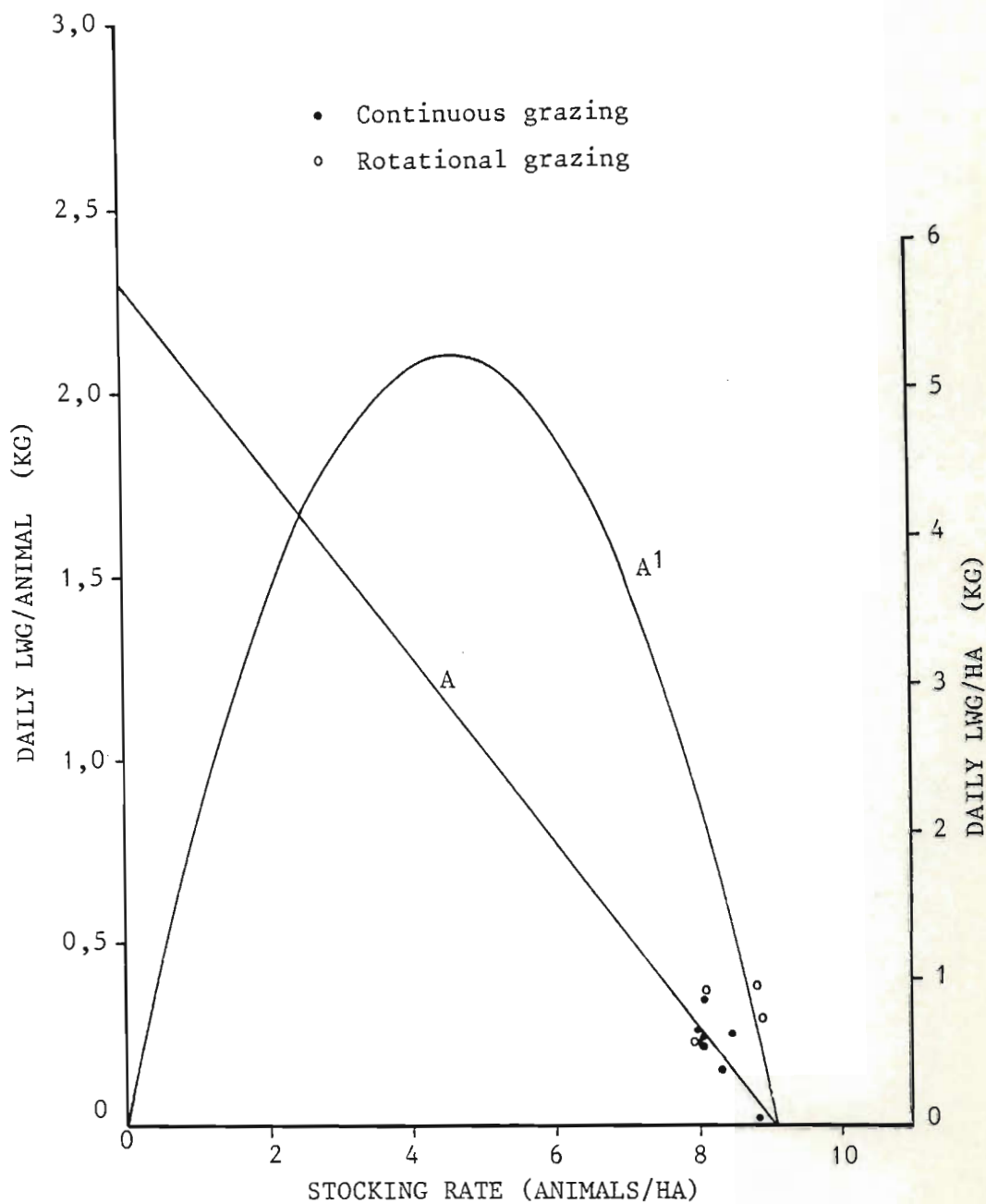


Fig. 6.7. The Jones and Sandland model for continuous grazing (A as  $y = 2,31 - 0,25x$ ,  $r = -0,84^*$  and A<sup>1</sup> as  $y = 2,31x - 0,25x^2$ ) on kikuyu in the 1979/80 season.

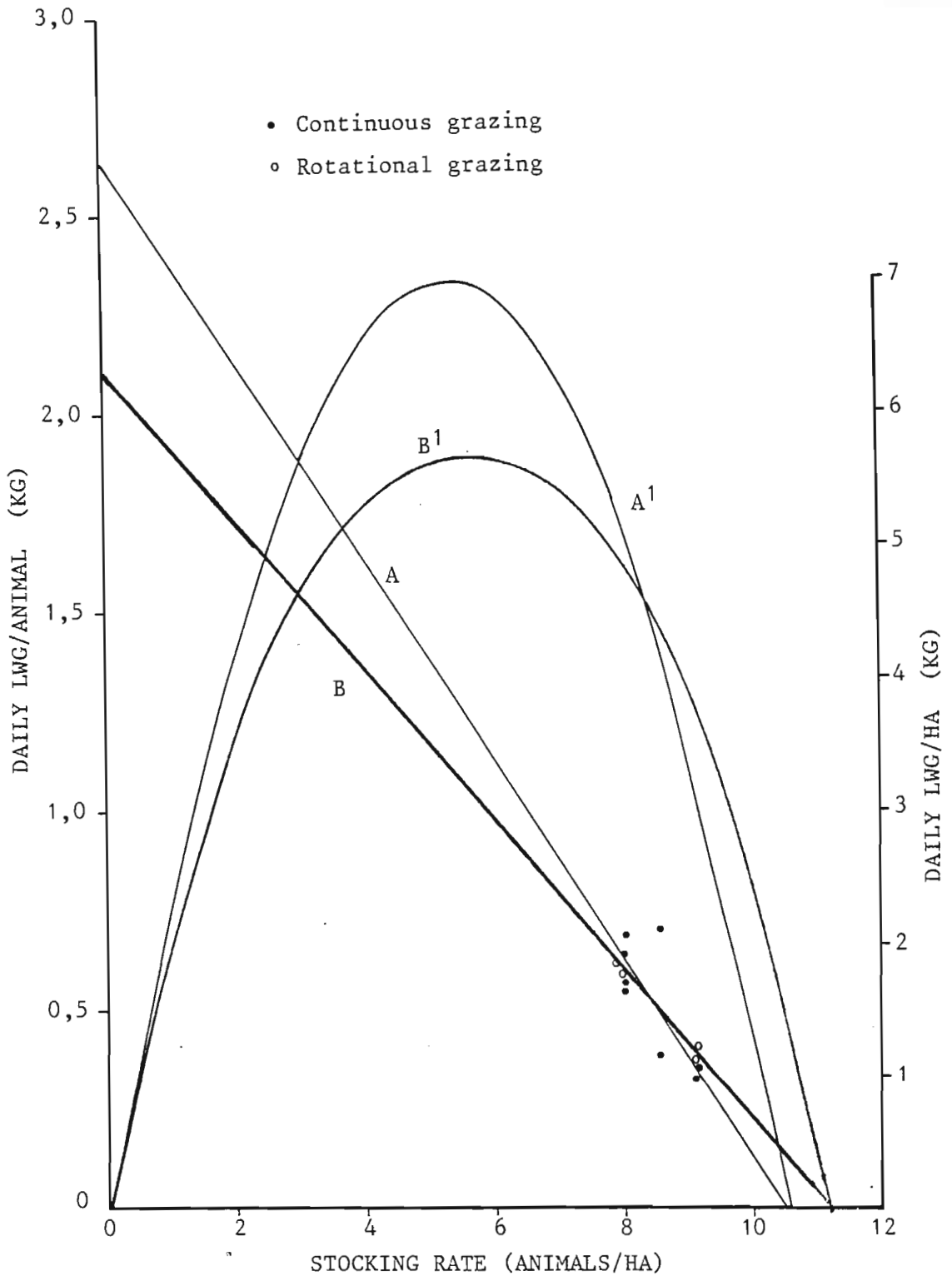


Fig. 6.8. The Jones and Sandland model for continuous grazing (A as  $y = 2,65 - 0,25x$ ,  $r = -0,75^*$  and A<sup>1</sup> as  $y = 2,65x - 0,25x^2$ ) and rotational grazing (B as  $y = 2,08 - 0,19x$ ,  $r = -0,99^*$  and B<sup>1</sup> as  $y = 2,08x - 0,19x^2$ ) on kikuyu for the 1980/81 season.

on the stocking rate axis and the estimate of SR<sub>max</sub> is likely to be fairly reliable. Finally, in the last season (1981/82) there was no correlation between liveweight gain per animal and stocking rate (Fig. 6.9). This was partly due to a third consecutive season of low rainfall which restricted the experimental period to only 85 days. In view of this it was doubtful whether the results from the last season should be used in establishing a relationship for the average of four years, or whether the average for the first three years only should be used. The Jones and Sandland model was therefore established for both a three and four year average (Fig. 6.10).

In the case of the four year average there was an apparent difference in the slopes of the regression lines between liveweight gain per animal and stocking rate for continuous and rotational grazing (Fig. 6.10a). However, this difference was not significant. Use of the three year average for each paddock reduced SR<sub>max</sub> considerably and reduced the difference between the two methods of grazing. On average, therefore, no difference in liveweight gain was evident between the two methods of grazing on kikuyu at equivalent stocking rates.

The regressions between liveweight gain per animal and stocking rate for continuous and rotational grazing on Rhodesgrass in the 1978/79 season had significantly different slopes ( $P < 0,05$ ) (Fig. 6.11). This resulted in an estimated SR<sub>max</sub> of 10 animals/ha for rotational grazing and 6.2 animals per ha for continuous grazing. Corresponding daily liveweight gain per ha at SR<sub>max</sub> was 4,75 and 4,55 kg for rotational and continuous grazing respectively. This result was thus in agreement with the four year average for Coastcross (Fig. 6.5) showing considerable difference between SR<sub>max</sub> for the two methods of grazing but very

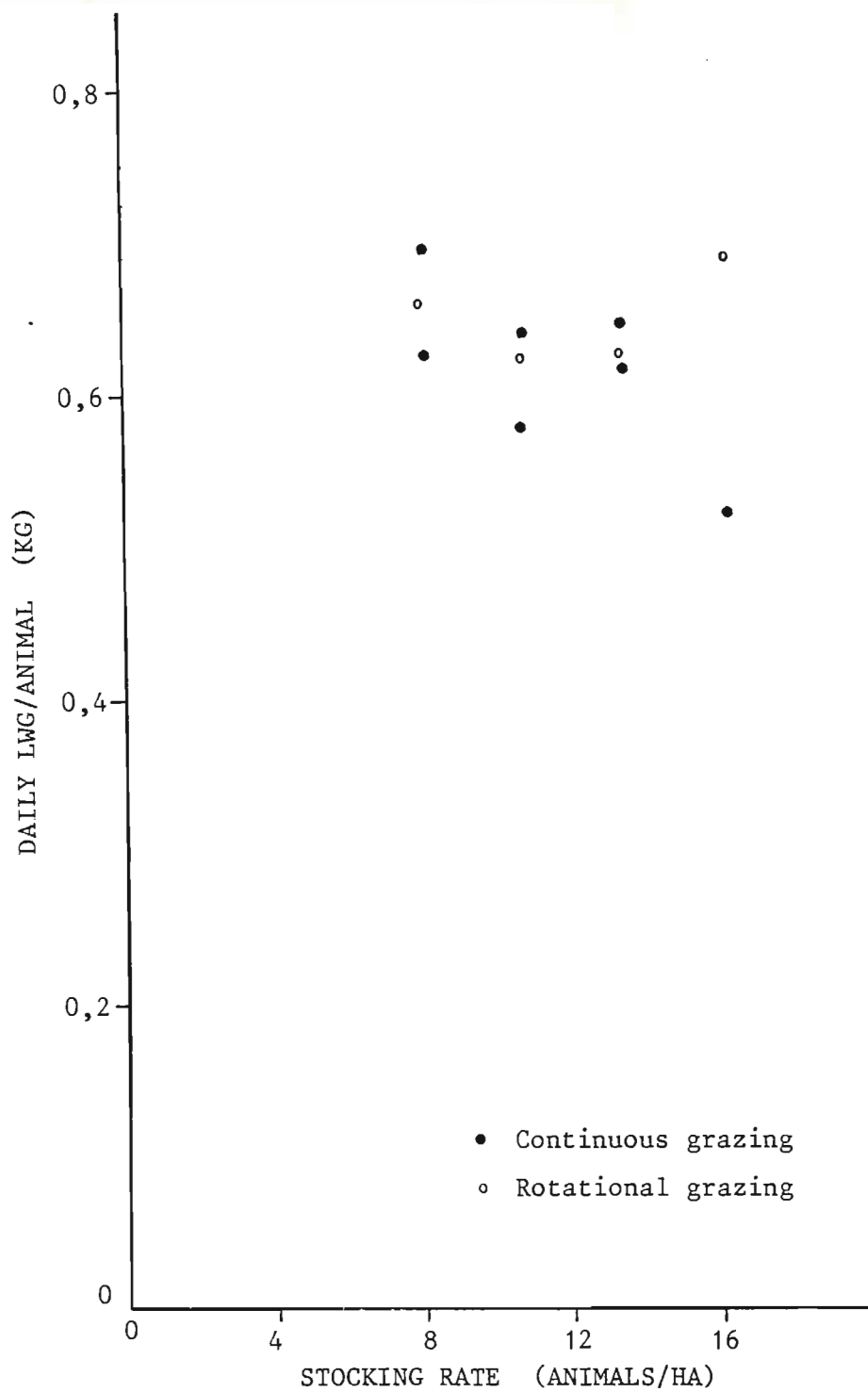


Fig. 6.9. A scatter diagram of liveweight gain/animal and stocking rate for rotational and continuous grazing on kikuyu in the 1981/82 season.



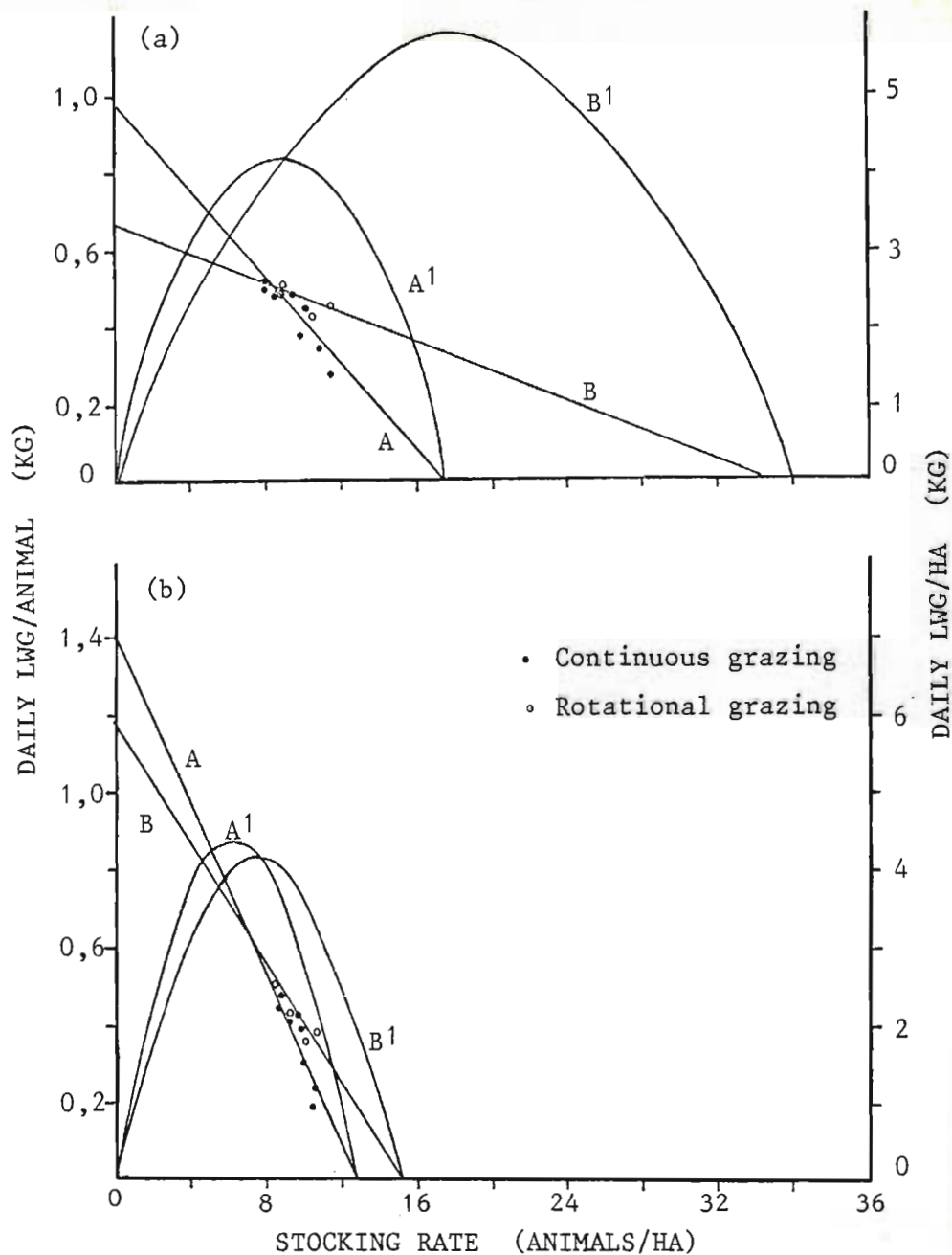


Fig. 6.10. The Jones and Sandland model for continuous grazing (A and A<sup>1</sup>) and rotational grazing (B and B<sup>1</sup>) from an average of the data from all four seasons (a) and from the first three seasons (b) on kikuyu.

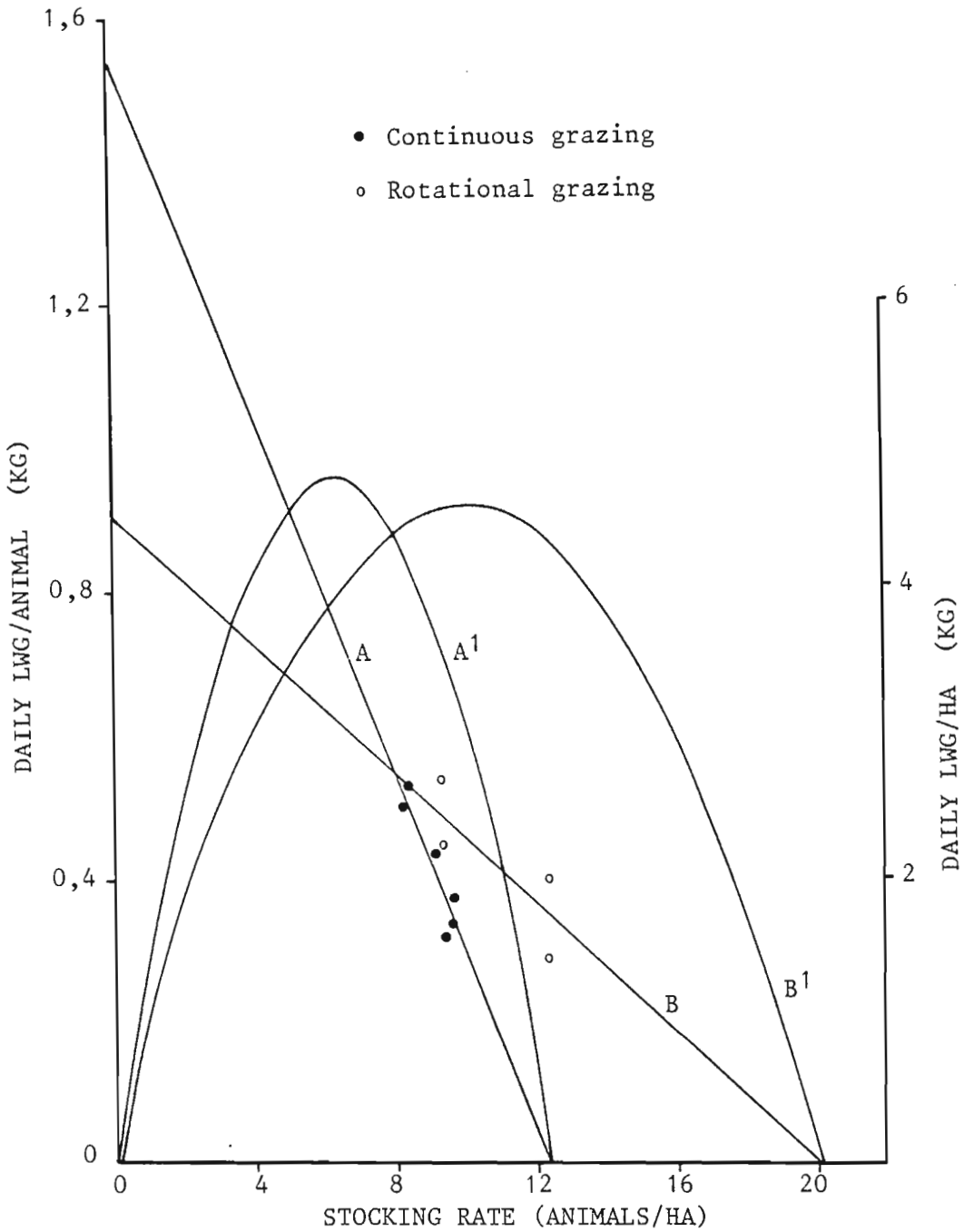


Fig. 6.11. The Jones and Sandland model for continuous grazing (A as  $y = 1,54 - 0,12x$ ,  $r = -0,91^*$  and  $A^1$  as  $y = 1,54x - 0,12x^2$ ) and rotational grazing (B as  $y = 0,91 - 0,045x$ ,  $r = -0,79$  and  $B^1$  as  $y = 0,19x - 0,045x^2$ ) on Rhodesgrass in the 1978/79 season.

little difference between the daily liveweight gain per ha at SRmax. However, this was the only set of data from an individual season which showed this trend clearly.

## 6.2 Variation within seasons

### 6.2.1 Relationships between stocking rate and liveweight gain

As in Chapters 4 and 5, only the first three high rainfall years were examined for differences in performance between early and late summer. However, no difference was observed between rotational and continuous grazing in early or late summer in any one season. The three year averages from Coastcross were therefore used to derive regressions for early and late summer from the pooled data of both grazing methods (Fig. 6.12).

Despite the apparent difference in the slopes of the regressions for early and late summer, this difference was not significant. Nevertheless, there was a significant difference ( $P < 0,01$ ) in the location of parallel lines fitted to these data. SRmax was almost identical in early and late summer (10,7 animals/ha) but the daily liveweight gain per ha at SRmax was 8,1 and 3,7 kg respectively. Hence, the trend in Chapter 4 which showed higher liveweight gain per animal at equivalent herbage availability in early summer as compared with late summer was repeated for equal stocking rates.

### 6.2.2 Changes in liveweight gain of animals with time

To examine the changes in liveweight gain of animals over the season, the means of the two heavy, the two medium and the two light utilization continuously grazed, put-and-take treatments were plotted against time. For rotational grazing the means of

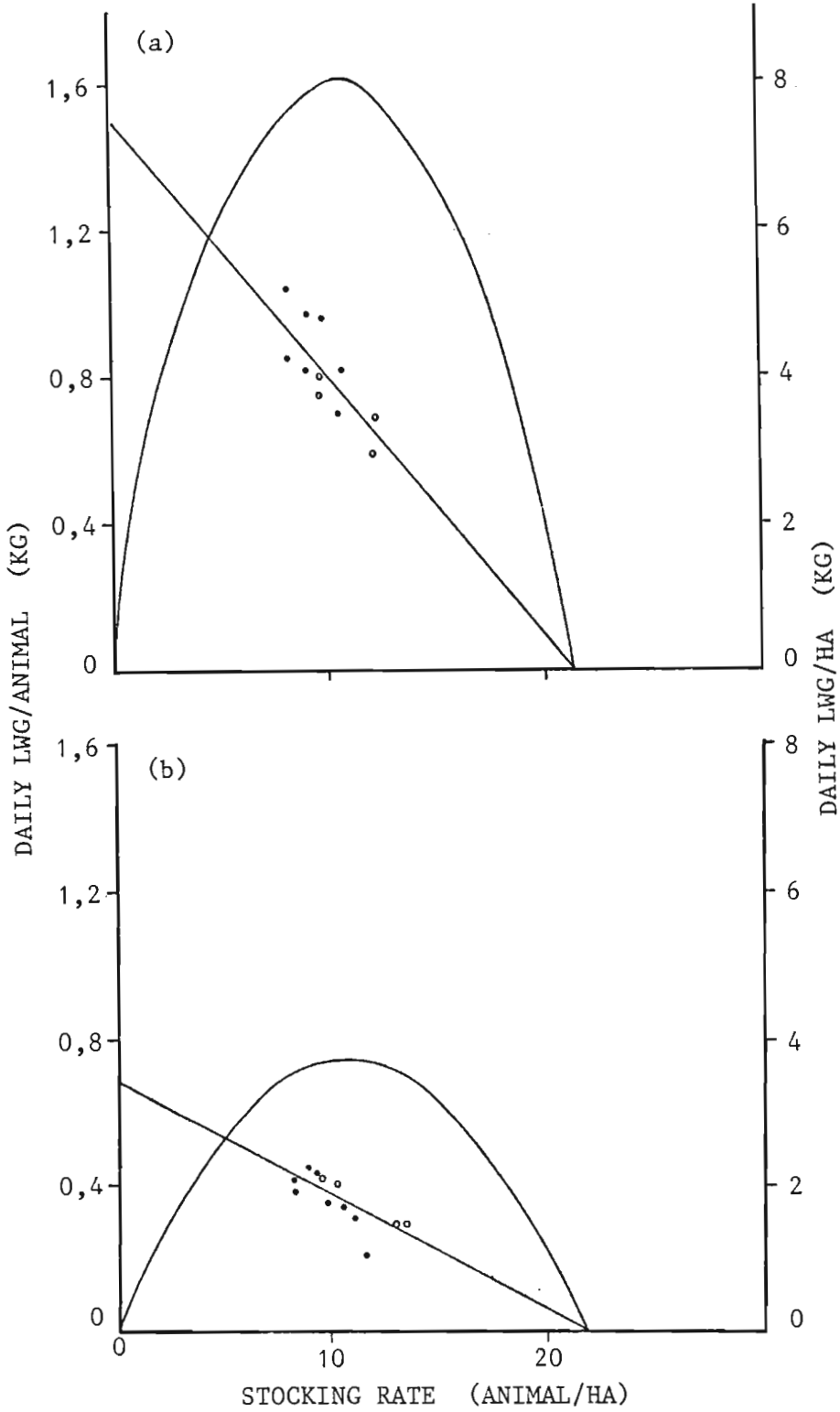


Fig. 6.12. The Jones and Sandland model for early summer (a) and late summer (b) derived from the means of the pooled data under rotational and continuous grazing on Coastcross in the 1976/77, 1977/78 and 1978/79 seasons.



the two light and the two heavy utilization treatments were used. Since the calculation of daily liveweight gain per animal is based on periods between weighing dates, the points in the figures were located at the mid-points of these intervals.

In the 1976/77 season on Coastcross there was considerable variation in relative differences between utilization intensities for individual intervals between weighing dates, as well as between continuous and rotational grazing (Fig. 6.13a). This was not surprising because variation amongst animals over periods as short as three weeks is known to be high. However, for all treatments under both continuous and rotational grazing there was a distinct pattern of variation in daily liveweight gain of animals over the season. The peaks occurred in early to mid-December, mid- to late January and early March, while the troughs occurred at the end of December, in early to mid-February and in late March.

Since each of these peaks and troughs was identified by one weighing interval only, it could be argued that this variation was not real and that it could be ascribed to experimental error. In the 1977/78 season, therefore, the interval between weighing dates was shortened to two weeks, but similar patterns emerged (Fig. 6.13b). The troughs in this season were in late December/early January, mid-March, and at the end of April, while the peaks were in November/early December, late January/early February and early April. These peaks and troughs were each described by a number of points and are therefore considered to be better defined than those which occurred in the 1976/77 season. The pattern for rotational grazing was less distinct than that for continuous grazing and this could have been related to variation in time between the weighing date and the date on which animals were last

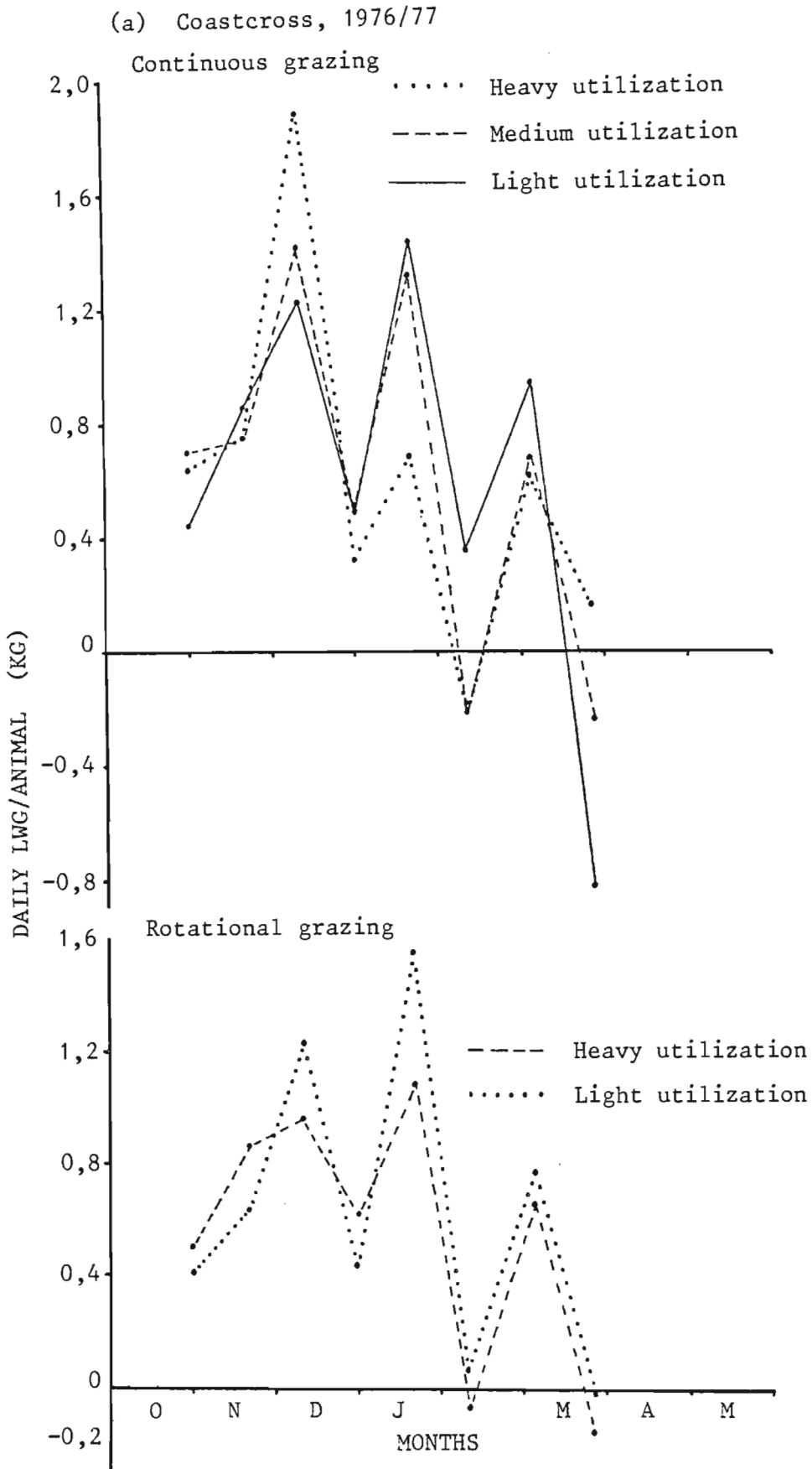


Fig. 6.13. The variation in daily liveweight gain per animal over individual seasons for continuous and rotational grazing at different levels of utilization on Coastcross, kikuyu and Rhodesgrass.

(b) Coastcross, 1977/78

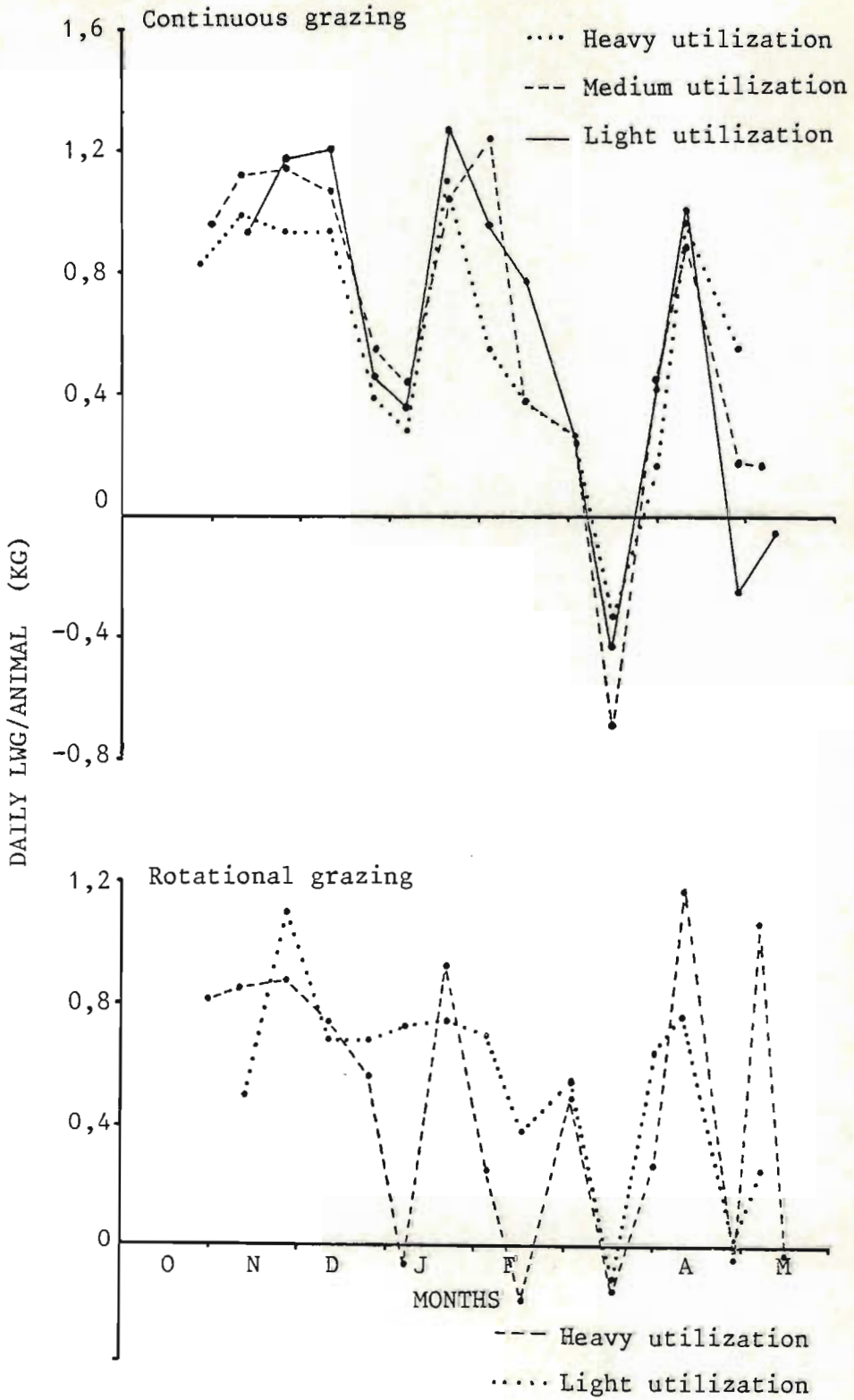


Fig. 6.13. Continued

(c) Coastcross, 1978/79

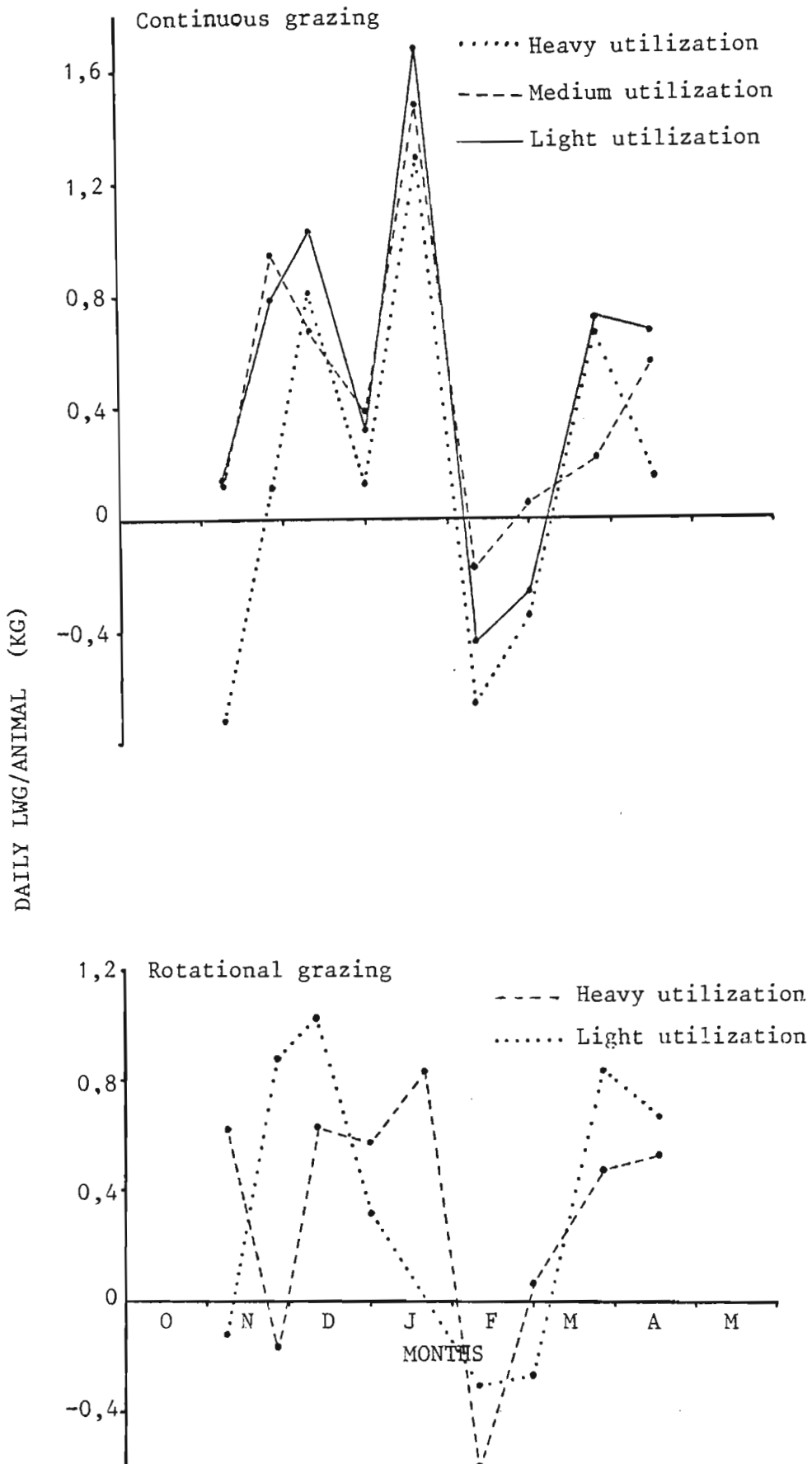


Fig. 6.13. Continued



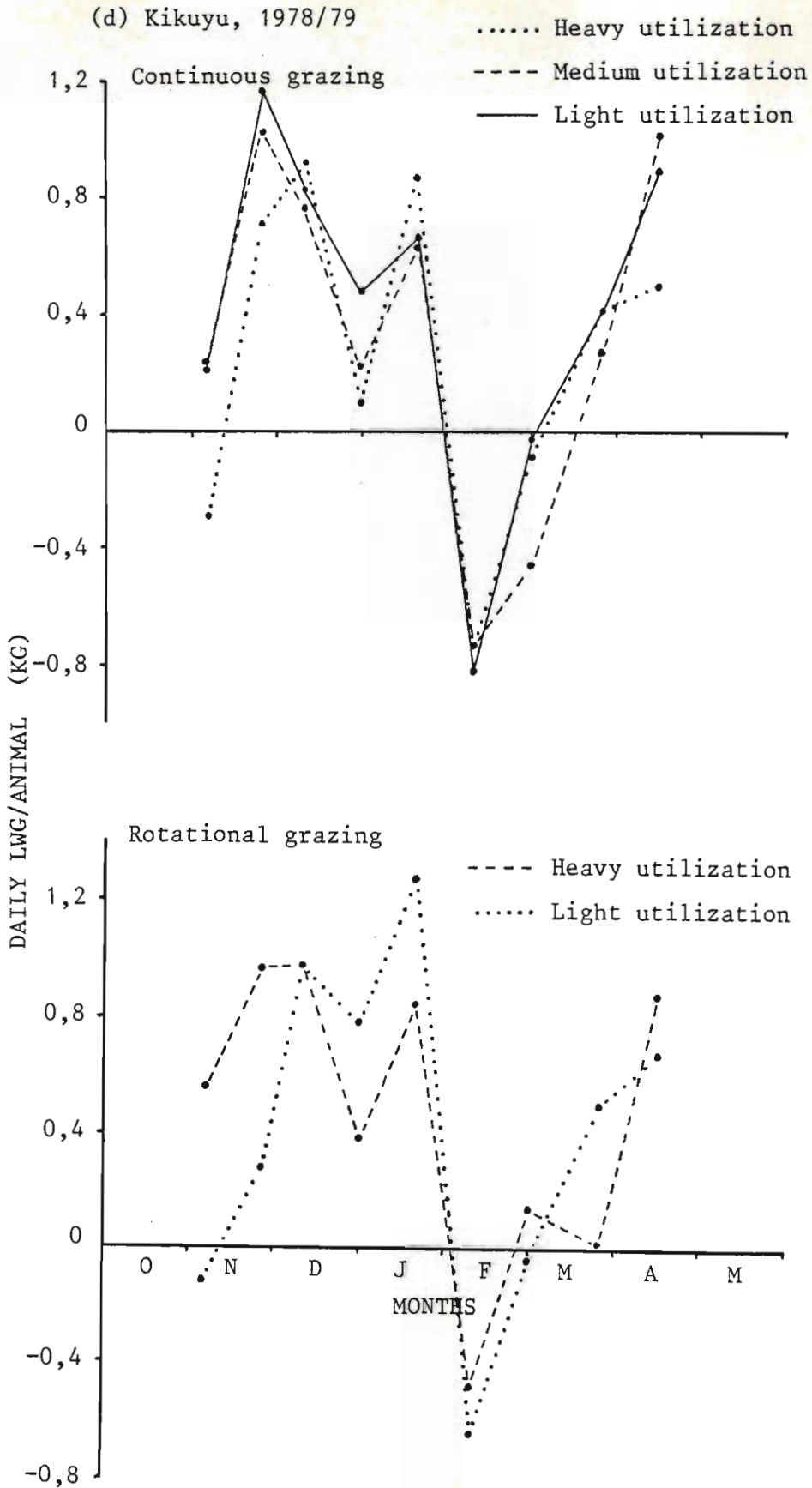


Fig. 6.13. Continued

(e) Rhodesgrass, 1978/79

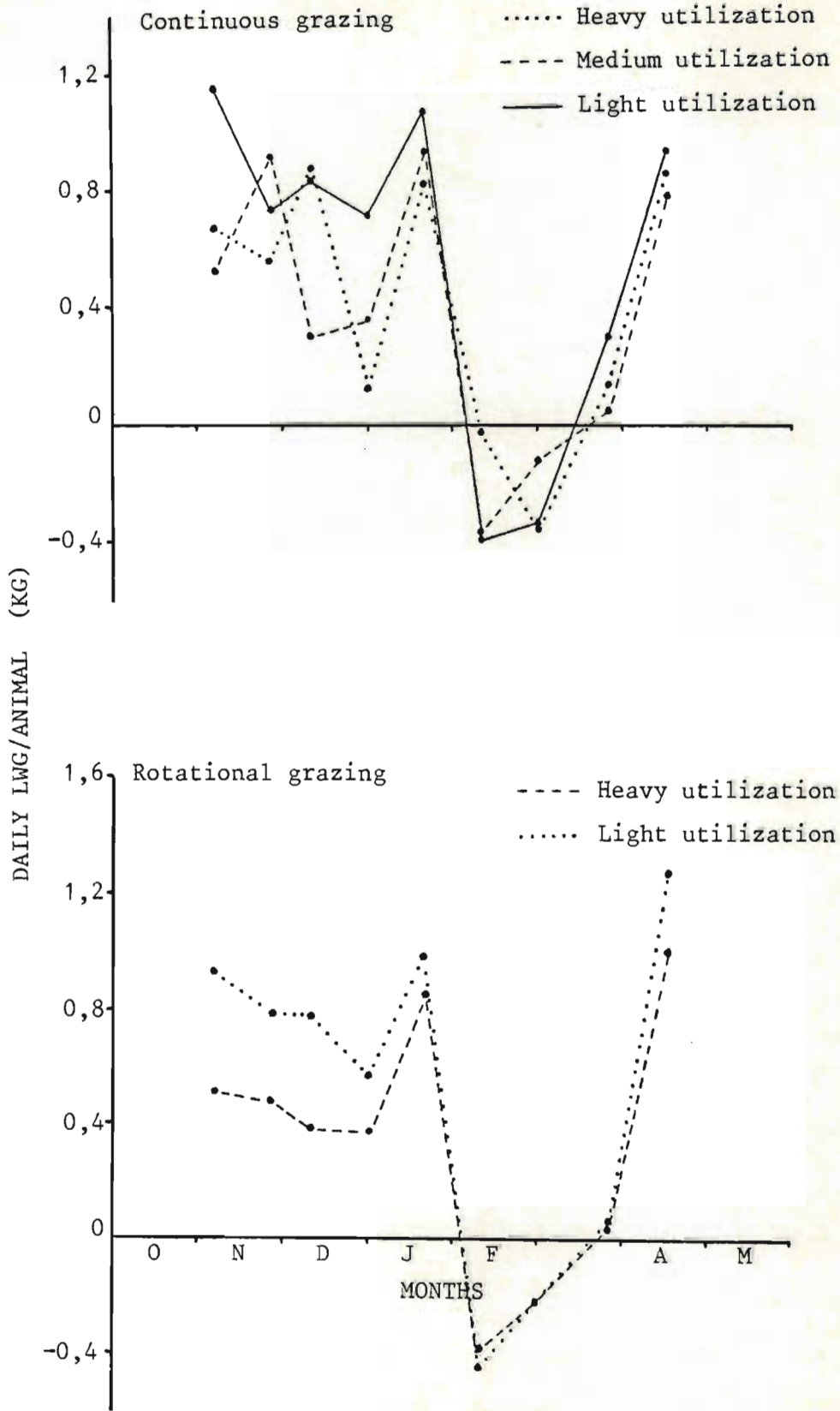


Fig. 6.13. Continued

(f) Coastcross, 1979/80

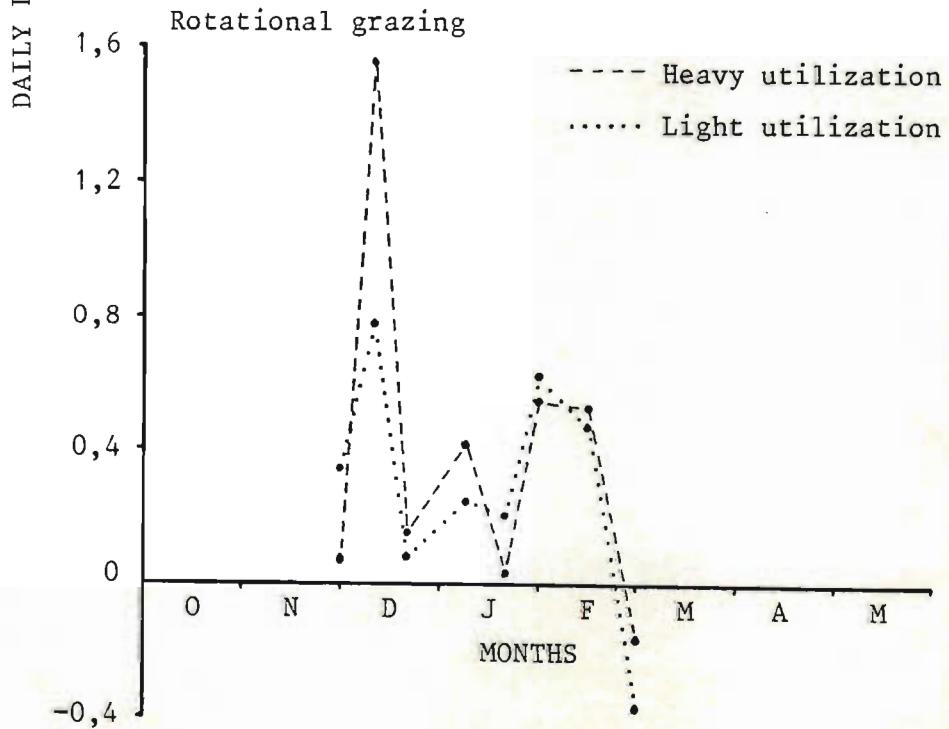
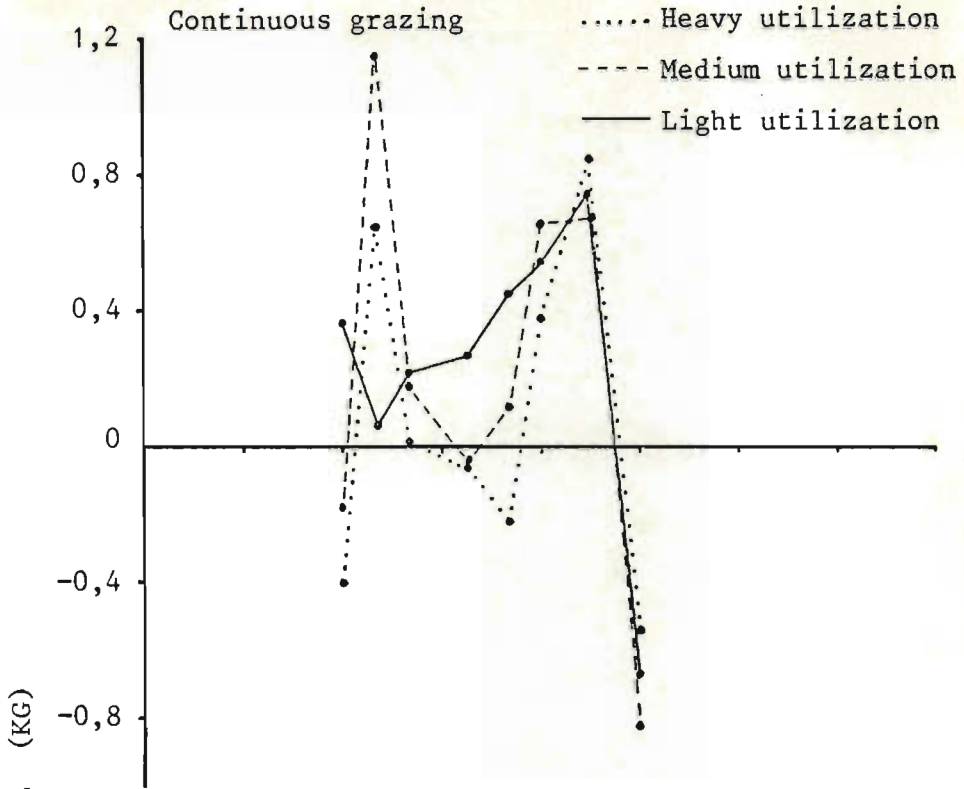


Fig. 6.13. Continued

(g) Kikuyu, 1979/80

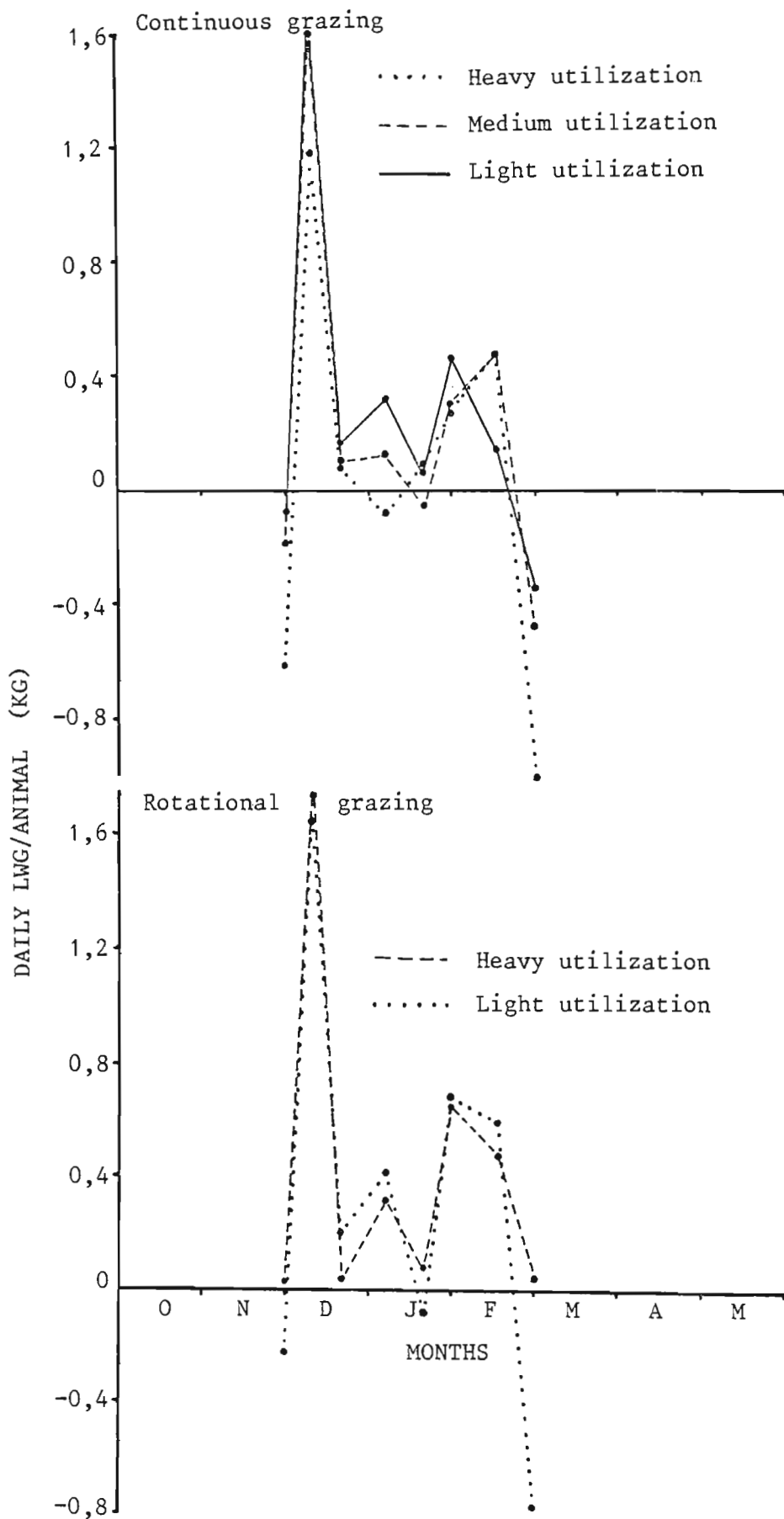


Fig. 6.13. Continued



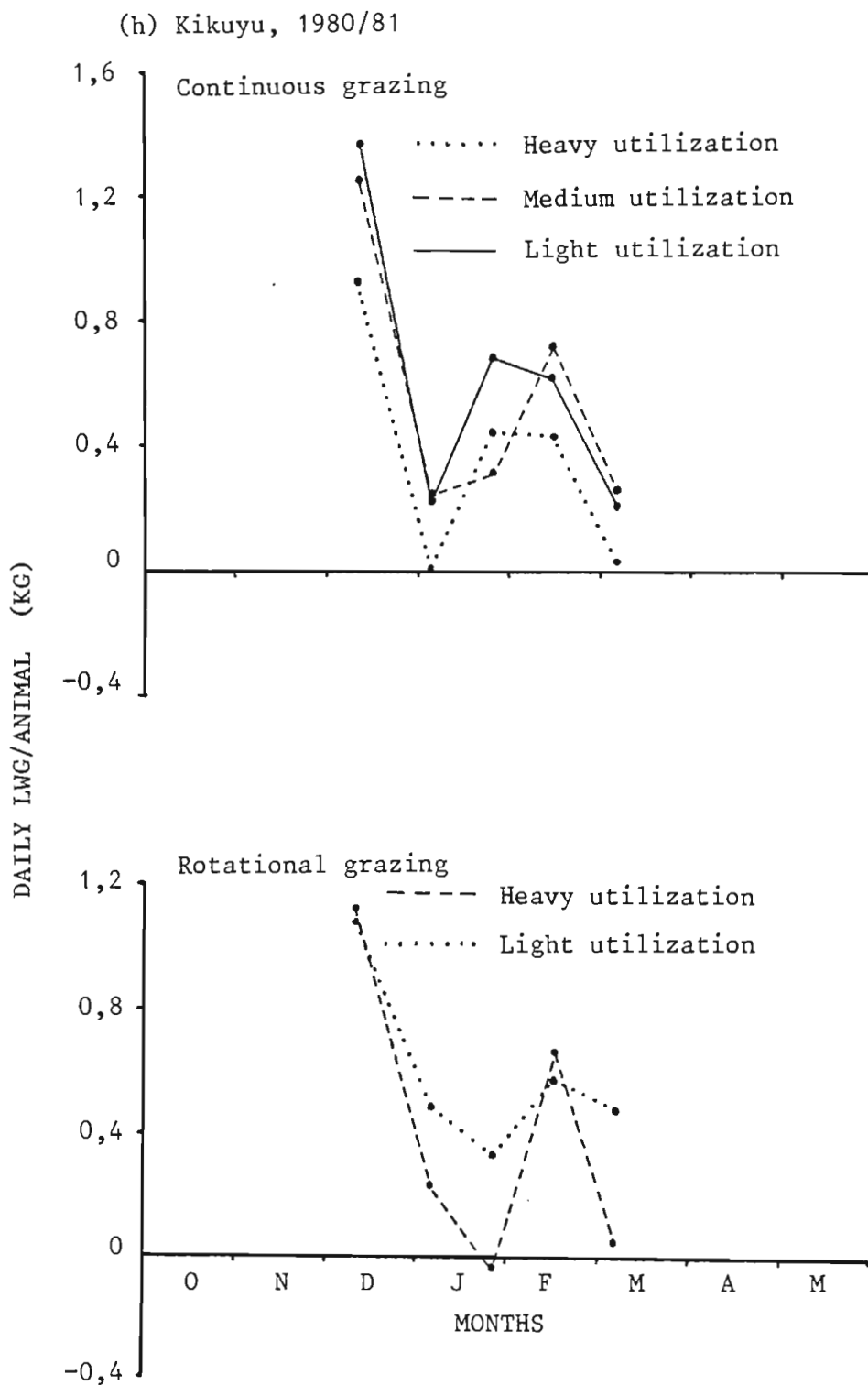


Fig. 6.13. Continued

moved to a fresh sub-paddock. If this was the cause of less distinct patterns being observed for rotational grazing, it would seem that overnight starving of animals was not sufficient to eliminate the differences in gut-fill which resulted from differences in availability under rotational grazing on different weighing dates.

In subsequent seasons similar peaks and troughs occurred at different times in each season (Fig. 6.13c-h). Since all levels of utilization, both methods of grazing, and all species showed similar patterns of variation in daily liveweight gain within seasons, it would seem that this variation was caused by weather variables. However, from comparing the patterns of variation in liveweight gain with rainfall distribution in each season (Fig. 6.14) there appeared to be no clear relationship with monthly rainfall. In the 1976/77 season high and low liveweight gain of animals corresponded to high and low rainfall in certain parts of the season, but not in others. From December to April in the 1977/78 season monthly rainfall was 100 mm or more, but during March animals lost weight. In the 1978/79 season monthly rainfall was close to or above 100 mm but liveweight gain of animals fluctuated, being lowest in February, which was the month that received the highest rainfall.

Forage quality is another factor which could have caused the fluctuation of liveweight gain per animal over the season. However, due to limited resources, measurement of forage quality was limited to analysis for crude protein (CP) and crude fiber (CF) at the Cedara laboratory in the 1978/79 season only. From these two measurements total digestible nutrients (TDN) was estimated by using the regression of Bredon (undated). The

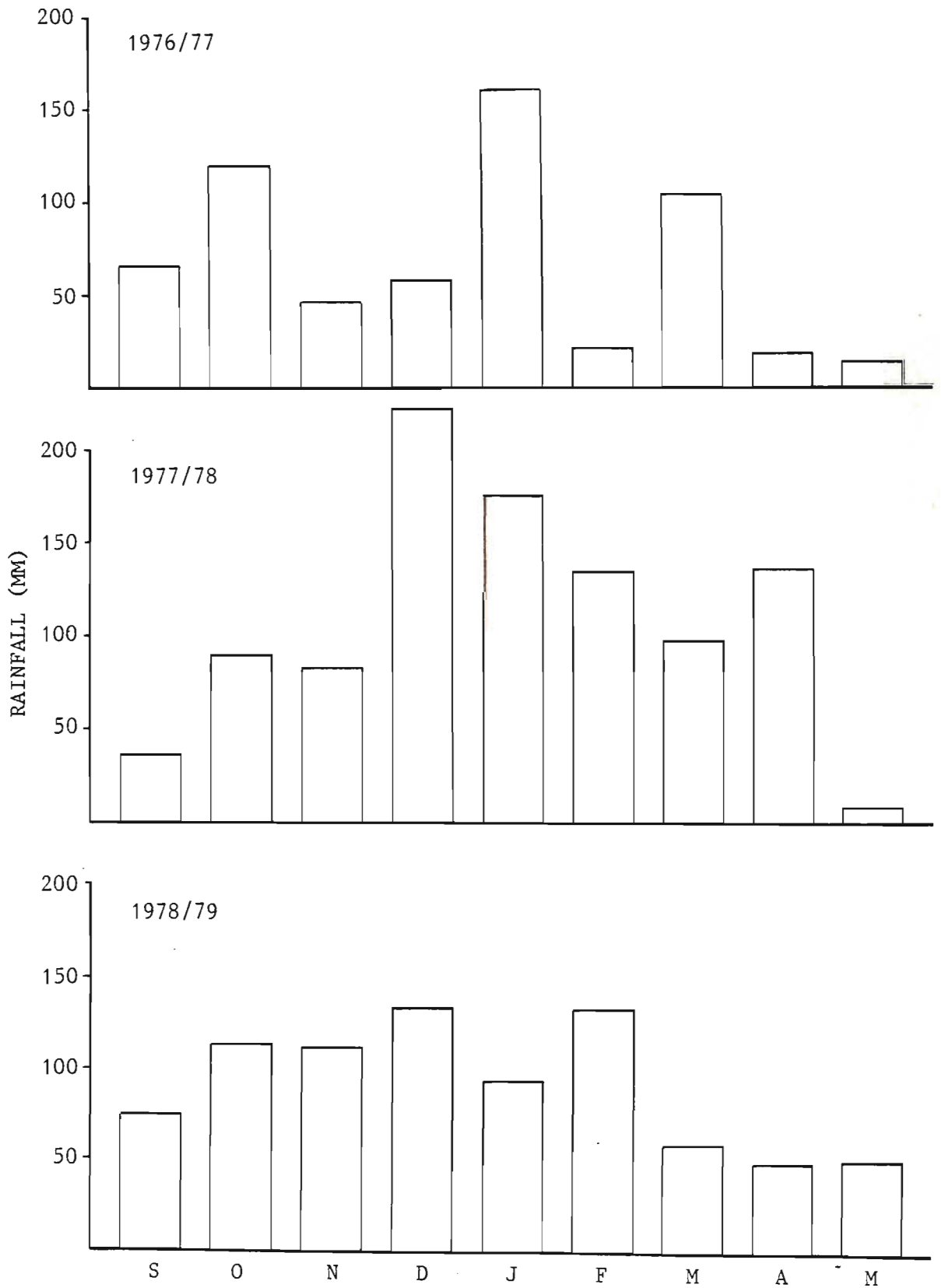


Fig. 6.14. The distribution of rainfall for the six seasons of grazing.

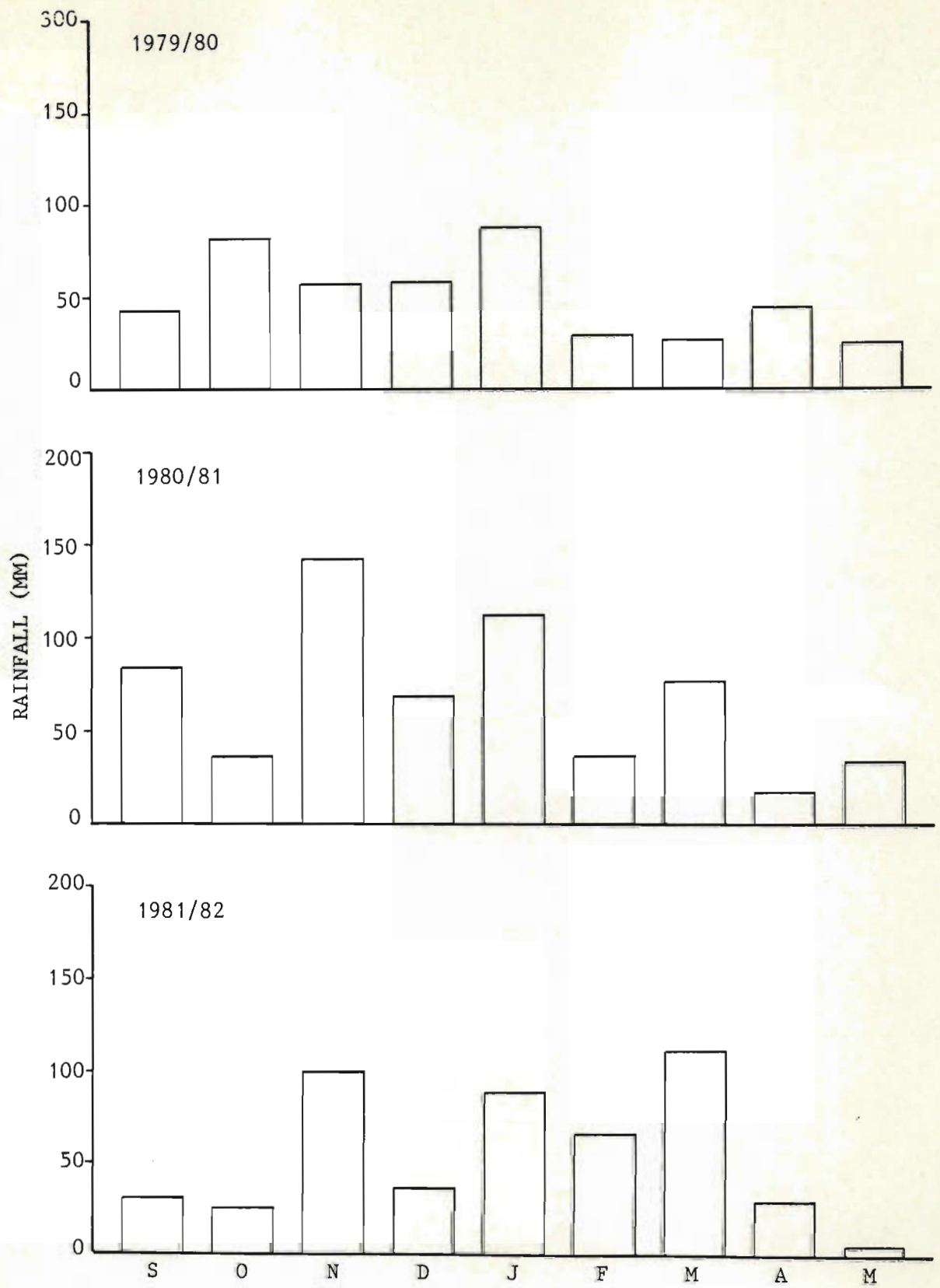


Fig. 6.14. Continued



material which was used for CP and CF analysis was collected by means of grab samples in the sub-paddock of rotational grazing systems which was due to be grazed next. It therefore represented the quality of available herbage in the rotational grazing treatments at the beginning of a grazing period.

The variation of CP with time differed between species (Fig. 6.15) but bore no relation to the variation in liveweight gain (Fig. 6.13c, d and e). For example, variation in CP was low over the season for Rhodesgrass but liveweight gain showed marked variation, and the CP of Coastcross, and kikuyu reached a low level at the end of February while liveweight gain per animal was lowest in early to mid-February. The three species also differed in the variation of CF (Fig. 6.16) and TDN with time (Fig. 6.17) but none of these patterns was related to that of liveweight gain per animal.

According to Matches (Pers. Comm.) another factor which may cause low liveweight gain of animals is high night temperatures which result in high levels of plant respiration and low levels of soluble carbohydrates in the herbage. However, examination of trends in liveweight gain in relation to the distribution of monthly means of daily minimum temperatures (Table 6.1) did not reveal any clear effect, although low liveweight gain of animals often occurred when daily minimum temperatures were high.

### 6.3 Discussion

No differences in liveweight gain of animals at equivalent stocking rates were evident between rotational and continuous grazing on either kikuyu or Coastcross. However, results for the average of all four seasons on Coastcross and for Rhodesgrass in

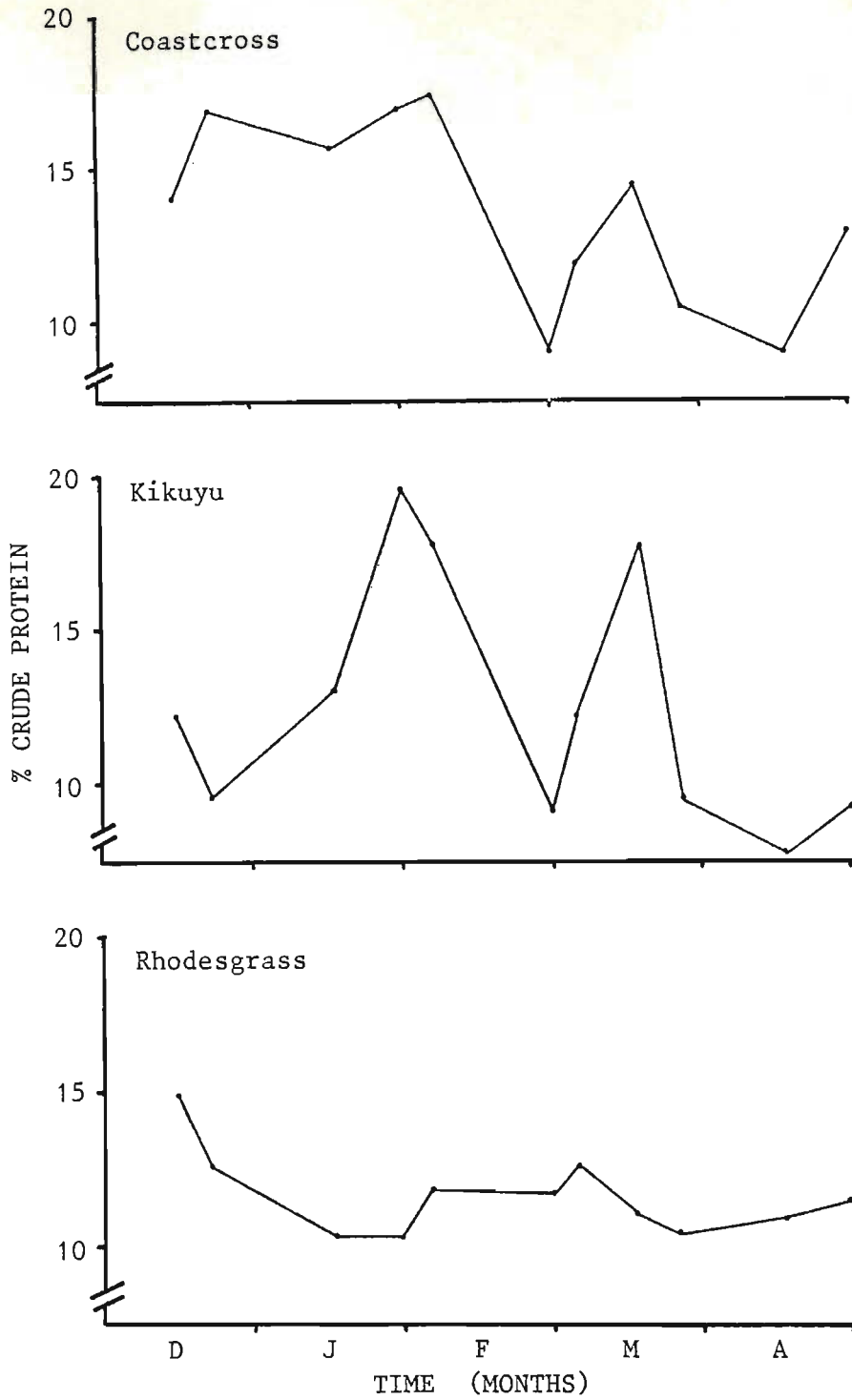


Fig. 6.15. Variation in crude protein of Coastcross, kikuyu and Rhodesgrass from December to April in the 1978/79 season.

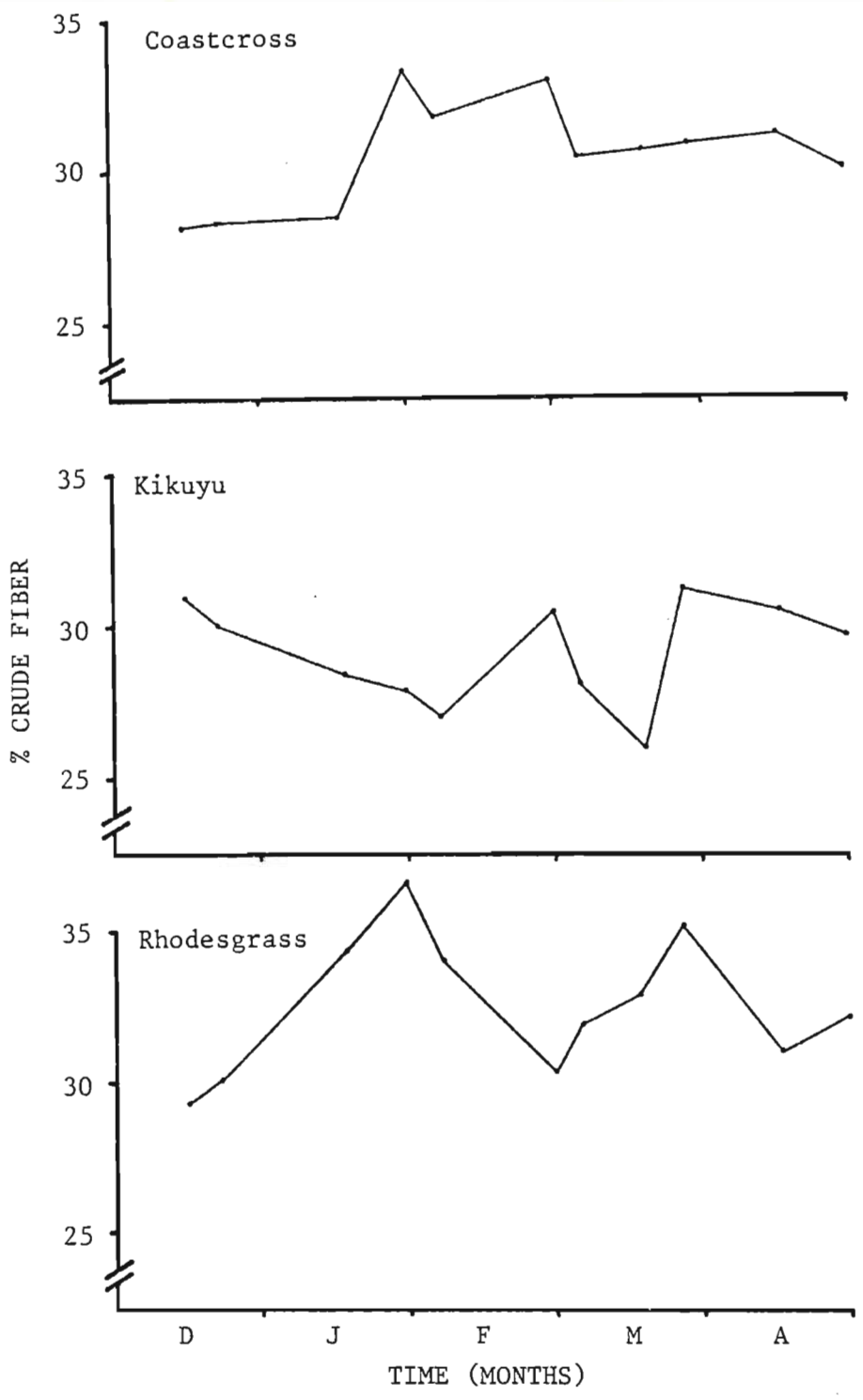


Fig. 6.16. Variation in crude fiber for Coastcross, kikuyu and Rhodesgrass from December to April in the 1978/79 season.

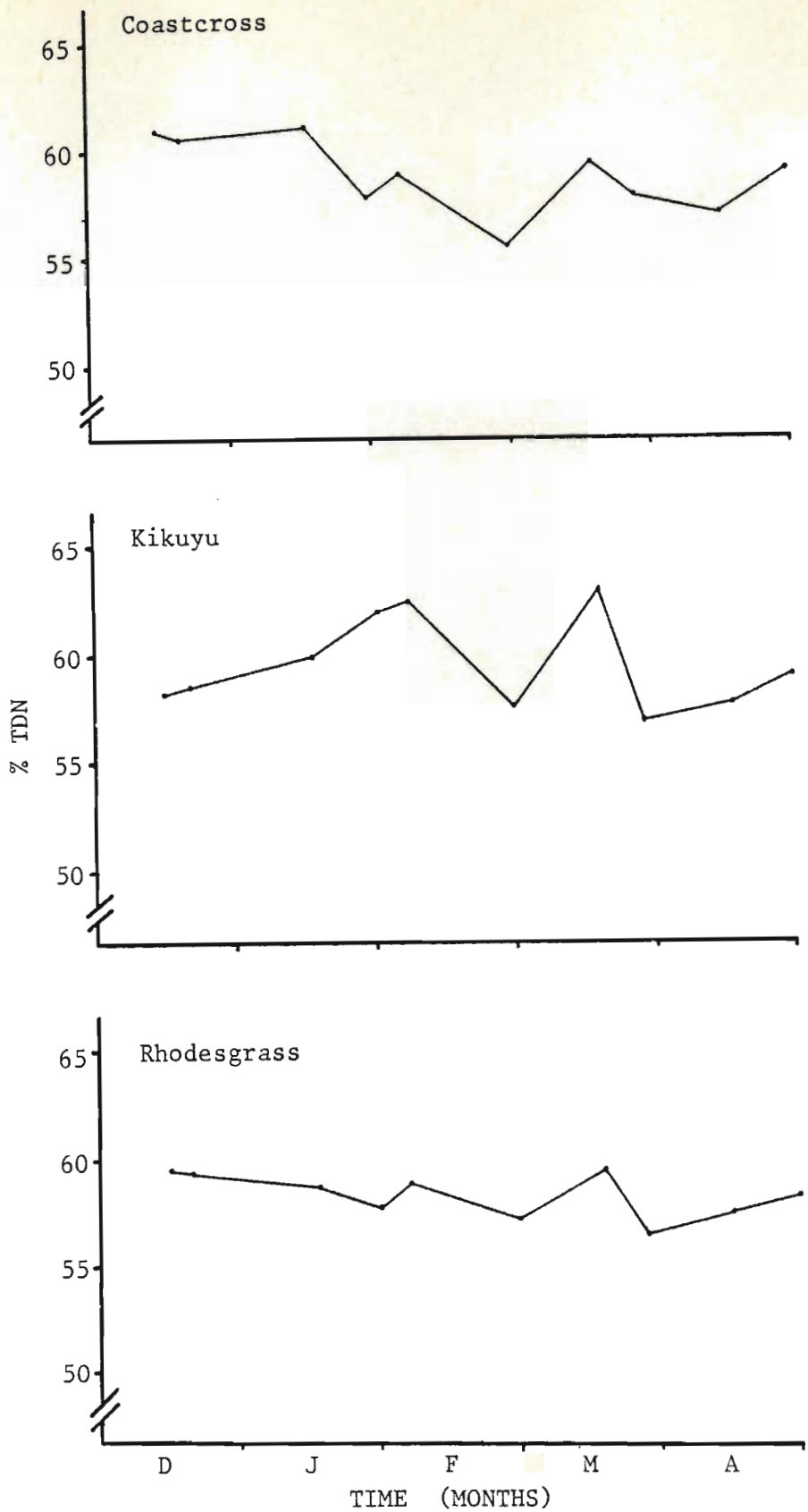


Fig. 6.17. Variation in TDN for Coastcross, kikuyu and Rhodesgrass from December to April in the 1978/79 season.



TABLE 6.1. Monthly average of daily maximum and minimum temperatures from July to June for the six test years.

| Month | 1976/77 |      | 1977/78 |      | 1978/79 |      | 1979/80 |      | 1980/81 |      | 1981/82 |      | Mean  |       |
|-------|---------|------|---------|------|---------|------|---------|------|---------|------|---------|------|-------|-------|
|       | max     | min  | max     | min  | max     | min  | max     | min  | max     | min  | max     | min  | max   | min   |
| July  | 21,3    | 9,4  | 20,8    | 8,3  | 20,8    | 9,0  | 18,6    | 7,9  | 21,2    | 8,4  | 20,2    | 8,5  | 20,48 | 8,58  |
| Aug   | 20,6    | 9,1  | 20,4    | 8,2  | 20,1    | 10,5 | 20,6    | 10,6 | 22,3    | 10,6 | 19,9    | 8,4  | 20,65 | 9,57  |
| Sept  | 25,0    | 12,6 | 24,4    | 12,7 | 21,5    | 10,3 | 20,7    | 10,8 | 20,2    | 10,6 | 20,2    | 9,2  | 22,00 | 11,03 |
| Oct   | 20,6    | 13,1 | 23,3    | 13,3 | 21,5    | 11,0 | 23,0    | 12,7 | 22,8    | 12,3 | 23,0    | 10,9 | 22,37 | 12,22 |
| Nov   | 21,1    | 14,3 | 22,5    | 14,2 | 23,2    | 14,3 | 23,2    | 13,6 | 23,9    | 14,3 | 25,5    | 15,0 | 23,23 | 14,28 |
| Dec   | 25,3    | 16,7 | 26,9    | 16,5 | 25,5    | 15,2 | 24,3    | 15,2 | 26,3    | 16,0 | 25,7    | 15,7 | 25,67 | 15,88 |
| Jan   | 26,0    | 16,1 | 24,2    | 16,0 | 24,9    | 15,6 | 24,4    | 14,8 | 26,9    | 17,1 | 25,4    | 16,8 | 25,30 | 16,07 |
| Feb   | 26,6    | 17,5 | 24,1    | 16,5 | 27,6    | 17,1 | 28,2    | 16,5 | 24,8    | 16,4 | 28,1    | 17,1 | 26,57 | 16,85 |
| March | 23,3    | 14,8 | 25,4    | 17,0 | 25,4    | 15,5 | 26,9    | 15,9 | 26,0    | 15,6 | 25,5    | 15,6 | 25,42 | 15,73 |
| April | 24,9    | 14,4 | 21,3    | 12,9 | 24,9    | 14,9 | 25,3    | 13,4 | 26,4    | 14,1 | 22,2    | 12,9 | 24,17 | 13,77 |
| May   | 21,9    | 10,7 | 21,8    | 10,8 | 21,9    | 11,9 | 23,3    | 11,6 | 21,2    | 11,4 | 22,8    | 12,0 | 22,15 | 11,40 |
| June  | 21,4    | 9,3  | 19,1    | 7,6  | 20,3    | 9,4  | 21,2    | 8,8  | 19,7    | 8,3  | 20,7    | 9,2  | 20,40 | 8,77  |

the 1978/79 season suggest that rotational grazing results in higher liveweight gain of animals than continuous grazing, particularly as stocking rate increases.

The SR<sub>max</sub> of 14,3 animals/ha for rotational grazing was slightly higher than the 11,1 animals/ha obtained by Edwards and Mappledoram (1979) on star grass (Cynodon nlemfuensis) in the same Bioclimatic Group. This difference was probably caused by differences in pasture species, type of animal, level of nitrogen, the rate of movement of cattle in the rotation and the fact that on average, the star grass pastures were grazed for a longer period of time than was Coastcross. The daily liveweight gain per ha at SR<sub>max</sub> was 5,87 kg on star grass as opposed to 4,75 kg on Coastcross.

Other comparable research is that of Parkin and Boulwood (1981) and of Aucamp and Nel (1981). Both these studies were on star grass and resulted in estimates between 9 and 10 animals/ha for SR<sub>max</sub>. The estimated SR<sub>max</sub> of 14,3 animals/ha in this study therefore seems a little high, particularly since the average rainfall was lower than that reported in all three publications cited above.

However, in the 1977/78 season which received 990 mm, two of the actual stocking rates applied under rotational grazing were just below and above 14 animals/ha (Fig. 6.2). At high rainfall, therefore, stocking rates of this order are certainly realistic. Notwithstanding, the SR<sub>max</sub> of 7,8 animals/ha estimated for continuous grazing appears to be more realistic for the 778 mm average precipitation which occurred over the four seasons in which Coastcross was evaluated.

The differences between Coastcross and kikuyu were not significant, implying that either grass can be used under dryland

conditions in this Bioclimatic Group. In addition, the absence of significant differences between the two grass species enabled the data to be pooled for the development of the model in Chapter 7.

The general decrease in liveweight gain at equivalent stocking rates from early to late summer and at certain specific times in the season suggests that the precise reasons for this effect need to be investigated. Once this information is available it may be possible to devise systems of supplementing the pasture to ensure a more uniform level of animal performance through the season.

## 7. A MODEL RELATING LIVWEIGHT GAIN TO STOCKING RATE AND RAINFALL

Although annual rainfall is known to have a strong influence on DM production of pastures, it cannot be controlled and it is therefore seldom possible to study its effect on liveweight gain within a four to six year grazing trial. However, the unusually high range in annual rainfall which occurred within the study seasons described in this thesis offered a unique opportunity to examine the effect of rainfall on pasture production parameters. Furthermore, this large range in rainfall enhanced the extrapolation value of the results. In this chapter, therefore, an attempt is made to link pasture production parameters to stocking rate and rainfall by means of mathematical equations which can be incorporated into computer programmes for farm planning, or used directly by agricultural advisors.

The relationships between liveweight gain of animals and stocking rate were described with varying degrees of error for rotational and continuous grazing on Coastcross and kikuyu in individual seasons (Chapter 6). Since no difference was evident between the two grazing methods in each season, the regressions derived from the pooled data are used in the analysis which follows. However, if the regression for the pooled data was considered to be unrealistic e.g. for Coastcross in the 1979/80 season (Fig. 6.4), then the regression for either continuous or rotational grazing was used, depending on which was better. In other words, it was assumed that the effect of the grazing method on the parameters of the Jones and Sandland model was small in



relation to the effect of rainfall.

Details of the regressions which were used to represent Coastcross and kikuyu in each season appear in Table 7.1. The data from kikuyu in the 1981/82 season were not included because no correlation existed between daily liveweight gain per animal and stocking rate. The data for Rhodesgrass in the 1978/79 season were also omitted because of the significant difference which occurred between continuous and rotational grazing.

### 7.1 The relation between SRmax and rainfall

According to the Jones and Sandland model, daily liveweight gain of animals (G) is related to stocking rate (SR) by the equation  $G = b - c SR$  ..... (7.1)

Since daily liveweight gain per ha (GH) is obtained by multiplying stocking rate by daily liveweight gain per animal then  $GH = SR \times G = SR(b - cSR)$  and  $GH = bSR - cSR^2$  ..... (7.2)

The stocking rate at which daily liveweight gain per ha is at its maximum (SRmax) can then be calculated by equating the derivative of equation (7.2) to zero as follows:

$$\frac{dGH}{dSR} = b - 2cSR_{max} = 0$$

$$\text{then } b = 2cSR_{max}$$

$$\text{and } SR_{max} = \frac{1}{2} \frac{b}{c} \text{ ..... (7.3)}$$

As a starting point for the development of a model the relationship between estimated SRmax and rainfall (RF) was examined. This relationship was described by a linear function which showed an increase of SRmax with rainfall between 500 mm and 1000 mm (Fig. 7.1).

$$\text{Thus, } SR_{max} = n + m RF \text{ ..... (7.4)}$$

TABLE 7.1. Regressions between daily liveweight gain per animal and stocking rate for Coastcross and kikuyu in different seasons.

| Pasture species | Year  | Regression from:   | Regression equation for daily LWG/animal (G) on stocking rate (SR) | Correlation coefficient (r) |
|-----------------|-------|--------------------|--------------------------------------------------------------------|-----------------------------|
| Coastcross      | 76/77 | Continuous grazing | $G = 1,49 - 0,085 \text{ SR}$                                      | -0,76*                      |
| Coastcross      | 77/78 | Rotational grazing | $G = 0,79 - 0,026 \text{ SR}$                                      | -0,86                       |
| Coastcross      | 78/79 | Pooled data        | $G = 1,05 - 0,063 \text{ SR}$                                      | -0,84**                     |
| Coastcross      | 79/80 | Continuous grazing | $G = 2,72 - 0,290 \text{ SR}$                                      | -0,73*                      |
| Kikuyu          | 78/79 | Pooled data        | $G = 0,87 - 0,043 \text{ SR}$                                      | -0,60*                      |
| Kikuyu          | 79/80 | Continuous grazing | $G = 2,31 - 0,250 \text{ SR}$                                      | -0,84**                     |
| Kikuyu          | 80/81 | Pooled data        | $G = 2,43 - 0,226 \text{ SR}$                                      | -0,82**                     |

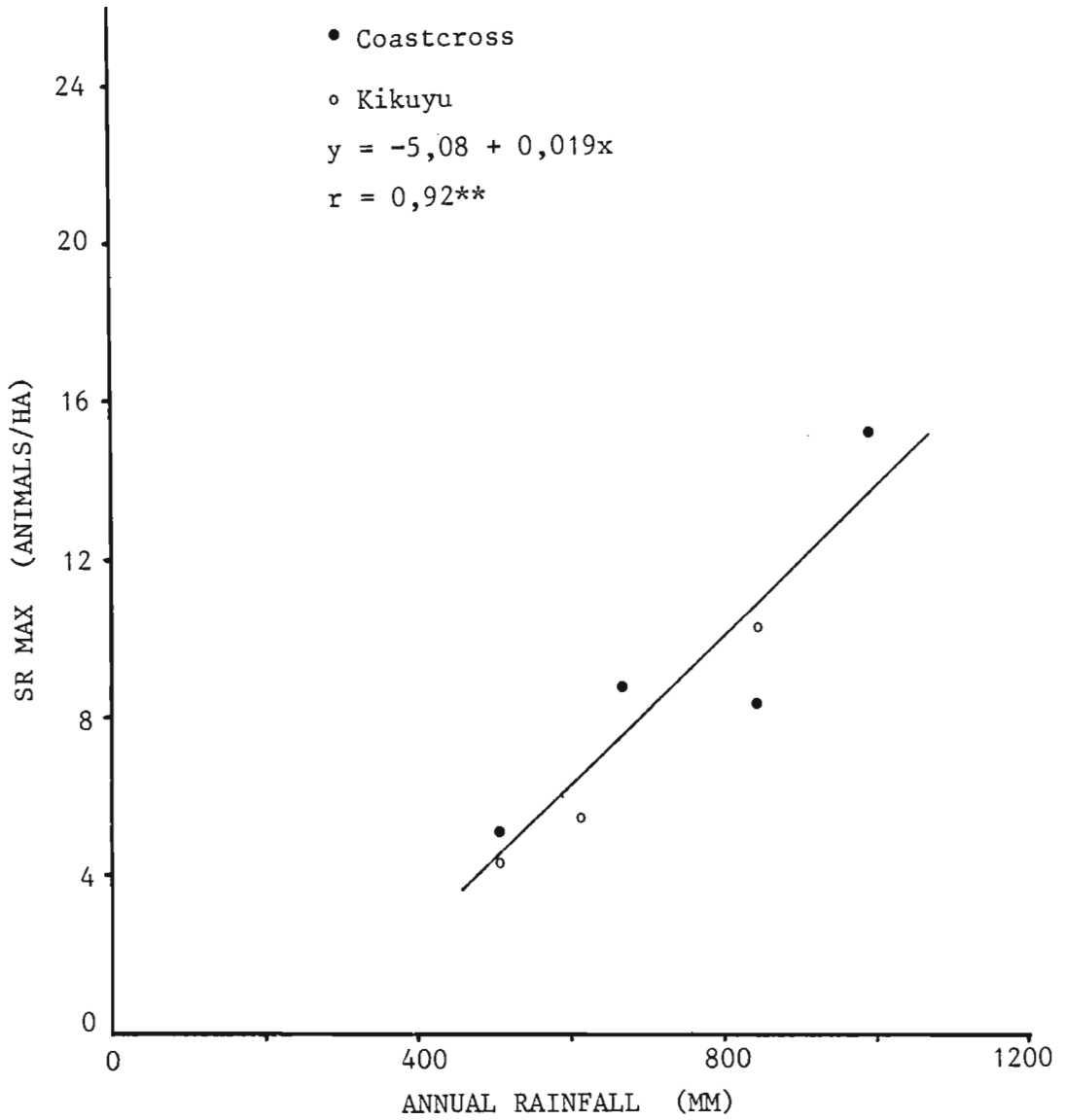


Fig. 7.1. The relationship between estimated SRmax and annual rainfall for Coastcross and kikuyu.

By fitting this function to rainfall and SR<sub>max</sub> derived from the regression equations in Table 7.1, the values of n and m were estimated to give the following equation:

$$SR_{max} = -5,08 + 0,019RF \dots\dots\dots (A)$$

From equation A, estimated SR<sub>max</sub> is 4,42 and 13.92 animals/ha for an annual rainfall of 500 mm and 1000 mm respectively. However, Edwards (1981) pointed out that there is a relatively wide range in stocking rates within which daily liveweight gain per ha is 90% or more of that at SR<sub>max</sub>. For convenience this range in stocking rates will be designated as RSR90<sub>max</sub> and the upper and lower limits of this range will be annotated as UL and LL respectively. The magnitude of the range is designated as MRSR90<sub>max</sub> and is calculated by subtracting LL from UL. These parameters are illustrated graphically in Fig. 7.2. However, in order to examine the effect of rainfall on RSR90<sub>max</sub> it is necessary to establish the effect of rainfall on the Jones and Sandland model. This, in turn, can be done only by establishing the influence of annual rainfall on the relationship between daily liveweight gain of animals and stocking rate.

## 7.2 The relation between daily liveweight gain of animals at SR<sub>max</sub> and rainfall

Once SR<sub>max</sub> was estimated for each pasture in each season, the daily liveweight gain of animals at SR<sub>max</sub> (G<sub>max</sub>) could also be estimated from equations 7.1 and 7.3 as follows:

$$\begin{aligned} G_{max} &= b - c SR_{max} \\ &= b - c \left( \frac{1}{2} \frac{b}{c} \right) \\ &= b - \frac{1}{2} b \end{aligned}$$



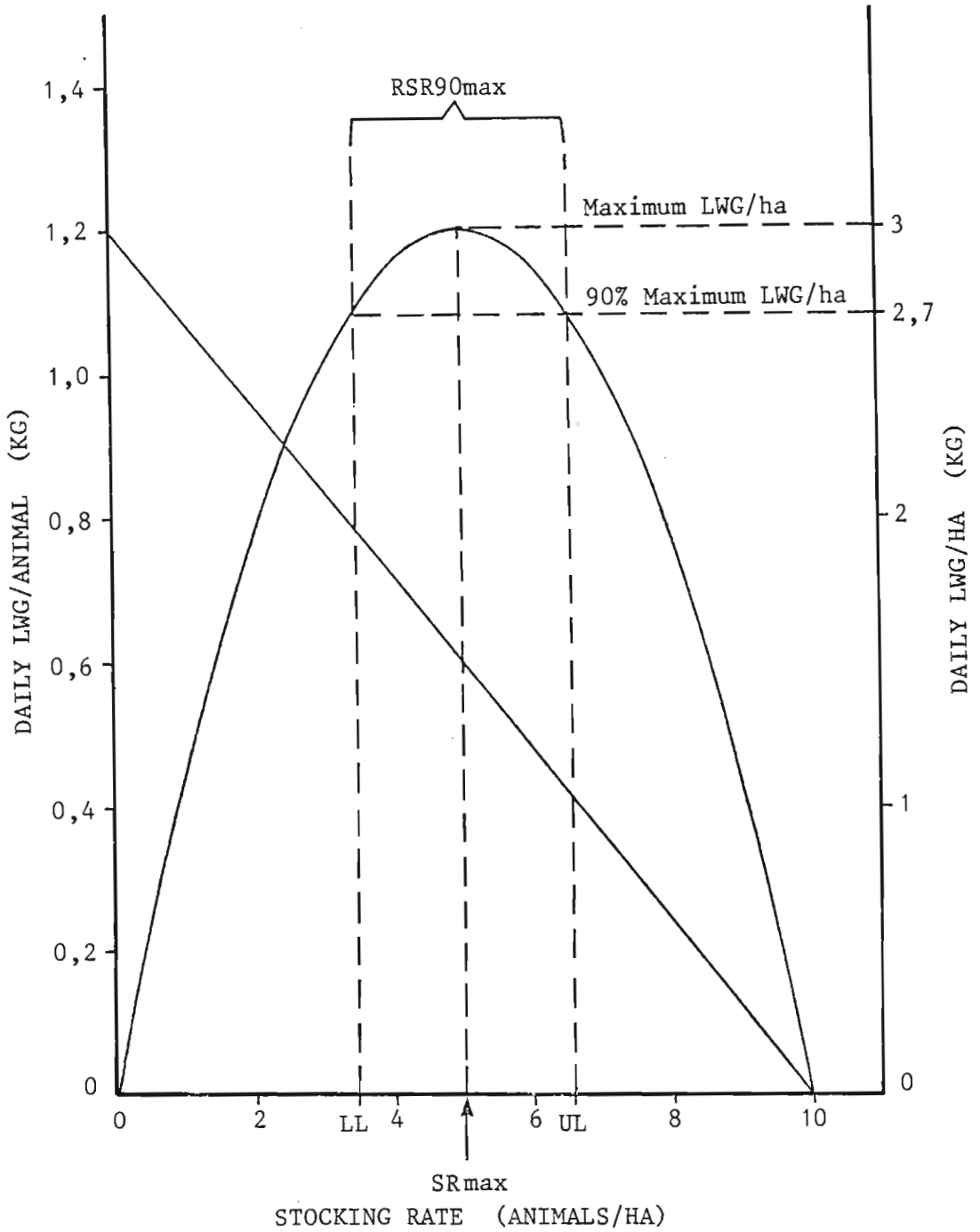


Fig. 7.2. An example of the Jones and Sandland model showing RSR90max with its lower limit (LL) and its upper limit (UL).

and thus  $G_{max} = \frac{1}{2}b$  ..... (7.5)

The relationship between the daily liveweight gain at  $SR_{max}$  and annual rainfall was also described by a linear function (Fig. 7.3).

Hence,  $G_{max} = p - q RF$  ..... (7.6)

By fitting this function to  $G_{max}$  derived from the regression equations in Table 7.1 and annual rainfall, the values of  $p$  and  $q$  were estimated to give the following equation:

$G_{max} = 2,07 - 0,0018 RF$  ..... (B)

From Fig. 7.3 it is clear that high rainfall has a depressing effect on daily liveweight gain of animals at  $SR_{max}$ . Although this result may at first seem strange, it is in agreement with the findings of Edwards and Mappledoram (1979).

There are a number of possible explanations for such a result. Edwards and Mappledoram suggested that the short coated bos-indicus type cattle gained poorly under high rainfall as a direct effect of above average occurrence of cool, wet weather. Such weather could also result in low levels of soluble carbohydrates in the forage from low light intensities causing decreased photosynthesis, and this could depress daily liveweight gain of animals. Other possible reasons are increased activity of internal parasites, and higher pasture growth rates which result in more mature, low quality forage being available to the animal under high rainfall.

### 7.3 The effect of rainfall on daily liveweight gain per ha

Since the correlation coefficients for the regressions of  $G_{max}$  and  $SR_{max}$  on annual rainfall were both significant ( $P < 0,01$ ), use of these two equations to investigate further effects

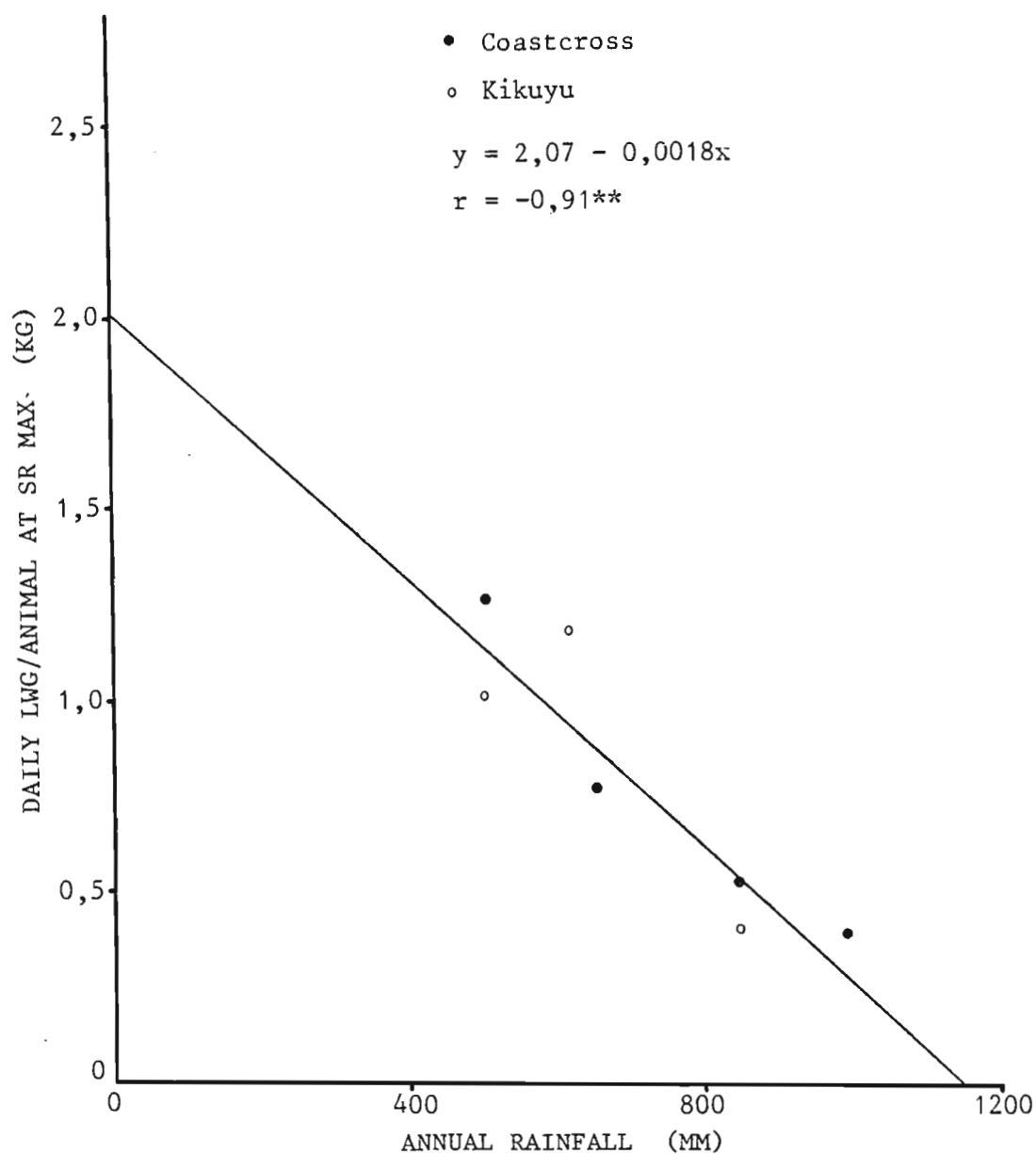


Fig. 7.3. The relationship between daily liveweight gain per animal at SRmax and annual rainfall.

of rainfall seemed justified.

For a given rainfall, then,

$$G = b - cSR \quad (\text{equation 7.1})$$

and

$$GH = bSR - cSR^2 \quad (\text{equation 7.2})$$

However, from equations 7.5 and 7.6

$$G_{\max} = \frac{1}{2}b = p - qRF$$

$$\text{and thus } b = 2(p - qRF) \quad \dots\dots\dots (7.7)$$

From equations 7.3 and 7.4

$$SR_{\max} = \frac{1}{2} \frac{b}{c} = n + mRF$$

$$\text{and thus } c = b / \{2(n + mRF)\}$$

From equation 7.7

$$\begin{aligned} c &= \{2(p - qRF)\} / \{2(n + mRF)\} \\ &= (p - qRF) / (n + mRF) \quad \dots\dots\dots (7.8) \end{aligned}$$

Then, substituting for b and c from equation 7.7 and 7.8 into equations 7.1 and 7.2:

$$G = 2(p - qRF) - \{(p - qRF)/(n + mRF)\}SR \quad \dots\dots\dots (7.9)$$

$$\text{and } GH = 2(p - qRF)SR - \{(p - qRF)/(n + mRF)\}SR^2 \quad \dots\dots (7.10)$$

Since n, m, p and q are known from equations A and B, the relationships between daily liveweight gain of animals and stocking rate, and between daily liveweight gain per ha and stocking rate can be obtained for a given rainfall by substitution. For example, the following equations are obtained for an annual rainfall of 700 mm.

$$\begin{aligned} G &= 2(2,07 - 0,0018 \times 700) - (2,07 - 0,0018 \times 700) \\ &\quad \div (-5,08 + 0,019 \times 700) \times SR \\ &= 1,62 - 0,099SR \end{aligned}$$

$$GH = 1,62SR - 0,099SR^2$$



Similar functions were derived for annual rainfalls of 500 mm, 600 mm, 800 mm, 900 mm and 1000 mm and the resultant Jones and Sandland models are presented in Fig. 7.4. It is clear from these graphs that daily liveweight gain per ha at SRmax increases initially as annual rainfall increases, but reaches a maximum and then decreases. This relationship can be derived as follows:

$$\text{since } GH = G \times SR$$

$$\text{then } GH_{\max} = G_{\max} \times SR_{\max}$$

Substituting for  $G_{\max}$  and  $SR_{\max}$  from equations 7.6 and 7.4 respectively

$$GH_{\max} = (p - qRF)(n + mRF) \dots\dots\dots (7.11)$$

Substituting further from equations A and B

$$\begin{aligned} GH_{\max} &= (2,07 - 0,0018RF)(-5,08 + 0,019RF) \\ &= -10,52 + 0,0393RF + 0,0091RF - 3,42 \times 10^{-5} RF^2 \\ &= 0,0483RF - 10,52 - 3,42 \times 10^{-5} RF^2 \end{aligned}$$

This relationship is presented in Fig 7.5. The position of the peak can be derived by equating the derivative of the function to zero as follows:

$$\frac{dGH_{\max}}{dRF} = 0,0483 - 2 \times 3,42 \times 10^{-5} RF = 0$$

$$\text{then } RF = 0,0483 / 6,84 \times 10^{-5}$$

$$= 706 \text{ mm}$$

Thus, daily liveweight gain per ha at SRmax reaches a maximum at an annual rainfall of 706 mm. By substituting in equation 7.11 the estimated daily liveweight gain per ha at SRmax is 6,66 kg.

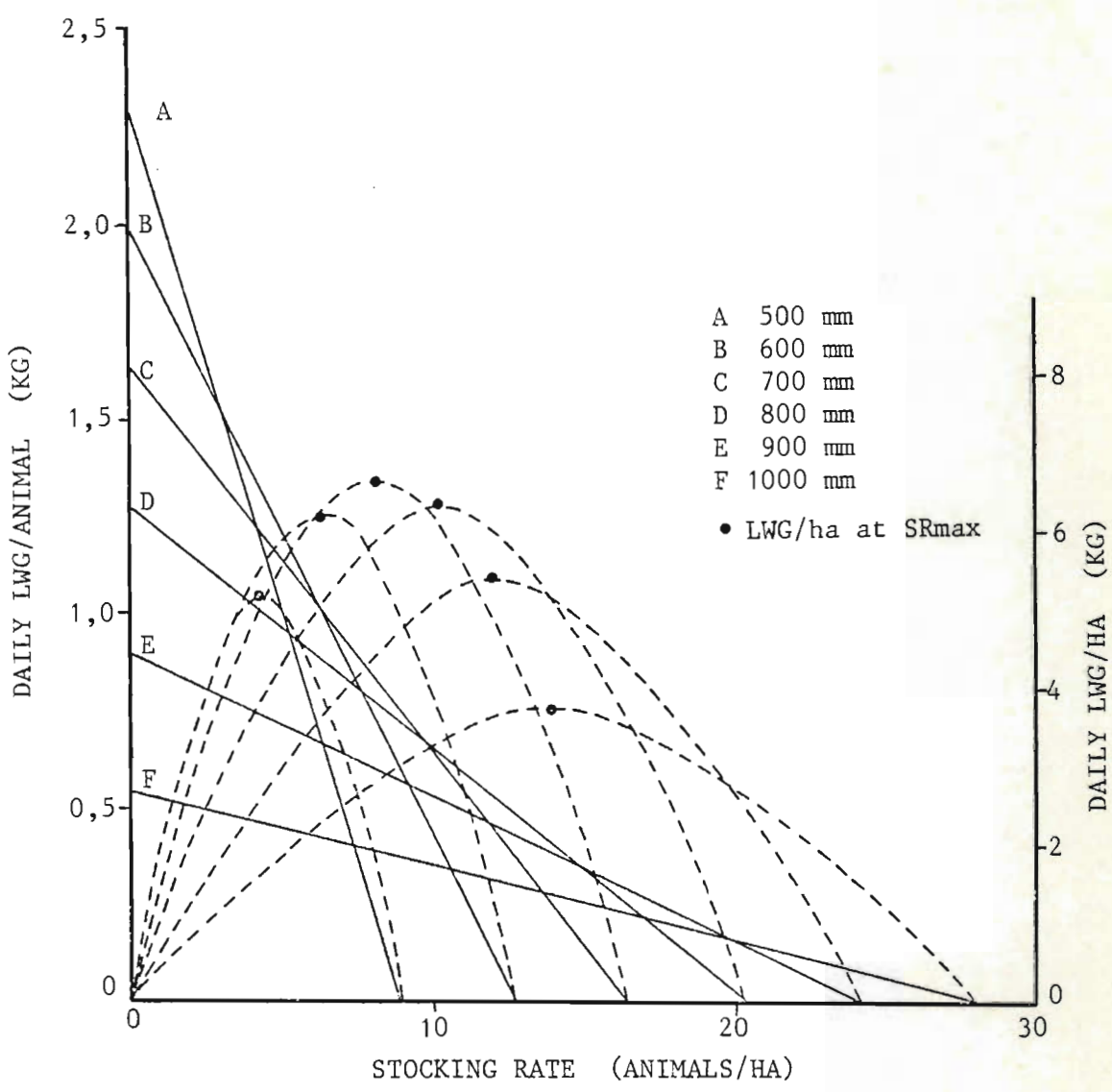


Fig. 7.4. Derived Jones and Sandland models for different levels of annual rainfall.

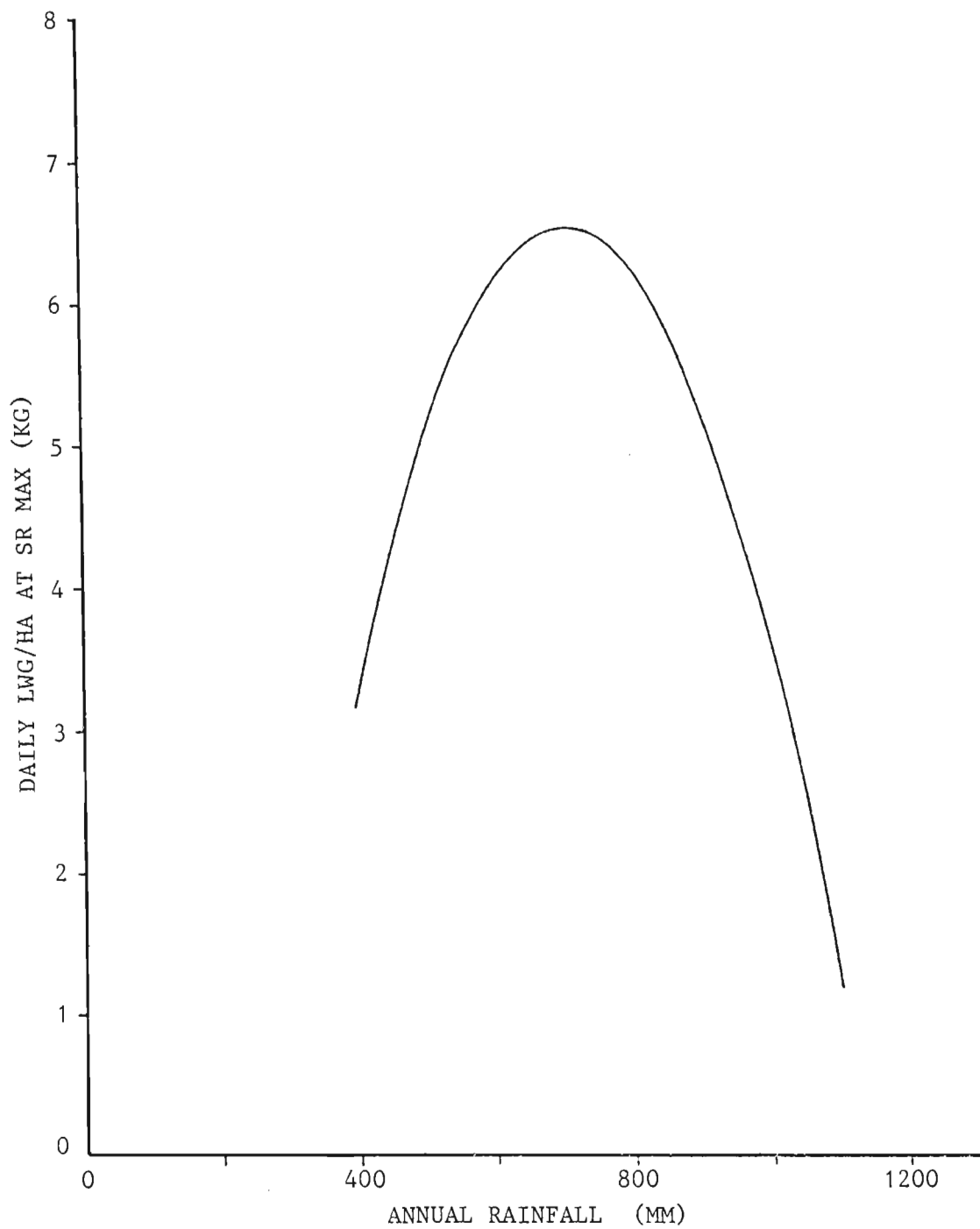


Fig. 7.5. The derived relationship between daily liveweight gain per ha at SRmax and annual rainfall.

7.4 The effect of rainfall on RSR90max

For a given rainfall, the relationship between stocking rate and daily liveweight gain per ha is described by equation 7.10, and GHmax is linked to annual rainfall by equation 7.11. From these two equations it is therefore possible to calculate the stocking rates at which daily liveweight gain per ha is 90% of that at SRmax, as shown below.

From equation 7.11

$$0,9 \times GH_{max} = 0,9 \{(p - q_{RF}) (n + m_{RF})\}$$

and substituting in equation 7.10

$$0,9 \{(p - q_{RF}) (n + m_{RF})\} = 2(p - q_{RF}) SR_{90max} - \{(p - q_{RF}) / (n + m_{RF})\} SR_{90max}^2$$
  
$$\text{and } \{(p - q_{RF}) / (n + m_{RF})\} SR_{90max}^2 - 2(p - q_{RF}) SR_{90max} + 0,9 \{(p - q_{RF}) (n + m_{RF})\} = 0$$

Since p, q, n, m and RF are known, this equation takes the form

$$ax^2 + bx + c = 0$$

which can be solved for x by using the following quadratic formula

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

where a = (p - q<sub>RF</sub>) / (n + m<sub>RF</sub>)

$$b = -2(p - q_{RF})$$

and c = 0,9 (p - q<sub>RF</sub>) (n + m<sub>RF</sub>)

This will then give the upper and lower limits (UL and LL) of the range in stocking rates which results in daily liveweight gain per ha being 90% or more of that which occurs at SRmax. The magnitude of this range (MRSR90max) is therefore UL - LL and since SRmax lies half way between these limits, the range can be expressed as SRmax ± ½(UL - LL) for a given rainfall.

By using the above equations and equations A and B, these functions are presented graphically in Fig. 7.6. It is thus clear



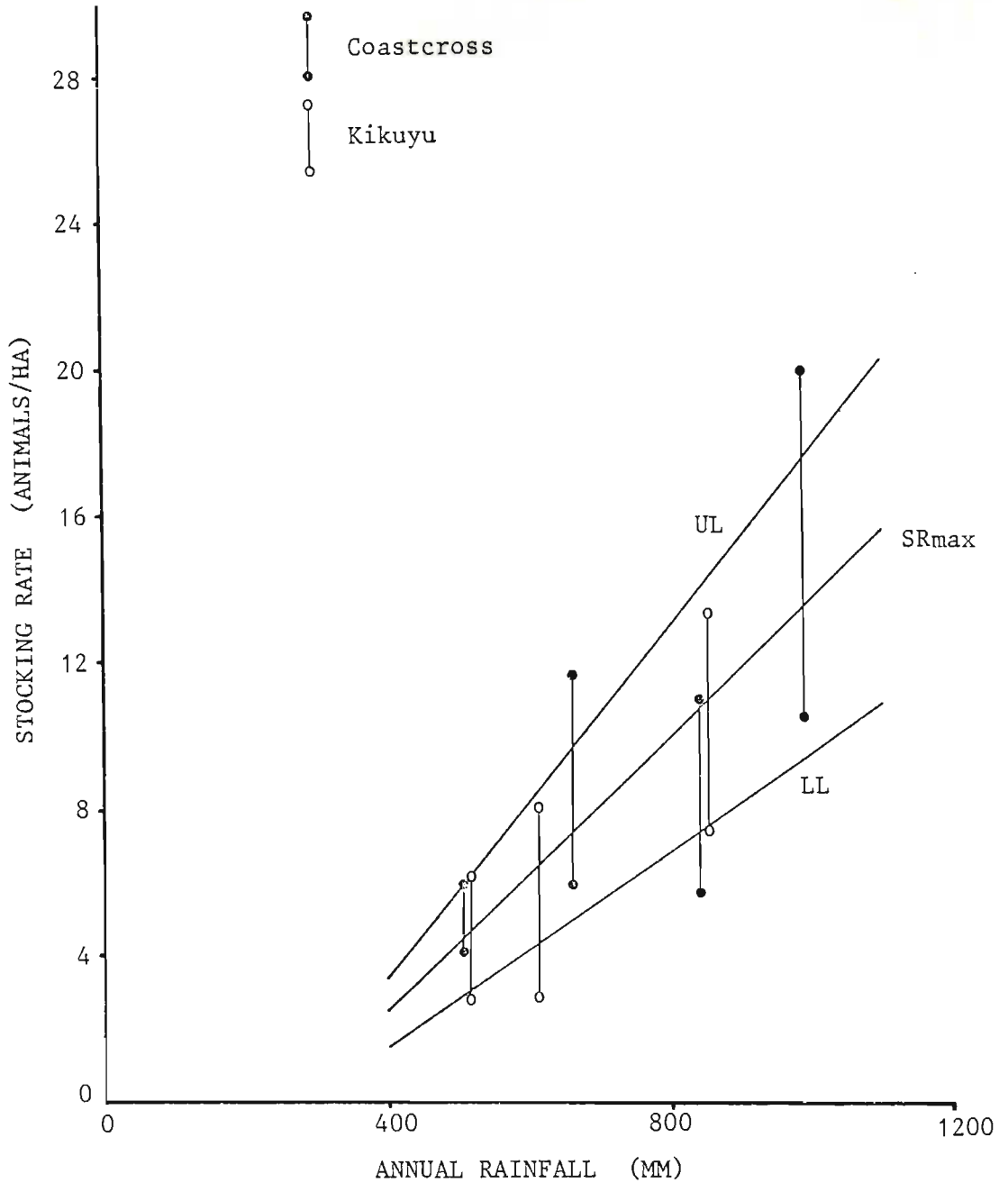


Fig. 7.6. RSR90max estimated from equations in Table 7.1 at different levels of annual rainfall, and the derived relationships for the upper limit of RSR90max (UL), SRmax and the lower limit of RSR90max (LL) against annual rainfall.

that as rainfall increases,  $SR_{max} \pm \frac{1}{2}(UL - LL)$  increases, being  $13,92 \pm 4,31$  animals/ha at 1000 mm and  $4,42 \pm 1,40$  animals/ha at 500 mm. These estimates, in turn, give values for  $MRSR90_{max}$  of 8,62 and 2,8 animals/ha for 1000 mm and 500 mm of annual rainfall respectively.

The relationships of  $SR_{max}$ , UL and LL to rainfall are presented in Fig. 7.6 together with the  $RSR90_{max}$  for each season derived from the original regression equation in Table 7.1.

#### 7.5 The effect of rainfall on liveweight gain per season

At this point the effects of annual rainfall on pasture production parameters have been considered in terms of daily liveweight gain per animal and per ha. However, seasonal liveweight gain per ha (GHS) is the product of daily liveweight gain per ha and the number of days in the grazing season (D).

Annual rainfall was linearly related to the length of the grazing period in any one season, within the limits of rainfall which occurred in the seasons studied (Fig. 7.7).

$$\text{Thus } D = g + hRF \dots\dots\dots (7.12)$$

and from Fig. 7.7

$$D = 31,3 + 0,16RF \dots\dots\dots (C)$$

For a given rainfall, therefore, the following function relating seasonal liveweight gain per ha to stocking rate can be derived from equations 7.10 and 7.12:

$$GHS = DXGH = (g+hRF) \{ 2(p-qRF)SR - (P-qRF) / (n+mRF)SR^2 \}$$

A similar series of curves to those in Fig. 7.4 can thus be drawn to relate seasonal liveweight gain per ha to stocking rate at any given rainfall (Fig. 7.8). The equation describing the seasonal liveweight gain per ha at  $SR_{max}$  ( $GHS_{max}$ ) with rainfall is

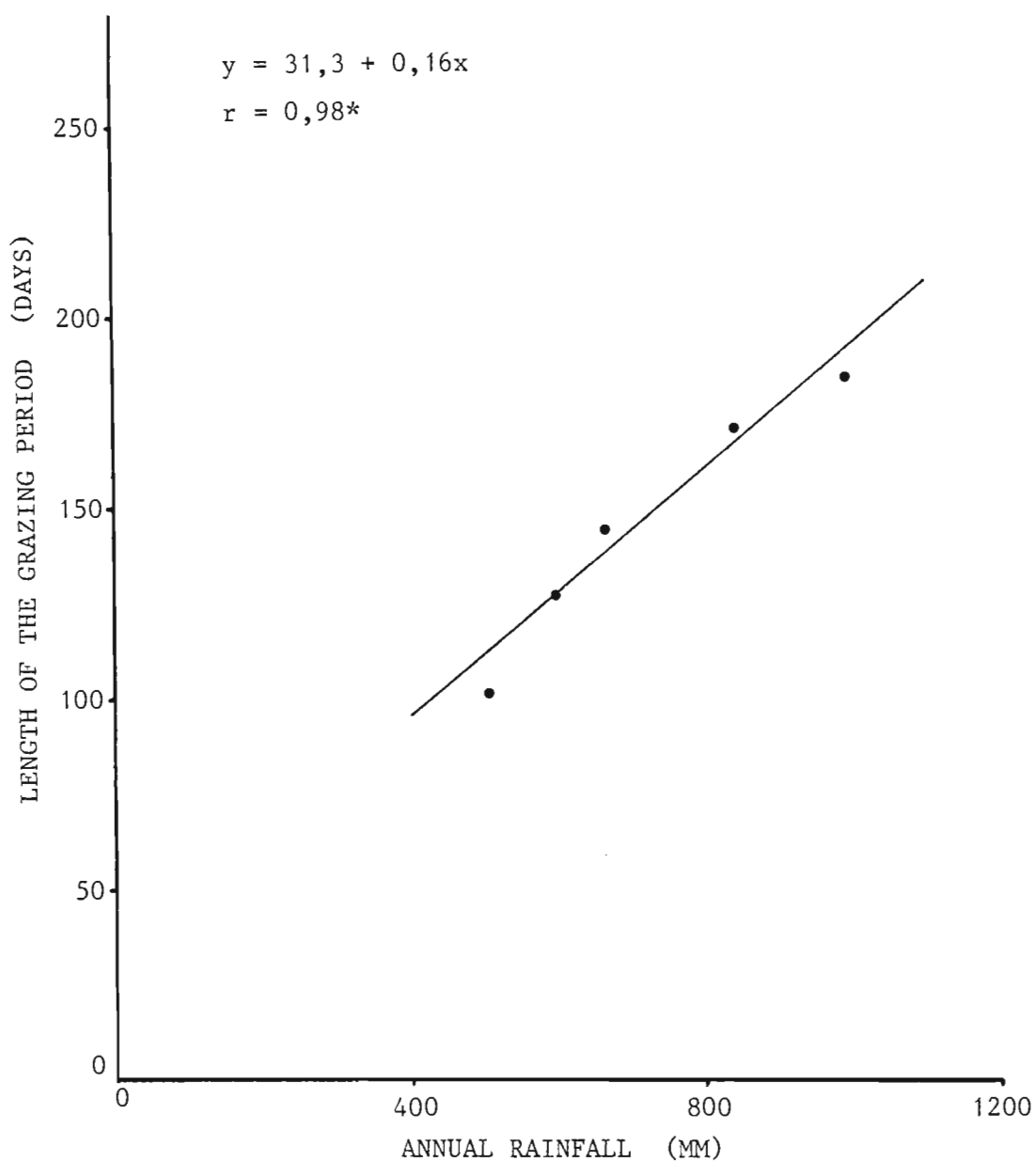


Fig. 7.7. The relationship between annual rainfall and length of the grazing period.

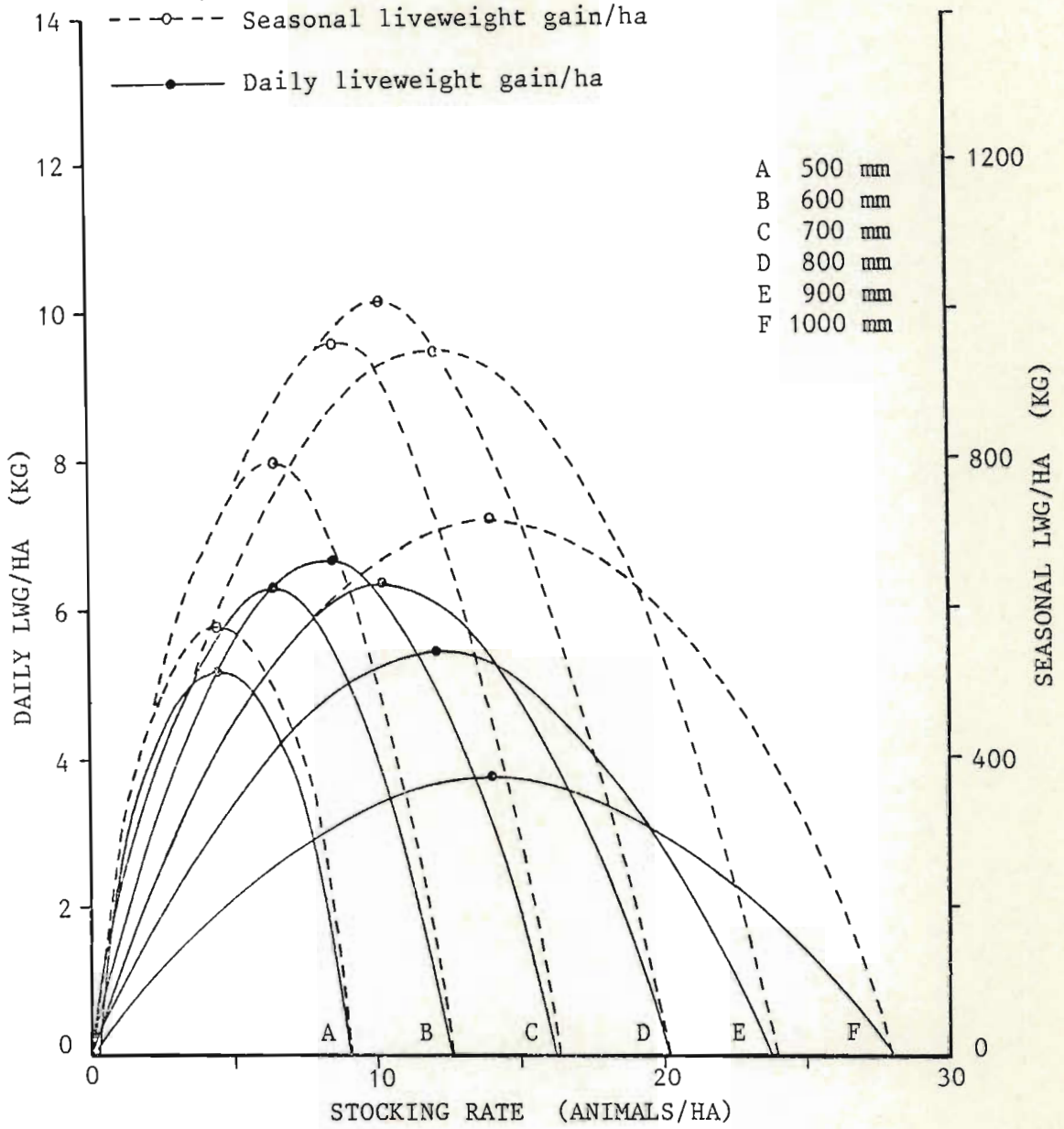


Fig. 7.8. Relationships for daily and seasonal liveweight gain per ha against stocking rate at different rainfalls.



obtained from equations 7.11 and 7.12 as follows:

$$\begin{aligned} \text{GHSmax} &= \text{GHmax} \times \text{D} \\ &= (p-q\text{RF}) (n+m\text{RF}) (g+h\text{RF}) \dots\dots\dots (7.13) \end{aligned}$$

Thus, from equations A, B and C

$$\begin{aligned} \text{GHSmax} &= (-5,08+0,019\text{RF}) (2,07-0,0018\text{RF}) (31,3+0,16\text{RF}) \\ &= 6,69 \times 10^{-3} \text{RF}^2 - 0,165\text{RF} - 329 - 5,47 \times 10^{-6} \text{RF}^3 \end{aligned}$$

This function is illustrated in Fig. 7.9 and the rainfall at which it reaches a maximum is calculated by equating the derivative to zero as follows:

$$\begin{aligned} \frac{d\text{GHSmax}}{d\text{RF}} &= 2 \times 6,69 \times 10^{-3} \text{RF} - 0,165 - 3 \times 5,47 \times 10^{-6} \text{RF}^2 \\ &= 0,0134\text{RF} - 0,165 - 1,64 \times 10^{-5} \text{RF}^2 = 0 \end{aligned}$$

$$\text{and } 1,64 \times 10^{-5} \text{RF}^2 - 0,0134\text{RF} + 0,165 = 0$$

Then, by means of the quadratic formula used in section 7.4, the estimated rainfall at which seasonal liveweight gain per ha at SRmax reaches a maximum is 817 mm and the corresponding liveweight gain per ha per season estimated from equation 7.13 is 1014 kg. Thus, maximum seasonal liveweight gain per ha at SRmax occurred at an annual rainfall of roughly 110 mm higher than that at which daily liveweight gain per ha at SRmax was a maximum. This means that between 706 mm and 817 mm of annual rainfall, the effect of the increased length of the grazing season more than compensated for the declining daily liveweight gain per ha at SRmax associated with increasing annual rainfall. However, as annual rainfall increased beyond 817 mm the decrease in daily liveweight gain per ha at SRmax had the overriding effect on seasonal liveweight gain.

## 7.6 Discussion

The model developed in this chapter will be used for the development of an economic model in Chapter 8. This discussion

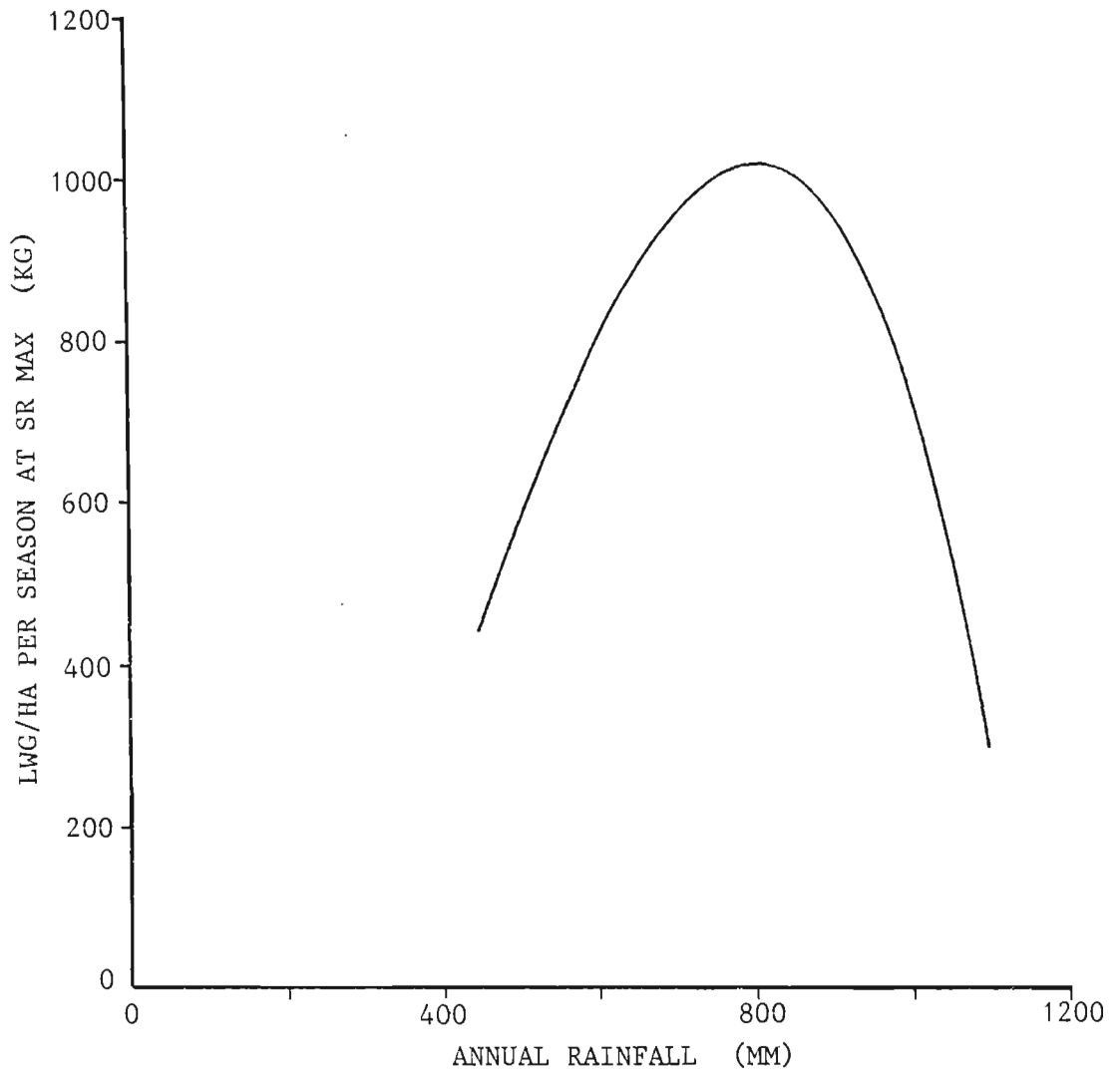


Fig. 7.9. The relationship between liveweight gain per ha per season at SRmax and annual rainfall.

will therefore be kept brief, but will be expanded in Chapter 9 which includes a general discussion and conclusions.

From a scientific viewpoint one of the weakest aspects of the model described in this chapter is the use of annual rainfall instead of effective rainfall, or even the rain which fell during the grazing season. However, the predictive value of a model is dependent largely on the availability of the input data. Annual rainfall is therefore extremely suitable as an input variable because a vast quantity of rainfall records exist for relatively long periods. In addition, many farmers have their own records because rainfall is so easily measured. Since the geographical variation in rainfall in Natal is high, this is a distinct advantage. It was, therefore, very fortunate that a number of the pasture production parameters recorded in the programme were so well related to annual rainfall, thus making it unnecessary to use a more sophisticated measure of precipitation in the model.

The decrease in liveweight gain per animal as annual rainfall increases has two important implications which need further investigation. Firstly, it suggests that pasture DM production equations which are commonly used in computer programmes to determine forage flow have limited value in predicting liveweight gain. In addition, caution must be exercised in developing models (such as that of Mentis, 1982) to predict liveweight gain of animals from trials in which liveweight gain is not measured. Secondly, alternative methods to achieve higher daily liveweight gains per animal under high rainfall conditions need to be investigated so that the potential benefit of the higher stocking rates and longer grazing seasons which occur under high rainfall can be realised. Limited supplementary feeding with energy and/or protein, and the use of animal growth stimulants such as Ralgro

ear implants (Harwin and Theron 1982) deserve attention. In addition, a European breed such as the Hereford is likely to be better suited to high rainfall conditions than bos-indicus types, and stricter parasite control measures under high rainfall could well be beneficial.

In the light of these comments it is clear that the model presented here describes seasonal liveweight gain per ha for a specific set of circumstances. For similar circumstances, the use of this model should provide agricultural advisors in Natal with better estimates of seasonal liveweight gain per ha than other methods that are currently available. However, the model should not be used to make predictions for circumstances outside the limits of the data from which it was derived. In particular, the model is not applicable to different levels of fertilizer, different types or classes of animals, environments with lower summer temperatures, and annual rainfall outside the limits which occurred during this study.



## 8. AN ECONOMIC MODEL

There are almost an infinite number of ways in which dryland pastures can be incorporated into livestock production systems. It could therefore be argued that economic evaluation of a pasture out of context of the system in which it is being used is meaningless. However, the ultimate objective of researching dryland pastures was to encourage the conservation of veld by persuading farmers to establish more dryland pastures. This made some form of economic analysis essential. The economic model constructed in this chapter is developed from that of Booysen (1975).

### 8.1 Economic theory

Economic theory of factor/product relationships for determining the factor level corresponding with maximum profit is well documented (Bishop & Toussaint, 1958; Doll & Orazem, 1978). If it is assumed that the factor is stocking rate (SR) and the product is daily liveweight gain per ha (GH) then according to the Jones and Sandland model

$$GH = bSR - cSR^2 \quad \dots\dots\dots (8.1)$$

The marginal physical product (MPP) is the rate of change of GH with respect to SR and is expressed as

$$\frac{dGH}{dSR} = b - 2cSR \quad \dots\dots\dots (8.2)$$

The value of the marginal product (VMP) then, is obtained by multiplying the MPP by the price of the product per kg (k):

$$VMP = \frac{dGH}{dSR} \times k = bk - 2ckSR \quad \dots\dots\dots (8.3)$$

The variable costs ( $m$ ) associated with keeping one animal can be defined as the interest on the purchase price of one animal plus other costs related to the number of animals kept, such as veterinary expenses, phosphate licks etc. The total variable costs (VC) must therefore be directly proportional to stocking rate and can be expressed on a daily basis as

$$VC = mSR$$

The cost of holding one extra animal is also called the marginal cost (MC) and can be described by the rate of change of VC with respect to SR as follows:

$$\frac{dVC}{dSR} = m$$

and therefore  $MC = m$

Profits will be maximized (or losses minimized) when the VMP is equal to the MC, that is, when

$$bk - 2ckSR = m \quad \dots\dots\dots (8.4)$$

The stocking rate at which profit is a maximum will be regarded as the economic optimum stocking rate ( $SReo$ ) and is calculated as follows from equation 8.4:

$$SReo = \frac{bk - m}{2ck} \quad \dots\dots\dots (8.5)$$

Finally, the profit (or loss) at any stocking rate can be calculated by the following accounting equations:

$$\text{Profit} = \text{income} - \text{expenditure}$$

$$\text{or } P = \{GH \times D \times k\} - \{i(j+d) + (ixwxSR \times D/365) + V\} \quad \dots\dots\dots (8.6)$$

where  $P$  = profit per ha per season

$$GH = \text{daily liveweight gain per ha at a given stocking rate} = bSR - cSR^2$$

$D$  = number of days in the grazing season

$k$  = price of 1kg liveweight

$i$  = current capital interest rate

$j$  = price per ha of land

d = cost of land development

w = cost of one animal unit

V = annual production costs such as fertilizer, feed supplement costs etc.

## 8.2 A model linking profit per ha to stocking rate and annual rainfall

To apply the economic theory described in section 8.1 it is necessary to assume that stock were bought at a particular price when the pasture was ready for grazing, and sold at a given price at the end of the grazing period. While this assumption may be unrealistic, it provides a simple method for separate economic evaluation of the role that dryland pastures might play in growing out young beef animals.

Income: The values for GH and D can be calculated for specific levels of annual rainfall and given stocking rates from equations 7.10 and 7.12. If the price received per kg liveweight at the end of the grazing season is assumed to be R1,00, total income is calculated as

$$GH \times D \times l = [2(p-qRF)SR - \{(p-qRF)/(n+mRF)\}SR^2] \times (g+hRF) \times l \dots (8.7)$$

Costs: The current capital interest rate (i) is assumed to be 15% and the price per ha of land (j) used in the analysis is R350. The cost of land development (d) includes establishment fertilization, costs of tilling and planting, and the cost of fencing and watering facilities, allocated as follows:

|                                                                                                                 |               |
|-----------------------------------------------------------------------------------------------------------------|---------------|
| 400 kg/ha KCl (50%K) at R229,80/ton to raise the level of K in the soil from 20ppm to 120ppm<br>(Booyesen 1981) | 91,92         |
| 800 kg/ha superphosphate (10,5%P) at R158,20/ton to raise the level of P in the soil from 2ppm to 15ppm         | 126,56        |
| Tractor and labour costs for ploughing, spreading fertilizer and planting                                       | 70,00         |
| Cost of fencing and watering assuming that the area is divided into 2 ha paddocks                               | 200,00        |
|                                                                                                                 | <hr/> R488,48 |

The cost of an animal at the beginning of the grazing season was calculated to be R226, assuming the purchase price per kg liveweight to be R1,20, and using the mean starting weight of 221,7 kg for the seasons studied. Finally, annual production costs (V) included an amount of 15 cents per animal per day for phosphate licks and veterinary expenses (u), labour costs (z) of R10/ha/season and the annual application of 800 kg/ha of limestone ammonium nitrate (28%N) and 100kg superphosphate (t). These costs came to R206,56 and R15,82 respectively.

The costs that were independent of stocking rate can be regarded as fixed costs (FC) and include interest on the value of land and the cost of developing it, as well as annual fertilizer and labour costs. These fixed costs are expressed as

$$\begin{aligned}
 FC &= i (j + d) + z + t \\
 &= 0,15(350 + 488,48) + 10 + 222,38 \\
 &= 125,77 + 10 + 222,38 \\
 &= R358,15
 \end{aligned}$$

The variable costs are those associated with stocking rate, and include the interest on the purchase price of the animals and



the cost of licks and veterinary requirements. This can be expressed as

$$\begin{aligned}
 VC &= (i \times w \times SR \times D/365) + (u \times SR) \\
 &= (0,15 \times 266 \times SR \times (31,3 + 0,16RF)/365) + (0,15 \times SR) \\
 &= 0,1093SR \times (31,3 + 0,16RF) + 0,15SR \\
 &= (3,57 + 0,01749RF)SR \dots\dots\dots (8.8)
 \end{aligned}$$

Total costs (TC) are then given by the sum of fixed and variable costs. Thus, for a given rainfall, total costs can be expressed as

$$\begin{aligned}
 TC &= FC + VC \\
 &= 358,15 + (3,57 + 0,01749RF)SR
 \end{aligned}$$

and total profit per season is described by the equation

$$P = (GH \times D \times k) - TC \dots\dots\dots (8.9)$$

The influence of stocking rate on fixed, variable and total costs at different levels of annual rainfall is illustrated in Fig. 8.1. Variable and total costs for a given stocking rate increase with rainfall because increased rainfall extends the grazing period and therefore increases the total amount of interest which accumulates against the purchase price of animals. Since the price of 1 kg liveweight is R1,00, the relationships between total income per ha for a season and stocking rate at different amounts of annual rainfall is the same as the relationships between seasonal liveweight gain per ha and stocking rate (Fig. 7.8).

Equation 8.7 can be expressed in terms of rainfall and stocking rate as follows:

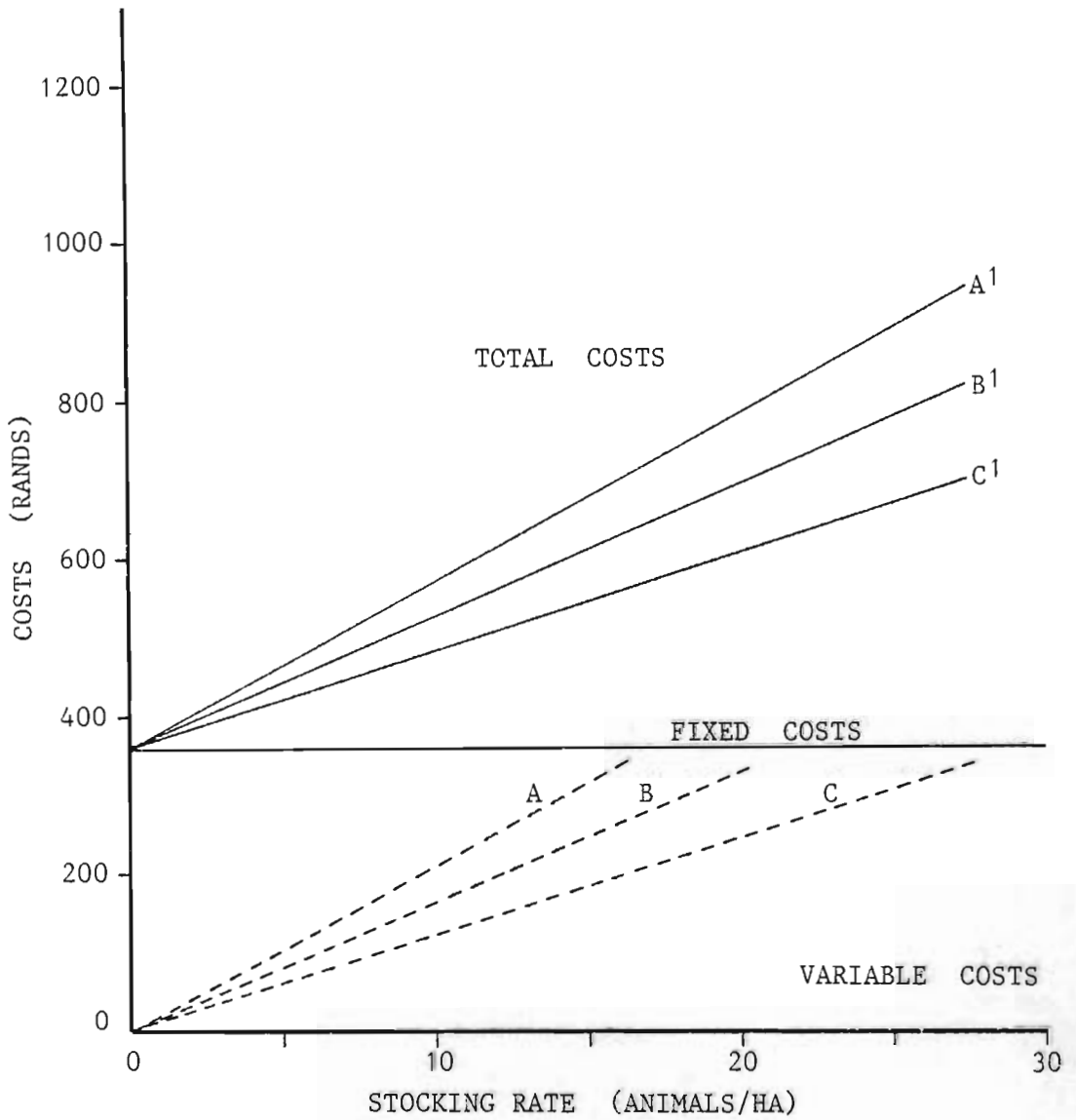


Fig. 8.1. The relationships of fixed costs, variable costs, A, B and C for annual rainfall of 1000 mm, 750 mm and 500 mm respectively and corresponding total costs (A', B' and C') with stocking rate.

$$\begin{aligned}
P &= [2(p-qRF)SR - \{(p-qRF)/(n+mRF)\}SR^2] \times (g+hRF) \times 1 \\
&\quad - \{358,15 + (3,57+0,01749RF)SR\} \\
&= 2(p-qRF)(g+hRF)SR - \{(p-qRF)(g+hRF)/(n+mRF)\}SR^2 \\
&\quad - 358,15 - (3,57+0,01749RF)SR \\
&= \{(2p-2qRF)(g+hRF) - (3,57+0,01749RF)\}SR \\
&\quad - \{(p-qRF)(g+hRF)/(n+mRF)\}SR^2 - 358,15
\end{aligned}$$

Since this is a quadratic equation when stocking rate is the independent variable, the derivative is easily obtained for a given rainfall, and by equating the derivative to zero, the stocking rate at which profit is a maximum (SReo) can be calculated:

$$\begin{aligned}
&2(p-qRF)(g+hRF) - (3,57+0,01749RF) \\
&- 2\{(p-qRF)(g+hRF)/(n+mRF)\}SReo = 0
\end{aligned}$$

$$\begin{aligned}
\text{and hence } SReo &= \{(2p-2qRF)(g+hRF) - (3,57+0,01749RF)\} \\
&\quad \div \{2(p-qRF)(g+hRF)/(n+mRF)\} \\
&= (n+mRF) - \frac{(3,57+0,01749RF)(n+mRF)}{2(p-qRF)(g+hRF)} \dots (8.10)
\end{aligned}$$

The same result could have been obtained by equating the derivative of equation 8.7 to that of equation 8.8 (as in equation 8.4) and then solving for stocking rate. Relationships for total costs, total income and profit with stocking rate are presented for an annual rainfall of 700 mm in Fig. 8.2. These clarify the economic theory discussed in section 8.1.

From observation it is clear that the difference between the income and cost lines is a maximum when the slopes of these two lines are the same. Then SReo can be calculated by equating the derivatives of the two equations, or alternatively, by equating the derivative of the profit equation to zero. Because total costs must increase with stocking rate, SReo will always be less than SRmax. Finally, in the same way that SR90max was relatively

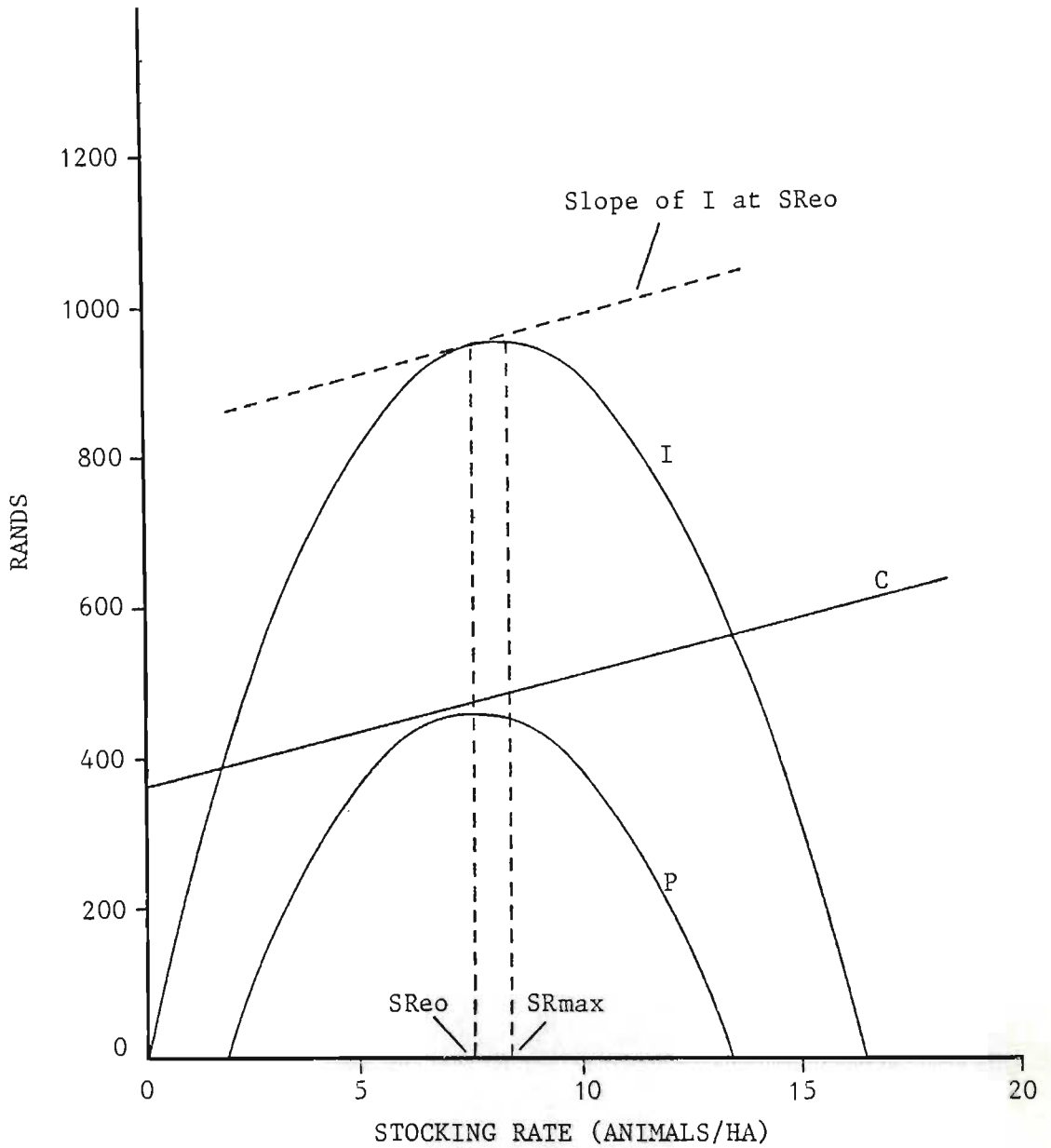


Fig. 8.2. Relationships for total costs (C), total income (I) and profit per ha (P) with stocking rate at an annual rainfall of 700 mm.



large, a similar range of stocking rates exists which will allow profit of 90% or more of maximum to be achieved.

Profit per ha at  $S_{Reo}$  increases initially with rainfall and then decreases to only R96 at an annual rainfall of 1000 mm (Fig. 8.3). The main reason for this is that as rainfall increases beyond a certain point, the decline in liveweight gain per animal has a stronger effect than the corresponding increase in  $S_{Rmax}$  and the length of the grazing season. However, costs also increase slightly with increased rainfall, but do not play a major role in the trend of profit at  $S_{Reo}$  with annual rainfall.

The  $S_{Reo}$  and  $S_{Rmax}$  diverge considerably above a rainfall of 800 mm but  $S_{Reo}$  does not reach a maximum within this range. The profit at  $S_{Reo}$  and the return on capital invested in land and its development reach maxima at levels of annual rainfall between 750 mm and 800 mm (Fig. 8.4).

### 8.3 The long term economic optimum stocking rate

Since annual rainfall cannot be predicted, it is necessary for farmers to apply what they feel would be the most economic long term stocking rate. The model relating profit per ha to stocking rate and annual rainfall provides a useful basis for estimating such a stocking rate from long term records of annual rainfall. If the annual rainfall for a farm had a normal distribution it would be logical to estimate the long term economic stocking rate by substituting the mean annual rainfall into equation 8.10.

The distribution of annual rainfall for the past 32 years at Ukulinga Research Farm, however, has a distinct positively skew

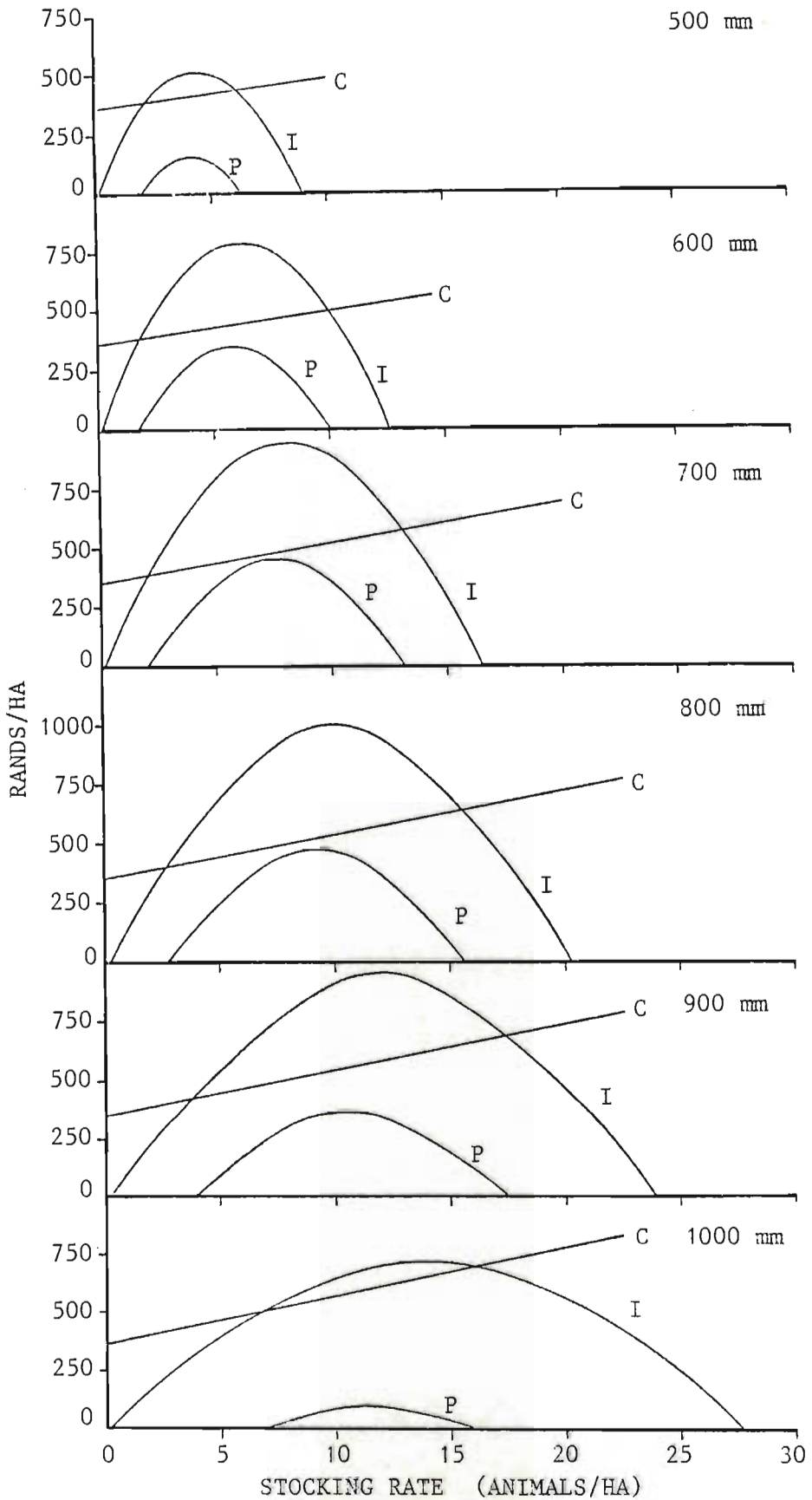


Fig. 8.3. Relationships for total cost (C), total income (I) and profit/ha (P) with stocking rate for different levels of annual rainfall.

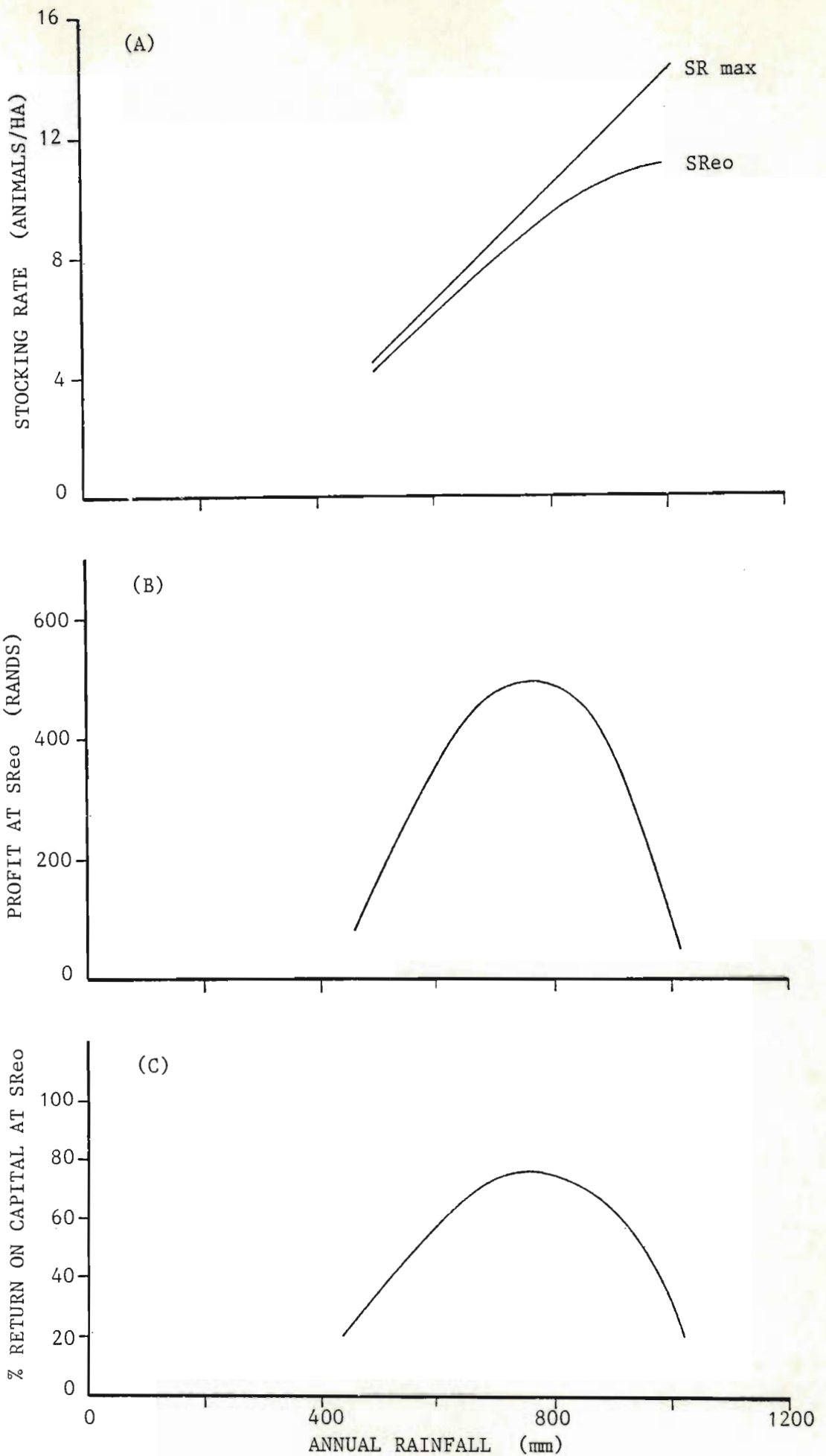


Fig. 8.4. Relationships of SRmax and SReo (A), profit at SReo (B) and % return on capital at SReo (C) with annual rainfall.

distribution (Fig. 8.5) and this is a common characteristic in many medium to low rainfall areas in Natal (Dent, Pers. Comm.). Thus, despite the long term average rainfall being just over 700mm, the highest frequency of annual rainfall occurs in the 550-650mm range. The long term economic stocking rate is therefore not likely to be associated with the long term mean annual rainfall. Neither is it necessarily that associated with the mid-point of the range of rainfall which has the highest frequency (in this case 600 mm), because profit at SReo is a maximum between 750 and 800 mm.

To examine the variation of profit with stocking rate, the profit for stocking rates between 3 and 11 animals per ha were calculated for levels of annual rainfall corresponding to the mid-points of the frequency classes shown in Fig. 8.5. These are presented in Table 8.1 together with the frequency of annual rainfall which corresponds to the associated rainfall class.

The frequency of annual rainfall in the range 550mm to 850 mm is 0,75 or 75%. The profits which occur within this range of annual rainfall are therefore likely to have the greatest effect on the average long term profit. From this table it is possible to estimate the probability of achieving different profits for a given stocking rate. For example, the probability of achieving the highest profit of R464 per ha at a stocking rate of 7 animals per ha is 25%, and the corresponding annual rainfall is  $700 \pm 50$  mm. Similarly, at a stocking rate of 7 animals per ha and for levels of annual rainfall between 550 mm and 850 mm there is roughly a 75% probability of profit being above R326/ha. Since the size of the frequency classes in annual rainfall is 100 mm and the profits in Table 8.1 are those associated with the mid-point of these intervals, the values for profit in the body of the table



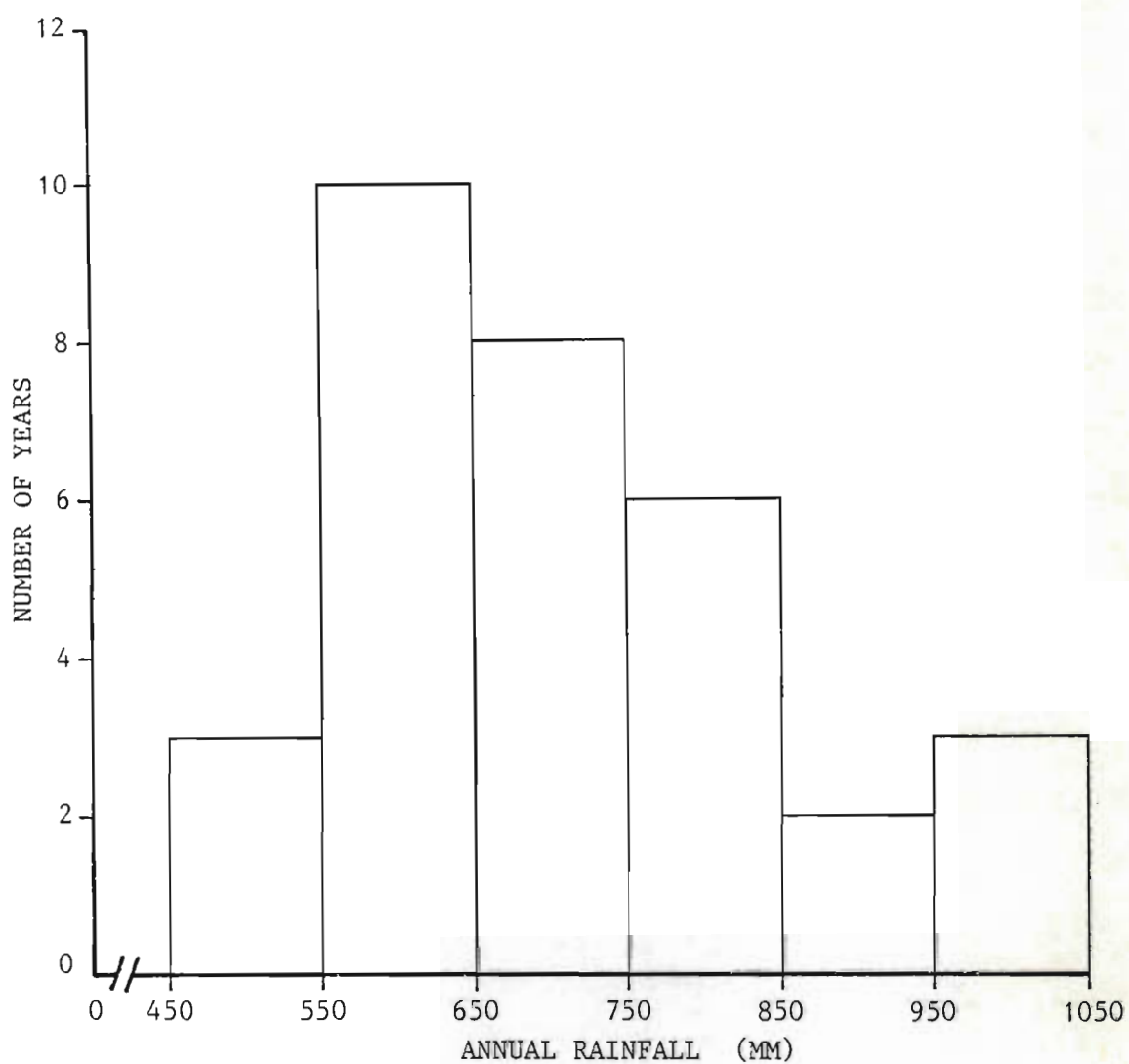


Fig. 8.5. The frequency distribution of annual rainfall for Ukulinga Research Farm for the 32 year period 1950 - 1982.

TABLE 8.1. The profit (rands) at different stocking rates for different rainfall which have various frequencies at Ukulinga Research Farm.

| Annual<br>Rainfall<br>(mm) | Frequency | Stocking rate (animals/ha) |     |     |     |     |      |      |      |       |
|----------------------------|-----------|----------------------------|-----|-----|-----|-----|------|------|------|-------|
|                            |           | 3                          | 4   | 5   | 6   | 7   | 8    | 9    | 10   | 11    |
| 500 ± 50                   | 0,09      | 122                        | 167 | 144 | 67  | -67 | -255 | -511 | -822 | -1200 |
| 600 ± 50                   | 0,31      | 174                        | 271 | 329 | 352 | 326 | 264  | 168  | 87   | 158   |
| 700 ± 50                   | 0,25      | 164                        | 280 | 368 | 432 | 464 | 468  | 452  | 392  | 312   |
| 800 ± 50                   | 0,19      | 100                        | 216 | 311 | 384 | 436 | 473  | 489  | 478  | 458   |
| 900 ± 50                   | 0,06      | -50                        | 83  | 167 | 233 | 283 | 333  | 350  | 367  | 367   |
| 1000 ± 50                  | 0,10      | -140                       | -90 | -40 | 0   | 30  | 60   | 80   | 90   | 100   |

TABLE 8.2. The estimation of expected profits for different stocking rates calculated by summing the products of frequency of rainfall and profit at that rainfall for different stocking rates.

| Annual<br>rainfall<br>(mm) | Frequency | Stocking rate (animals/ha) |     |     |     |     |     |     |     |      |
|----------------------------|-----------|----------------------------|-----|-----|-----|-----|-----|-----|-----|------|
|                            |           | 3                          | 4   | 5   | 6   | 7   | 8   | 9   | 10  | 11   |
| 500 ± 50                   | 0,09      | 11                         | 15  | 13  | 6   | -6  | -23 | -46 | -74 | -108 |
| 600 ± 50                   | 0,31      | 54                         | 84  | 102 | 109 | 101 | 82  | 52  | 27  | -49  |
| 700 ± 50                   | 0,25      | 41                         | 70  | 92  | 108 | 116 | 117 | 113 | 98  | 78   |
| 800 ± 50                   | 0,19      | 19                         | 41  | 59  | 73  | 83  | 90  | 93  | 91  | 87   |
| 900 ± 50                   | 0,06      | -3                         | 5   | 10  | 14  | 17  | 20  | 21  | 22  | 22   |
| 1000 ± 50                  | 0,10      | -14                        | -9  | -4  | 0   | 3   | 6   | 8   | 9   | 10   |
| Expected profit            |           | 108                        | 206 | 272 | 310 | 314 | 292 | 241 | 173 | 40   |

are approximations, but serve as good guidelines.

Despite the usefulness of Table 8.1 for examining the probability of different profits at given stocking rates and levels of annual rainfall, without further calculation it is still difficult to establish a long term strategy that will on average, provide the highest profit. This has been done by multiplying each profit in the body of Table 8.1 by the corresponding frequency and then adding these figures for each stocking rate (Table 8.2). The resultant totals are the expected profit or weighted long term average profit at the respective stocking rates. These are plotted in Fig. 8.6 and it is evident that a maximum long term annual profit of R316/ha can be expected at a stocking rate of 6,7 animals/ha. This represents a return of 52% on capital invested in land and its development.

#### 8.4 Discussion

The theory of factor/product analysis provides a useful basis for an economic evaluation of pastures which have been grazed by livestock at a number of stocking rates. However, it is recognized that in most farming situations dryland pastures will be incorporated into more complex farming systems, and the limitations of the assumptions required for the analysis in this chapter are therefore acknowledged.

The model suggests that there is a relatively wide range of stocking rates and levels of annual rainfall within which profit will exceed R350/ha in individual seasons. For medium to low rainfall regions and marginal soils this return is likely to be superior to that which would be expected from maize. Furthermore, the risk involved in beef production from dryland pastures appears

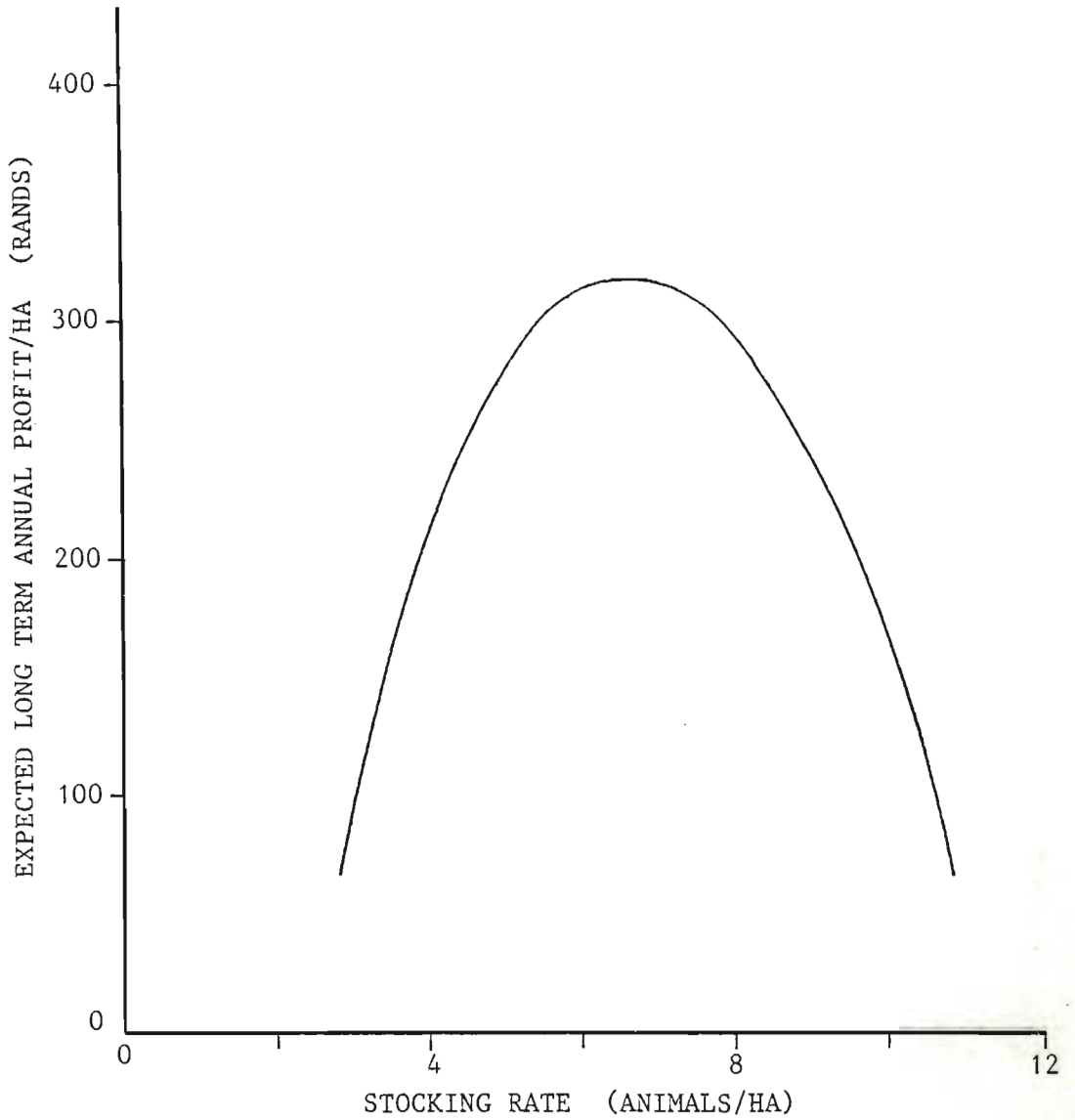


Fig. 8.6. The relationship between expected long term annual profit per ha and stocking rate for Ukulinga.



to be considerably less than that for maize because of the wide range in rainfall and stocking rates within which expected long term profit is good.

## 9. GENERAL DISCUSSION AND CONCLUSIONS

At the outset of this study the objective was to relate daily liveweight gain, herbage availability and average stocking rate to one another to formulate grazing management recommendations for kikuyu and Coastcross. However, the occurrence of an exceptionally high range in annual rainfall of nearly 500 mm (which has a probability of less than 6% of occurring in the span of 6 years) offered a valuable opportunity to study the response of pasture parameters to annual rainfall. Furthermore, it was possible to build stocking rate and annual rainfall into models for predicting liveweight gain and profit per ha.

Besides these objectives, this study facilitated some general observations on the response of Coastcross and kikuyu to grazing treatments as well as an observational assessment on the put-and-take technique.

### 9.1 General observations

Although Coastcross is a stoloniferous grass, the production of stolons seemed to be confined mainly to the establishment period and the early spring of each year. Even under heavy continuous grazing this species behaved more like a bunch or tufted grass than a sod forming grass, showing an erect rather than a lateral growth habit. Due to this growth characteristic Coastcross was more sensitive to heavy continuous grazing than kikuyu. Under such management bare patches of ground developed and these soon became colonized by broad leaf weeds, whereas weed

encroachment in kikuyu was minimal.

Despite no difference in liveweight gain being observed between the two grass species in the seasons studied, subsequent evaluation in the 1982/83 season indicated that Coastcross was more resistant to drought conditions than kikuyu. Coastcross also appeared to be suitable for hay making which is a valuable attribute in regions which have a distinct dry season, and where rainfall is erratic. In addition, these trials showed that Coastcross can persist on heavy clay soils even though it is generally recognized that Cynodon species grow best on sandy soils. In the spring, however, kikuyu tended to turn green and commence growth about three weeks earlier than Coastcross, but there was no measurable difference between the two grass species in herbage availability at the time that grazing started.

The implication from these observations is that Coastcross grows in a wide range of conditions but would probably produce best in the warm coastal regions of Natal. On the other hand, kikuyu is better adapted to the moister, high altitude, cooler conditions of Bioclimatic Group 4, and cannot tolerate drought conditions as well as Coastcross.

## 9.2 The put-and-take technique

The difficulties experienced with the put-and-take technique suggest that it does not warrant preference over fixed stocking in trials where differences in herbage availability between treatments and within treatments over time are relatively low. However, the put-and-take technique would be more appropriate than fixed stocking in situations where differences in herbage availability between treatments and within treatments over time

are relatively high and predictable. An example of such a situation is when treatments in a grazing trial are levels of applied nitrogen, which would produce large differences in herbage availability. Another example is irrigated ryegrass in Bioclimatic Group 4, where production is low during mid-winter as a result of low temperatures, and spring growth is two to three times more rapid than autumn growth.

Notwithstanding the above, a possibility of an interaction between stocking rate and treatments always exists. Each treatment should therefore be grazed at a range of herbage availabilities for put-and-take grazing, or at a range of stocking rates under fixed stocking. In addition, it would appear that such a design can be adequately analysed statistically, and provides more information than replicated trials with only one level of herbage availability or only one stocking rate.

### 9.3 Relationships between herbage availability, liveweight gain and stocking rate

The relationships between liveweight gain per animal and herbage availability, and between herbage availability and stocking rate were better defined than that between liveweight gain per animal and stocking rate. This was probably due to the variables in the former two relationships being directly linked and liveweight gain per animal being indirectly linked to stocking rate by means of herbage availability.

Depending on the season, liveweight gain per animal was either superior for continuous grazing or the same for the two grazing methods at equivalent levels of herbage availability. However, in most seasons rotational grazing resulted in higher



herbage availability than continuous grazing. The overall result was that very little difference in liveweight gain per animal at equal stocking rates occurred between the two grazing methods, although on average there was a tendency for liveweight gain per animal to be higher for rotational grazing than for continuous grazing as stocking rate increased.

#### 9.4 Buffer mechanisms

Buffer mechanisms can be defined as mechanisms whereby certain factors in a system resist change when the levels of other factors are altered. One of the notable features of the analysis presented in this study is the evidence of a number of buffer mechanisms in grazing systems.

The first buffer mechanism was described in sections 7.1 and 7.4. Here it was shown that over a given range of stocking rates at a given level of annual rainfall, the variation in liveweight gain per ha was relatively small. More specifically, if  $SR_{max}$  and liveweight gain per ha at  $SR_{max}$  are each considered to be 100%, then from Fig. 7.6 it can be shown that when stocking rate increases from 70% to 130%, liveweight gain varies between 90 and 100%. Thus, for a 60% change in stocking rate, liveweight gain varied by only 10%.

This phenomenon is clearly a result of a decrease in liveweight gain per animal as stocking rate is increased. In one sense, this buffer mechanism can be regarded as a disadvantage since little benefit can be derived by adjusting stocking rate within 30% of  $SR_{max}$ . However, the buffer effect could also be regarded as desirable because little is lost if the stocking rate applied is within 30% of  $SR_{max}$ . The advantage, therefore, is that

the buffer mechanism offers the farmer considerable flexibility in stocking rates.

The second buffer mechanism observed was the similar liveweight gains per ha which occurred at  $SR_{max}$  for continuous and rotational grazing, despite  $SR_{max}$  being, on average, considerably higher for rotational grazing than continuous grazing (Fig. 6.5 and 6.11). Whereas the first buffer mechanism discussed is a buffer of liveweight gain per ha as stocking rate is changed, this mechanism is a buffer of liveweight gain per ha at  $SR_{max}$  as grazing method is changed. Here again it was caused by the liveweight gain per animal at  $SR_{max}$  being lower for rotational grazing than for continuous grazing, thus balancing the higher  $SR_{max}$  which occurred under rotational grazing.

This buffer mechanism also has both a positive and a negative aspect. For a farmer who has limited finance it would be encouraging to know that similar returns per ha can be achieved under continuous grazing as under rotational grazing, because fewer animals are required and fencing and watering costs would be lower. However, besides higher DM production and higher  $SR_{max}$ , rotational grazing has animal management advantages such as control of internal parasites and the subdivision of cow herds during the mating season. In addition, it offers greater flexibility because feed can be rationed better and conserved by closing certain paddocks for hay or foggage. For the farmer who wishes to make use of these advantages, therefore, the additional expense of installing rotational grazing does not seem to be met by higher liveweight gain per ha.

The third buffer mechanism is the resistance of liveweight gain per ha at  $SR_{max}$  to change as rainfall increases (Fig. 7.9). For example, when rainfall increased from 600 mm to 975 mm,



seasonal liveweight gain per ha at SRmax varied only between 800 and 1016 kg/ha. If 800 mm of annual rainfall is considered to be 100%, then a 21% variation in liveweight gain per ha occurred with a 47% increase in rainfall. As for the previous buffer mechanisms discussed, the underlying cause was a decrease in liveweight gain per animal as rainfall increased. Nevertheless, in the medium to low rainfall regions of Natal annual rainfall is erratic, and this phenomenon should therefore be regarded mainly as an advantage because it reduces the level of risk.

From these three examples of buffer mechanisms in grazing systems it appears that if changing the level of a particular factor increases pasture DM production and SRmax, then liveweight gain per animal decreases and results in relatively small changes in liveweight gain per ha at SRmax. The data of Barrow et al. (1982) and Mears and Humphreys (1974b) who found relatively small responses in liveweight gain per ha over relatively large ranges in the level of nitrogen applied to pastures also support this hypothesis.

#### 9.5 Future research

In view of the buffer effects discussed in section 9.4, the potential for increasing liveweight gain per ha by increasing DM production seems to be limited. Hence, since nitrogen fertilizer is such an expensive input and is widely used on pastures in Natal, its effects on liveweight gain per ha and profit therefore need to be carefully assessed in relation to stocking rate under medium to low rainfall conditions. In addition, the advantage of applying nitrogen according to the quantity of rain which falls

could be investigated in small plots. The aim here would be to achieve more efficient use of applied nitrogen by "demand feeding" the pasture. For example, after the first application of nitrogen in spring, frequency of subsequent applications would be determined by the pattern of rainfall, and the total amount of nitrogen applied would depend on the total annual rainfall. Treatments for such a trial could, for example, be 50 75 and 100 kg N/ha per 200 mm of rainfall after a given date in spring.

Due to the depressing effect which high DM production per ha seems to have on liveweight gain per animal, the greatest opportunity for increasing liveweight gain per ha appears to lie in methods designed to extend the period of grazing. Hence, further research is required to develop pasture feeding systems aimed at achieving this. These could include more than one pasture, as well as hay and supplementary feed. The investigation of the precise reasons for the negative relationship between DM production and liveweight gain per animal could help in devising such systems, and grazing management strategies aimed at counteracting the buffer effect. For example, a possible reason for the buffer effect is that a higher proportion of stem material is associated with higher yields under commonly used grazing regimes. If this is so, alternative grazing strategies may need to be adopted to encourage leaf growth in relation to stem growth, and in so doing, improve the quality of the forage offered to animals.

Research is also required on the effect of annual rainfall on liveweight gain of different breeds or types of cattle, and different classes of animals. In particular, the liveweight gain per animal of bos-indicus and bos-taurus types needs to be established under high and low rainfall, and production from



steers should be compared with production from cow-calf units.

#### 9.6 Conclusions

The models developed in this study for predicting liveweight gain and profit per ha should be useful planning aids for farmers who wish to grow out young beef animals on dryland pastures in Natal. Although further research is required, these models provide strong evidence that such an operation can be a profitable method of using marginal soils in medium to low rainfall regions of Natal. As such they should be extremely valuable in persuading more farmers to establish dryland pastures and thus reduce the stocking pressure on the veld.

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