AN EVALUATION OF IRRIGATED RYEGRASS/CLOVER PASTURES FOR FAT LAMB PRODUCTION IN THE HIGHLAND SOURVELD OF NATAL

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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.

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ABSTRACT

The primary objective of this study was to increase net farm income in the Highland Sourveld of Natal by developing pasture based fat lamb production systems. Secondary objectives included (a) determination of the most suitable pasture species or species mixture; (b) determination of the optimum level of N fertilization; (c) establishment of biological and economic optimum stocking rates; (d) projection of expected profit and (e) verification of proposals on a farm scale. Midmar Italian ryegrass was compared to selected legumes alone, and in mixtures with ryegrass in a small plot trial conducted over two years at a 3- and 6-week harvesting frequency under irrigation. Ryegrass in combination with red and white clover provided the highest yields for both harvesting intervals in both years. When this pasture was subsequently compared to ryegrass alone under grazing, no significant difference could be detected in lamb gains at 20 and 28 ewe-lamb units/ha, but at 36 ewe-lamb units/ha the lambs on ryegrass started losing weight at 30 kg, while those on ryegrass + clover continued to gain until a market weight of 40 kg was achieved. In a small plot trial little response was detected to added N above 175 kg N/ha on ryegrass + clover, and under grazing, no significant difference was observed between 275; 375 and 475 kg N/ha over two single year periods. Relationships between average daily gain (ADG) and stocking rate, ADG and disc meter height, and stocking rate and disc meter height were mostly well described by linear functions. Expected pre-weaning ADG was 150 g higher ($p \leq 0{,}01$) than post-weaning ADG (100 g) in the first year, and a similar difference was observed in the second year. For the period common to all stocking rates an average maximum gain/ha of 824 kg was achieved at a stocking rate of 33,5 lambs/ha and a disc meter height of 4,5 cm. By lambing in April, lambs could be marketed in September at 40 kg and more weaned lambs could be grazed on the pasture and marketed in December, leading to an expected gain/ha of 1400 to 2200 kg, and expected profit/ha of R 1254 to R 2771, depending on stocking rate. When evaluated under farm conditions, this system produced 2060 kg live weight/ha and a profit of R 3206/ha. It is concluded from the present study that the fat lamb production system based on irrigated ryegrass + clover pastures can be recommended with confidence to farmers in the Highland Sourveld of Natal.

1. INTRODUCTION

1.1 Overview

An economic analysis carried out by economists of the South African Department of Agriculture from mail-in records showed that, in the Underberg district of Natal, net farm income for the 1978/79 financial year ranged from R4 476 to R25 535 per annum (Berry & Whitehead, 1979). However, for 77% of these farms, net farm income was less than R6 000. While it is recognized that due to concern of farmers about the confidentiality of this information, mail-in records may bias income downwards, these figures still suggest that average income per family in the farming community is lower than that in urban communities. In addition, farming constitutes a relatively high risk occupation compared to urban business and employment. Consequently, unless net farm income can be raised, many farmers may experience serious financial difficulty and be forced to leave farming and migrate to urban areas. The general aim of this study, therefore, was to conduct research that would promote economic viability of farms in the Underberg and neighbouring districts.

1.2 Background

Underberg is situated in the Highland Sourveld of Natal (Bioclimate 4; Phillips, 1969). This region constitutes 21% of the province (Fig. 1.1) and is situated between 1400 and 1950 m above sea level. The topography varies from rolling to mountainous, with limited arable land on flat "bottomland" and some "topland" sites (Plate 1 and 2). Annual precipitation for the region varies between 800 and 1500 mm and most of this occurs between September and April. Mean annual temperatures are 13 - 15°C. Severe frosts occur regularly during mid-winter and occasional snowfalls are also

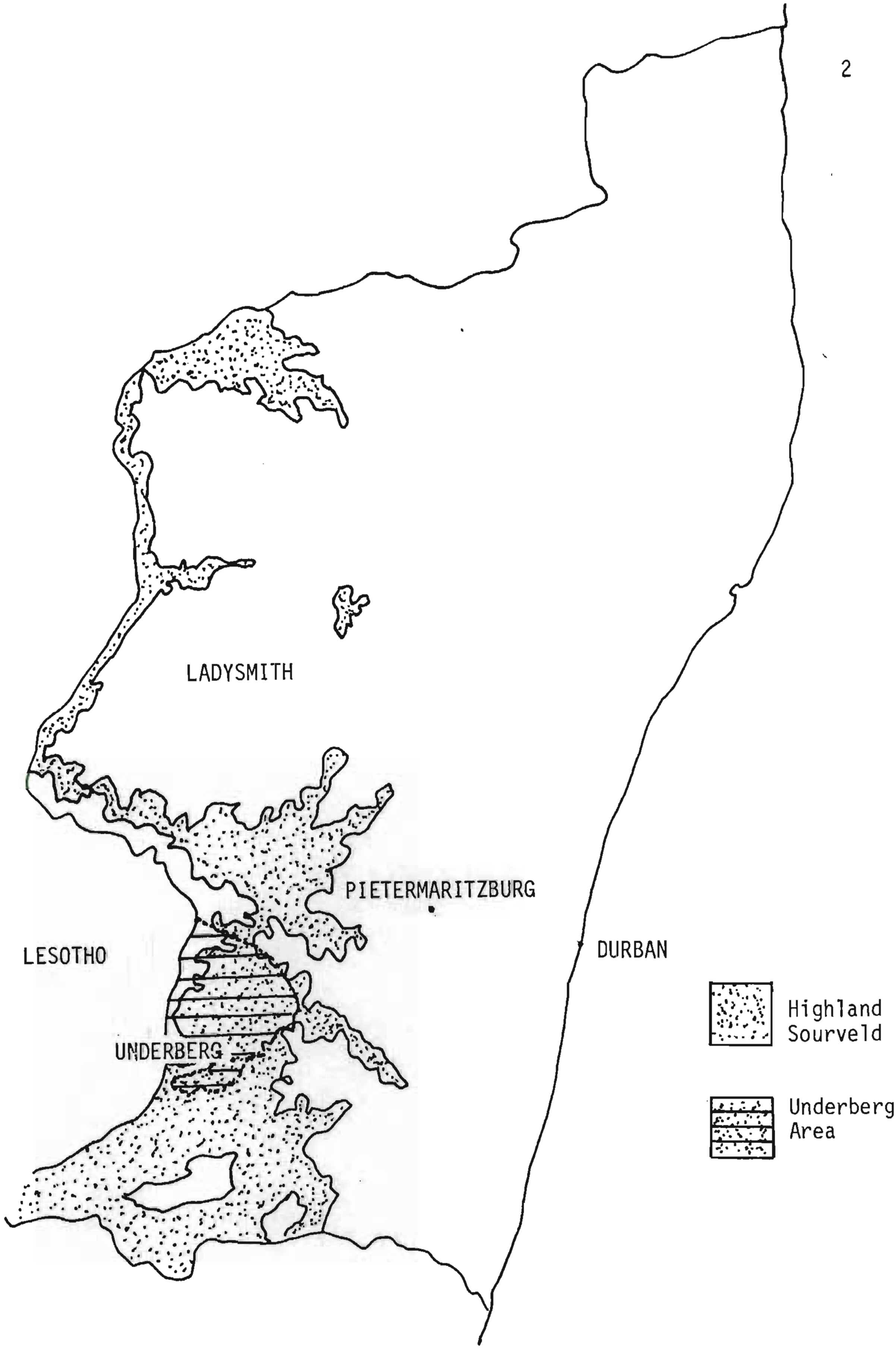


Fig. 1.1 Map indicating the extent of the Highland Sourveld and the Underberg extension area in relation to the whole of Natal.

PLATE 1. A typical landscape in the Highland Sourveld, showing rolling topography in the foreground and mountainous terrain in the distance.

PLATE 2. The ryegrass + clover grazing trial in the foreground with rolling topography in the background.

experienced, while hailstorms during the summer months constitute a serious hazard for crop farmers.

Soils of the Highland Sourveld are typically acid (pH between 4,0 and 4,9) with high levels of aluminium and a severe deficiency of phosphorus. The soil erosion hazard, however, is low due to most of the area being occupied by a short, dense grassland that is relatively stable. This perennial grassland is considered to be maintained by fire and grazing, and is nutritious and palatable to livestock during summer, but very low in quality during winter. Isolated pockets of yellowwood forest occupy sites that are protected from fire. Many perennial streams and rivers provide a reliable source of water for irrigation.

Farming in the Highland Sourveld has traditionally emphasized stock production from systems that rely heavily on the natural grassland. Approximately 30% of the cattle and 65% of the sheep in Natal are found in this region. Natural grassland covers 85% of the region (1,1 million ha) and cropping land constitutes 10%. There are 30 000 ha under planted pastures which represents 38% of the total area in Natal down to improved pasture species. About 13 000 ha are under irrigation, but there is still considerable potential for expansion.

The average size of farms in the Underberg district is just over 800 ha (Berry & Whitehead, 1979). In the context of extensive livestock farming off natural grassland, land units of this size are considered to be economically marginal, and units which are smaller would be economically non-viable. For many farmers on such units, purchase of additional land is beyond their financial means. Vertical expansion by intensification is therefore the only option open to them for increasing net farm income.

Due to the inherent emphasis on livestock in farming enterprises of the region it was logical to consider options for intensification in this context. Opportunities for extensive farmers to intensify by establishing dairy units seemed remote as a result of the extremely high capital requirement for a parlour and cow herd. Dairying was therefore considered to be an unrealistic option. On the other hand, the relatively low price obtained for beef, and a tendency towards oversupply on a national scale suggested that prospects for intensive beef production were also poor.

Intensive sheep production systems were therefore the logical remaining option which deserved research attention. A major proportion (70%) of the sheep in the Highland Sourveld are wooled sheep (mostly Merino), although these animals are not well suited to the moister phase (Bioclimate 4e; Phillips, 1969) of the region. However, Natal is a net importer of lamb and mutton, with sheep being trucked in from the Orange Free State and as far a field as the Karoo in the Cape Province.

Due to high infestations of internal parasites associated with spring lambing and correspondingly high lamb mortality, lambing in the Highland Sourveld is predominantly in the late summer. Unfortunately, this period represents the end of the rainy season. Intensification, therefore, requires capital outlay for installation of irrigation in addition to the establishment of pastures. Despite the transport cost advantage that local producers would enjoy over those outside Natal, experience in the agricultural extension service has indicated a reluctance amongst farmers to intensify. The primary reason for this appeared to be the distinct lack of convincing evidence indicating that irrigated winter pastures can lead to stocking rates and lamb gains that are high enough to justify the required capital outlay. In particular, the information needed was the most suitable pasture species, optimum levels of N fertilization, optimum stocking rates and an economic evaluation of a potential farm production system.

1.3 Pasture species

Due to the requirement for winter pasture production resulting from autumn lambing, potential pastures species for inclusion in this investigation were confined to those which were adapted to temperate conditions. According to Rhind and Goodenough (1976), Italian ryegrass (Lolium multiflorum Lam.) was the most widely grown temperate pasture in the high rainfall regions of Natal. In a separate study Heard, Tainton and Edwards (1984) also found that Italian ryegrass was the most commonly used irrigated pasture on dairy and beef farms sampled from certain regions including the Highland Sourveld of Natal.

Despite the popularity of Italian ryegrass amongst farmers, the necessity to re-establish this pasture every year constitutes a major disadvantage. However, use of cool season perennials on farms in Natal has been extremely limited (Heard et al., 1984). The major problem with perennial ryegrass (Lolium perenne) has been lack of persistence under grazing, while tall fescue (Festuca arundinaceae) is low in quality (Riewe, Smith, Jones & Holt, 1963) and in the U.S.A. has been shown to be frequently infested with a toxic endophyte (Acremonium coenophialum). Cocksfoot (Dactylis glomerata) has been used to a limited extent under dryland conditions, but its response to irrigation is usually regarded as too low to warrant the additional cost. Consequently, Italian ryegrass was the only grass included in the species evaluation phase of this study.

Due to the yield, forage quality and N-fixing advantages of mixed legumes/grass pastures, it was important to evaluate all pasture legumes that had shown potential as a companion for Italian ryegrass in the Highland Sourveld of Natal. In an irrigated pasture trial du Plessis (1978) recorded 14,7 t/ha of hay (sun dried) from Midmar Italian ryegrass alone, while a mixture of Midmar ryegrass and ladino white clover (Trifolium repens) yielded 15,1 t/ha.

The superior forage quality of legumes over grasses has been widely recognised. In particular, digestibility of legumes is generally higher than for grasses, and decreases less rapidly with maturity (Harkess, 1963; and Harkess & Alexander, 1969). Crude fiber contents of 22% for Italian ryegrass alone and 14,3% for a mixed ryegrass/clover pasture were measured by Bredon and Stewart (1978) in the winter, while corresponding levels in the spring were 21,6% and 19,5% respectively. Although these quality differences may appear to be relatively small, they often lead to a large difference in animal response. For example, Betts, Newton and Wilde (1983) found that weaned lambs grazing a perennial ryegrass/clover pasture had growth rates 40% higher than those grazing ryegrass alone.

The N-fixing value of pasture legumes in legume/grass mixtures has received little attention in South Africa. However, a considerable amount of research has been conducted in this field in other countries (Dart & Day, 1971; Masterson & Murphy, 1976; Schubert & Evans, 1976; Ball, Brougham, Brock, Crush, Hoglund & Carran, 1979; Hoglund, Crush, Brock, Ball & Carran, 1979).

In summary, estimates of annual symbiotic N-fixation by legumes in pastures vary widely from 35 kg/ha to 500 kg/ha (Sears, Goodall, Jackson & Robinson, 1965a), depending on species, management, soil and environmental conditions etc.

Scott (1967) suggested that white clover was one of the best legumes for mixed grass/legume pastures in most parts of South Africa. Theron (pers. comm., 1978) observed that both white and red clover (Trifolium pratense) were used by farmers in the Highland Sourveld of Natal. Despite the apparent popularity of clovers as a companion for Italian ryegrass in this region, their potential to cause bloat has deterred many producers from introducing them into pasture production systems. With this partly in mind, Wasserman (1978) also suggested Boyds clover (Lotus hispidus), wooly pod vetch (Vicia dasycarpa) and serradella (Ornithopus sativus) as possible alternatives to red and white clover.

1.4 Nitrogen fertilization

Many comparative studies have been conducted between grass and mixed grass/legume pastures (Ball, 1970; During, 1972; Holmes & Wheeler, 1973; Harris, Turner, Johnstone, Ryan & Hirkey, 1973). A typical response is that published by the British Ministry of Agriculture, Fisheries and Food (Anon, 1980) showing relatively high yield of the mixed grass-legume pasture at low levels of N and a lower response to N compared to grass alone (Table 1.1). Similar yields were obtained at high levels of N. However Tainton (1981) suggested that these responses were unlikely to be the same under irrigated conditions in South Africa. Furthermore, little information seems to be available on animal responses to grass and grass/legume pastures at different levels of N-fertilization. However, although N application is known to increase dry matter (DM) production, two recent studies (Barrow, Bransby & Tainton, 1979; Bransby, unpublished data) have shown that animal weight gain on kikuyu (Pennisetum clandestinum) pastures decreases with increasing levels of N. Consequently, recorded gain/ha was little different between low and high levels of N.

Most on farm experience with temperate irrigated pastures in the Highland Sourveld has been obtained in dairy enterprises using Italian ryegrass without the inclusion of a legume. Traditionally, therefore, relatively high levels of N (300 to 400 kg/ha) have been applied to these

TABLE 1.1 Nitrogen use and expected herbage production.

	N application kg/ha	Herbage dry matter yield t/ha	Cow grazing days/ha	ha/cow for summer grazing
	0	6,6	330	0,60
	100	8,4	420	0,48
GRASS CLOVER	200	9,8	490	0,41
SWARDS	300	11,0	550	0,36
	400	12,0	600	0,33
	0	3,2	160	1,25
	100	6,2	310	0,65
ALL GRASS	200	8,6	320	0,47
SWARD	300	10,4	520	0,39
	400	11,8	590	0,34

pastures. Even at an N level of 225 kg/ha on dryland pastures Bransby (1985) identified the cost of N fertilization as a major component of expenditure in a beef stocker system based on grass pastures. As such, he concluded that animal response (as opposed to response of DM yield) to pastures fertilized by different levels of N deserved further research attention.

1.5 Stocking rate

Edwards (1981), stated that the rate at which a pasture is stocked (animals/ha) is perhaps the most important single factor in grazing management which affects the level of animal production under grazing conditions. Although there is some disagreement on the details of the average daily gain (ADG) - stocking rate relationship, it is generally accepted that, as stocking rate increases, ADG decreases while gain/ha increases to reach a maximum and then decreases (Riewe, 1961; Mott & Lucas, 1952; Jones & Sandland, 1974; Edwards, 1981; Bransby, 1984). However, although stocking rate affects ADG through its affect on the pasture, ADG and gain/ha in most stocking rate trials has been related to stocking rate. Bransby et al.(1985) point out that this is essentially relating animal gain to animal numbers, thus giving no indication of how the condition of the pasture influenced animal performance in grazing intensity studies. They therefore suggested that at least the quantity of herbage present should be measured in grazing intensity trials, and subsequently showed how gain/ha can be related to herbage present (Fig. 1.2). This procedure then facilitates the estimation of a level of herbage present which results in maximum gain/ha.

Bransby, Conrad and Dicks (unpublished data, 1985) also pointed out that there is always a possibility that stocking rate x treatment

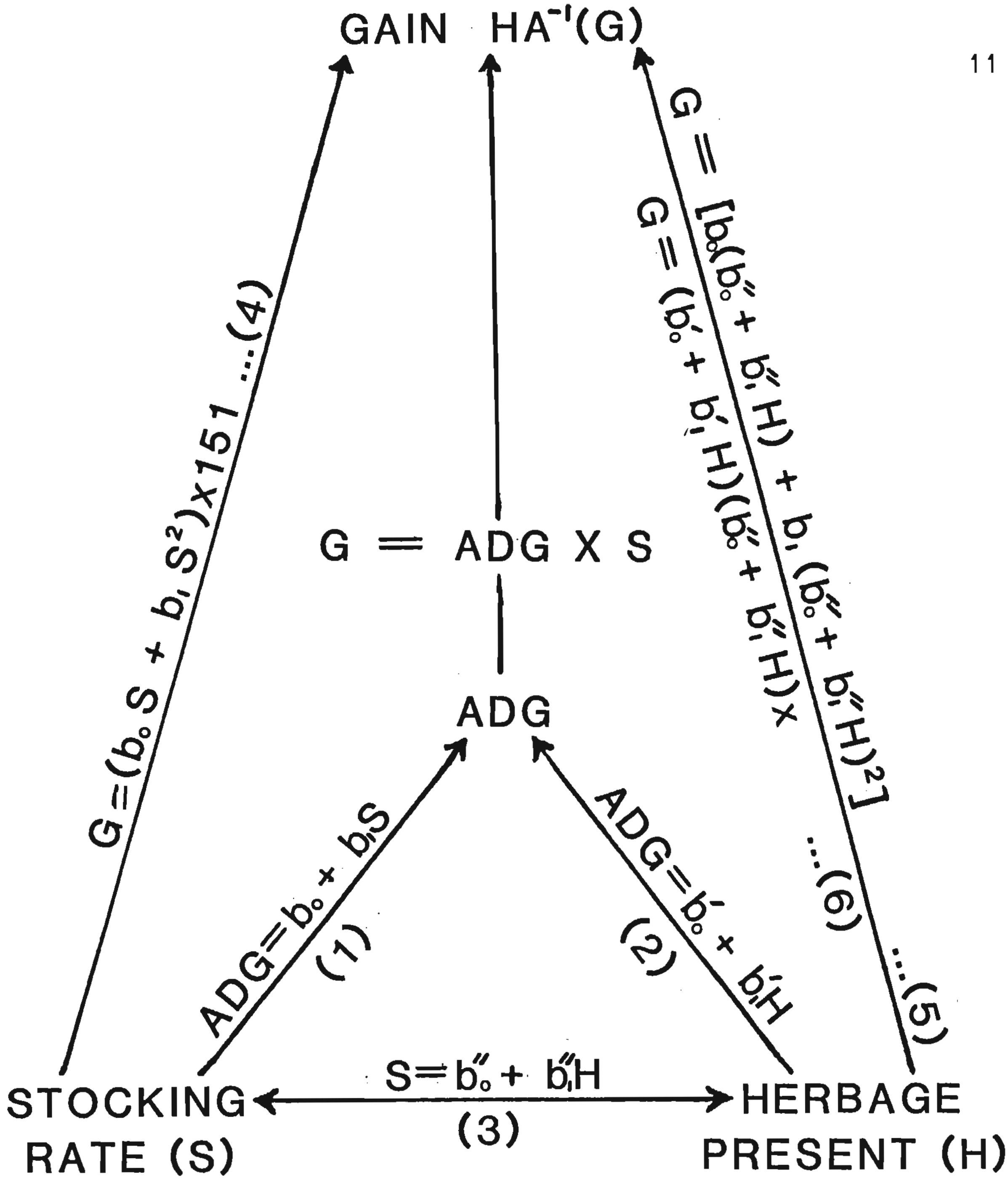


Fig. 1.2 Mathematical links between grazing variables (after Bransby *et al.*, 1985, unpublished data).

interactions may exist in grazing trials. Consequently, grazing trials which are conducted at a single stocking rate or grazing intensity (in the case of put-and-take trials) are not able to detect such interactions. Furthermore, if an interaction does exist, results from single stocking rate trials will apply only to the stocking rate used in the particular grazing trials concerned.

1.6 Grazing management and method of stocking

In general terms, pastures may be grazed either continuously or rotationally. Under continuous grazing the main variables under the control of the producer are stocking rate, size of paddocks, shape of paddocks and location of fencing. Rotational grazing, however, introduces a number of additional variables such as the number of sub-paddocks and rate of movement of stock. Consequently, rotational grazing schemes are complex and likely to be less repeatable than continuous grazing. This lead to Bransby, et al. (1977) suggesting that, due to its relative simplicity, continuous grazing might be regarded as a standard form of grazing management for testing pasture treatments under grazing, and with which other forms of grazing management can be compared.

Grazing trials may be conducted under variable stocking (put-and-take) or fixed stocking, but there has been considerable disagreement about the suitability of these two methods of stocking. Critics of fixed stocking suggest that this method of stocking may allow animal potential to exceed pasture potential, thus introducing bias, and that variable stocking overcomes these difficulties (Mott and Lucas, 1952; and Matches, 1970). Proponents of fixed stocking, on the other hand, have claimed that results derived from variably stocked trials may often have little application tc farm practice. Comparisons between the two methods have shown little or no difference in results (Burns, Mochrie, Gross, Lucas and Teichman, 1970; Brockett, 1978).

In general, Wheeler, Burns, Mochrie and Gross (1973) concluded that fixed stocking was appropriate where approximate carrying capacities were known and did not vary, and where results were to be directly applied to practice. Variable stocking was considered more appropriate when results were to be extrapolated to practice and when the carrying capacity of the pasture was both unknown and expected to vary.

1.7 Economic analysis

The development of production functions facilitates a functional approach to economic analysis (Bishop & Toussaint, 1958; Doll & Orazem, 1978). Expression of gain/animal and /ha in terms of stocking rate therefore allows income, expenditure and profit to be expressed in terms of stocking rate. This was demonstrated by Booysen, Tainton and Foran (1975) and Edwards (1981), but the weakness of procedures described by these authors is that they did not allow for differential buying and selling prices. Riewe (1981) and Bransby (1985) on the other hand, presented more realistic analyses by allowing for different price margins (selling price minus buying price). In addition, Bransby (1985) was also able to build annual rainfall into his model which was used to predict long term economic optimum stocking rates, while Bransby and Conrad (1985) demonstrated how income, expenditure and profit can be expressed in terms of standing herbage. The latter approach facilitated identification of an economic optimum level of standing herbage.

All economic analyses of stocking rate data which were reviewed were open to the criticism that they had narrow application in practice. For example, none of the animals used by Bransby (1984; 1985) were in slaughter condition at the end of the grazing trial. Hence, economic analysis of these data represent only the grazing phase of a production system which would presumably include a finishing phase in the feedlot. This analysis would therefore apply only to a producer who bought stocker cattle, grazed them on pasture and sold them to a feedlot. Consequently, if a producer wished to feedlot his cattle himself after the pasture phase, such analyses would not indicate the economic implications of compensatory growth which might be expected from animals which had low gains as a result of a high stocking rate. In other words, the economic optimum stocking rate for a stocker operation on pasture alone may be quite different to that for a system which included both a pasture and feedlot phase.

1.8 Objectives

The primary objective of this study was to increase net farm income in the Highland Sourveld of Natal by developing pasture based fat lamb production systems. In order for such a system to be accepted by the farming community, it was important that it be compatible with current farming practice, and that the study include a realistic and detailed economic analysis. Secondary objectives therefore, included the following:

a) determination of the most suitable currently available pasture species or species mixture;
b) determination of the optimum level of N fertilization;
c) establishment of biological and economic optimum stocking rates;
d) projection of expected income, expenditure and profit and, if possible,
e) verification of proposals eminating from the study on a farm scale.

2. GENERAL PROCEDURE

2.1 Introduction

The research programme described in this study consisted of two small plot trials (for evaluating pasture species and response to nitrogen) and two grazing trials (for evaluating pasture species, response to N and response to stocking rate). The site was common to all experiments and the same procedure was used in many aspects of the two grazing trials. For convenience, therefore, all aspects of the procedure for these experiments are described in this chapter. However, the procedure for the economic evaluation (Chapter 6) is integrated into the total analysis.

2.2 Site description and climate

The research site was situated on the author's farm, "Wilanda Downs", 15 km east of Underberg in Natal (29°20'E and 29°40'S). It was almost level (slope 3%) and the soil was classified as a Hutton form (Scotney, 1979; MacVicar, Loxton, Lambrechts, Le Roux, von M. Harmse, de Villiers, Verster, Merryweather & van Rooyen, 1977). This soil was well drained, highly leached and was mostly deeper than 90 cm. The soil pH was 4,3 in KCl, but due to previous liming, contained low levels of free aluminium.

"Wilanda Downs" falls within the moist phase of the Highland Sourveld (Bioclimatic sub-region 4e according to Phillips, 1973). The mean annual rainfall over 20 years was 1025 mm, with 80 mm falling between May 1 and September 30. Mean daily temperature per month varied from 7,7°C in July to 17,3°C in January. Although winter days are warm (20,0°C), heavy frosts occur (with temperatures as low as -9°C) almost every night for a 100 - 120 day period in mid-winter.

2.3 Species trials

Different pasture species were initially evaluated alone and in mixtures in a small plot trial. Based on the results of this trial, the best grass/legume mixture was compared with ryegrass alone in a grazing trial, since ryegrass pastures were the most widely used temperate pastures on farms, primarily due to the fear of bloat from legume or grass/legume pastures.

2.3.1 Small plot trial

The small plot trial was conducted in 1980, 1981 and 1984. In each year plots were seeded on a well prepared seedbed in February and monitored from April until January the following year. Following a soil analysis (Table 2.1) phosphate (P) and potassium (K) were applied at rates of 60 and 150 kg per hectare respectively during seedbed preparation.

TABLE 2.1 Soil analysis of the species small plot trial.

	Parts per million (ppm)
Phosphate (P)	22
Potash (K)	58
Calcium (Ca)	751
Magnesium (Mg)	146
Aluminium (Al)	68

Treatments included five legumes, a mixture of red and white clover and Midmar Italian ryegrass alone, each legume mixed with ryegrass and both red and white clover mixed with ryegrass (Table 2.2). The trial was laid out in a split plot design with cutting interval (3 and 6 weeks) forming the whole plot treatments and pasture species or species mixtures in sub-plots. Sub-plots measured 8 x 4 m and there were 6 replicates (Plate 3).

PLATE 3. A view of the small plot trial for species evaluation.

PLATE 4. Harvesting the species small plot trial in the foreground, with the adjacent grazing trial in the background. Note also, the evidence of typical misty spring weather in the distance.

At harvesting a 1 m border was allowed at each side of every sub-plot, and a 1,5 m border at each end. This resulted in a net sub-plot size of 5 x 2m.

Seeding rates used (Table 2.2) were those recommended by the Department of Agriculture (Edwards, 1979) and the same rate was used for each species whether it was planted alone or in a mixture. Legume seeds were inoculated with appropriate species of Rhizobium and pelleted with lime. The seed was planted in rows by hand and where there was a grass/ legume combination the legume rows alternated with the grass rows. Thereafter, the trial was rolled and irrigated with a sprinkler system. Supplementary irrigation was subsequently applied throughout the trial to ensure at least 25 mm every 10 days.

Ryegrass sub-plots were top-dressed with 300 kg N/ha (as limestone ammonium nitrate) per season while legume and grass/legume sub-plots received 200 kg N/ha. This was based on the assumption that legumes would fix in the order of 100 kg/ha of atmospheric N. Equal applications of 50 kg N/ha were applied during March, May, August and September to the legumes and grass/legume mixtures. The ryegrass received 100 kg N/ha in March and August, and 50 kg N/ha in May and September.

At harvesting, border rows were mown with a rotary mower mounted on a tractor. This material was removed, before mowing the remaining area of the plots with a tractor-mounted sickle bar mower (Plate 4). The cut herbage was then raked over by hand, weighed and sub-sampled. Sub-samples were weighed wet and dried in a forced draught oven for 48 hrs at 90°C to determine dry matter (DM) yield. Results were analysed by means of a computerized analysis of variance programme.

2.3.2 Grazing trial

Based on results from the small plot trial, ryegrass mixed with red and white clover was chosen as the best pasture to be compared with

TABLE 2.2 Species and species combinations, together with seeding rates, included in the small plot trial.

			Seed Rate (kg/ha)
1	Midmar Italian ryegrass (ryegrass)	Lolium multiflorum	15
2	Ladino clover (white clover)	Trifolium repens	3
3	Kenland red clover (red clover)	Trifolium pratense	8
4	Boyds clover (lotus)	Lotus hispidus	5
5	Serradella (serradella)	Ornithopus sativus	15
6	Wooly pod vetch (vetch)	Vicia dasycaspa	15
7	Red and white clover		
8	Ryegrass and white clover		
9	Ryegrass and red clover		
10	Ryegrass and red and white clover		
11	Ryegrass and lotus		
12	Ryegrass and serradella		
13	Ryegrass and vetch		

ryegrass alone (the most widely used irrigated winter pasture on farms) under grazing. These two pastures were established to a 2 ha area after preparing a good seedbed in February, 1981. During seedbed preparation P, K, Ca and Mg were applied to raise the levels of these elements in the soil to 80, 250, 750 and 50 ppm respectively, based on soil analysis. The same seeding rates and irrigation schedule that were used in the small plot trial were also applied in the grazing trial. The whole trial was top-dressed with 75 kg N/ha in March, May, August and October, making a total of 300 kg N/ha for the season.

A randomized blocks design was used to evaluate each of the two pastures grazed at three stocking rates (20, 28 and 36 sheep units/ha) in three replicates. Grazing started on May 1 with 50 - 60 kg ewes suckling single lambs with an average weight of 10.8 kgs. Three ewe-lamb pairs were randomly allocated to each treatment and stocking rate was adjusted by varying the size of experimental paddocks. Consequently, there were 9 sheep units per stocking rate (3 sheep units x 3 replicates) and 27 sheep units for each of the ryegrass and ryegrass/clover pastures (3 sheep units x 3 stocking rates x 3 replicates).

Once the lightest lambs had reached 18 kg (which meant that the heavier lambs on the light stocking rates ranged from 24 to 28 kg) all lambs were weaned. Ewes were returned to graze on veld while lambs remained on their respective experimental paddocks at the same stocking rate in lambs/ha as had previously been applied in ewe-lamb pairs/ha. When the average weight of lambs in a paddock reached 40 kg the group was marketed immediately to the abattoir.

While grazing on the experiment, ewes and lambs were weighed (unshrunk) periodically and dosed every 18 days for internal parasites. Prior to the trial the ewes had been inoculated for blue tongue and pulpy kidney, and the lambs were inoculated for pulpy kidney during the trial period.

Pasture accessibility was measured periodically with a pasture disc meter and expressed in cm of disc meter height (disc height). This was done by calculating the mean of 50 readings taken in each paddock on a given day. Average disc height for a paddock in a given period was calculated as an average of the mean disc heights for that paddock over all the days on which disc height was measured within that period. The disc meter used was constructed according to the standard specifications recommended by Bransby and Tainton (1977). Since the relationship between disc height and DM yield changes continually with time (Bransby & Tainton, 1977; Bransby, 1983) and in view of no technical assistance in this research programme, it was decided not to calibrate the disc meter against DM yield. However, Bransby, Matches and Krause (1977) suggested that this might well not be necessary in grazing trials. It was therefore considered that the disc meter was used to measure pasture accessibility (as an index of how easily animals could prehend the herbage) rather than herbage availability or herbage present (kg/ha).

Initially the intention was to analyse the data by means of an analysis of variance. However, since the interest was primarily in the different stocking rate trends which might occur between ryegrass and ryegrass/clover pasture, the regression modelling procedure described by Bransby, Conrad and Dicks (unpublished data) was considered more appropriate. Assuming that average daily gain (ADG) is linearly related to stocking rate (S), then

$$ADG = b_0 + b_1 S \qquad [2.1]$$

Considering equation 2.1, the regression lines for a number of treatments can be compared by using dummy variables (Draper & Smith, 1966).

A model was set up as follows :

$$ADG = \beta_0 + \sum_{j=1}^{n-1}\alpha_j\beta_{0j} + \beta_1 S + \sum_{j=1}^{n-1}\alpha_j\beta_{1j}S \qquad [2.2]$$

The parameters β_0 and β_1 measure the intercept and slope respectively of the line for the "control" treatment (arbitrarily chosen), and β_{0j} and β_{1j} the difference in intercept and slope between treatment j and the control treatment. The dummy coefficients α take on values 0 for the control and 1 for the jth subsequent treatment, there being n treatments in total.

In terms of this model, a test of the null hypothesis $\beta_{1j} = 0$ is equivalent to testing whether the lines for treatment j and the control are parallel. If such a test is not significant the term β_{1j} may be set to zero, which is equivalent to reducing the model by one term and effectively making the control and the jth lines parallel. If, after accepting the null hypothesis $\beta_{1j} = 0$, a test is made for $\beta_{0j} = 0$ and this is also accepted, the control and jth line are in effect reduced to one co-incident line. In each case the error term used was the pooled deviations from regression. A procedure of this nature was followed, testing for parallelism and co-incidence until the model was reduced to its simplest form. Significantly different slopes represent a treatment x stocking rate interaction, while significantly different intercepts of parallel lines represent a significant main effect. The relationship between ADG and disc height, and between stocking rate and disc height were examined in the same way.

2.4 Nitrogen fertilization trials

As for the species evaluation, pasture response to nitrogen fertilization was evaluated in a small plot trial and under grazing. However, in both these trials ryegrass mixed with red and white clover was the only pasture examined, since it had proved superior to the other pastures tested in small plots and under grazing.

2.4.1 Small plot trials

The small plot trial for assessing DM yield response to nitrogen fertilization was situated adjacent to the small plot species evaluation trial, and established in February, 1981. Seeding procedure was precisely the same as for the species evaluation trial, as was the harvesting procedure (section 2.3.1). All plots received 75 kg N/ha at planting to reduce the negative-N effect which was expected following the ploughing in of organic residue. Six levels of N were then applied to the pasture in a randomized blocks design with three replicates. These levels were 0, 100, 200, 300, 400 and 500 kg N/ha in total over the growing season (which ended in January the following year), excluding the initial 75 kg N/ha on all plots. This nitrogen was applied as limestone ammonium nitrate in four equal dressings during March, May, August and September.

2.4.2 Grazing trial

The trial to evaluate the response of ryegrass/clover pasture to nitrogen under grazing was established in 1982, and repeated in 1984. It essentially replaced the 1981 grazing trial in which ryegrass had been compared with ryegrass + clover. In view of the uniform nature of the site (Plates 5 & 6), replication was considered unnecessary. The trial therefore included three levels of N (200; 300 and 400 kg N/ha*), each grazed at five stocking rates. Four stocking rates of the 200 and 300 kg N/ha treatments were common, while three stocking rates were common to all three levels of N (Table 2.3). Treatments were randomly distributed within the experimental area and nitrogen was applied in equal top-dressings during March, May, August and September in the form of limestone ammonium

*These levels are in addition to an initial application of 75 kg N to offset the negative effect, but for convenience will be referred to as 200; 300 and 400 kg N/ha.

PLATE 5. A view of the grazing trial in June, 1984 with typical, dense, natural grassland in the foreground.

PLATE 6. The grazing trial was grazed by ewes + lambs until weaning which took place when the lightest lambs were 18 kg. At least 25 mm of irrigation water was applied every 10 days to all paddocks.

TABLE 2.3 Sheep grazing trial with three nitrogen levels. Each nitrogen level was grazed at five stocking rates.

	Nitrogen Level (kg N/ha)		
	200	300	400
	16		
	20	20	
Stocking	24	24	24
Rate	28	28	28
(sheep/ha)	32	32	32
		36	36
			40

nitrate. Animal management and allocation to treatments was done in the same way as in 1981 (section 2.3.2).

However, in 1982 the May 1 average initial lamb weight was 6.7 kg. In 1984, due to a shortage of suitable ewes and lambs, the trial started on May 15, when the average lamb weight was 3.6 kg. Mutton Merino ewes were used in 1982 while in 1984 they were Corriedale. Furthermore, in 1984 there was a high proportion of twins. Consequently, ewes were blocked and randomly allocated to treatments so that one out of the three ewes in each paddock was suckling twins. In 1982 the procedure at weaning was the same as for 1981 i.e. lambs remained in their respective paddocks so that the stocking rate in lambs/ha was equivalent to the pre-weaning stocking rate in ewe-lamb pairs/ha. However, this procedure could not be followed in 1984 because of the twins. The two single lambs and one of the twins (randomly identified) were therefore retained on each paddock to achieve the same stocking rate in lambs/ha as was applied in ewes/ha before weaning. Animal weighing procedure and measurement of herbage accessibility was the same as in 1981, as was the method of analysis. Due to considerable pasture growth occurring after lambs had been marketed in 1981 and 1982, in 1984 additional lambs were purchased and used to graze each paddock on a put-and-take basis after the first group of lambs had been slaughtered. This part of the trial, however, was not monitored in detail. The objective was primarily to facilitate an economic evaluation of lamb production over the entire growing season of the irrigated ryegrass/clover pasture. Analysis of the stocking rate data for ewes and their lambs was conducted by means of the same regression modelling procedure used for the 1981 species evaluation under grazing (section 2.3.2).

3. PASTURE SPECIES EVALUATION

Results discussed in this chapter are from the small plot trial in which selected legumes were evaluated alone and in mixtures with Italian ryegrass, and from a comparison between ryegrass and ryegrass mixed with red and white clover under grazing. The procedure for these two trials is described in sections 2.3.1 and 2.3.2 respectively.

3.1 Small plot trials

Due to the considerable distance of the research site from a forced draught oven (2 hrs. by road), in the first season (1980) of the small plot trial an attempt was made to air-dry sub-samples before transporting them to the oven for dry matter determination. The purpose of this procedure was to economise on travelling costs. However, results in this season appeared to be variable and, therefore, unreliable. They are consequently not presented, and in the 1981 and 1984 seasons sub-samples were transported to the oven for drying immediately after harvesting on each harvesting date.

In view of the expected mid-winter drop in yield of irrigated temperate pasture species in high lying regions of South Africa (du Plessis, 1978; Smith, 1985), results were considered in terms of DM yield for the whole experimental period (May to December) as well as for the mid-winter period (June 15 to August 15). Furthermore, since the objective of this trial was to establish which pasture species or species mixtures were worthy of further evaluation under grazing, attention in the discussion of results is confined primarily to the high yielding treatments.

For the 1981 season ryegrass with red and white clover (ryegrass + clovers) provided the highest yields at both cutting intervals (Table 3.1).

TABLE 3.1 The 1981 total dry matter yields/ha for Italian ryegrass and five pasture legumes grown alone and in selected mixtures.

Grass species	3-week cut t/DM/h		6-week cut t/DM/h		% increase in yield of 6-week over 3-week cutting interval
Midmar Italian Ryegrass	9,273	(8)*	12,585	(7)*	35,7
Kenland Red & Ladino Clover	9,517	(7)	8,887	(9)	-6,6
Kenland Red (R) Clover	8,858	(9)	10,407	(8)	17,5
Ladino White (W) Clover	8,281	(10)	7,433	(11)	-10,2
Vetch	7,527	(11)	8,010	(10)	6,4
Serradella	6,324	(12)	5,109	(12)	-19,2
Lotus	0,933	(13)	1,153	(13)	-23,6
Ryegrass + R + W Clover	14,584	(1)	15,607	(1)	7,0
Ryegrass + R Clover	12,447	(4)	13,931	(5)	11,9
Ryegrass + W Clover	13,926	(2)	14,979	(2)	7,6
Ryegrass + Vetch	11,736	(5)	14,283	(4)	21,7
Ryegrass + Serradella	12,539	(3)	14,425	(3)	27,0
Ryegrass + Lotus	9,560	(6)	12,975	(6)	35,7

* Values in parentheses represent the ranking of treatments within a cutting interval.

At the 3-week cutting interval total DM yield for ryegrass + clovers was significantly higher ($p \leq 0,05$) than for the 6-week cutting interval. The yield of ryegrass + clovers was significantly higher ($p \leq 0,01$) than ryegrass or any of the legumes and the clover mixture grown on its own. At the 3-week cutting interval the ryegrass + clovers yield was 57% higher than ryegrass alone, while for the 6-week cutting interval the corresponding advantage was 24%. However, ryegrass + clovers yielded only 4,7% and 4,2% higher than ryegrass + white clover for the 3- and 6-week cutting intervals respectively. All treatments except Serradella, white clover and red + white clover showed an increase in yield from the 3-week to the 6-week cutting interval. This suggests that these three treatments were not well adapted to grown out conditions. On the other hand, ryegrass on its own yielded 35,7% higher when cut every 6 weeks than when cut every 3 weeks, and obviously contributed strongly to the trend from the 3- to 6-week cutting interval when grown with the legumes.

On the whole, trends in the 1984 season were similar to those in the 1981 season (Table 3.2). However, the advantage of ryegrass + clovers over serradella in this year over the second highest yields, that of ryegrass + serradella, was highly significant ($p \leq 0,01$). For the 3-week interval this difference was 11,7% while for the 6-week interval it was 20,6%. In addition, the advantage of ryegrass + clovers over ryegrass alone was greater for the 6-week cutting interval (34,7%) than for the 3-week interval (23,4%). The opposite trend was observed in the 1981 season. White clover and serradella again showed a decrease in yield from the 3-week to the 6-week cutting interval, but red + white clover showed an increase in yield, compared to a decrease in the 1981 season. A possible reason for this difference between the two seasons is that in the 1981 season white clover might have had the major influence in the red + white

TABLE 3.2 The 1984 total dry matter yield/ha of Italian ryegrass and five pasture legumes grown alone and in selected mixtures.

Grass species	3-week cut t/DM/h		6-week cut t/DM/h		% increase in yield of 6-week over 3-week cutting interval
Midmar Italian Ryegrass	10,92	(5)*	12,71	(6)*	16,4
Kenland Red & Ladino Clover	8,20	(10)	8,73	(9)	6,5
Kenland Red (R) Clover	7,68	(1)	8,07	(10)	5,1
Ladino White (W) Clover	8,98	(9)	7,49	(11)	-16,6
Vetch	5,33	(12)	6,12	(12)	14,8
Serradella	9,56	(8)	9,09	(8)	-4,9
Lotus	5,09	(13)	6,11	(13)	20,0
Ryegrass + R + W Clover	13,53	(1)	17,12	(1)	26,5
Ryegrass + R Clover	10,05	(7)	13,30	(4)	32,3
Ryegrass + W Clover	11,07	(4)	12,94	(5)	16,9
Ryegrass + Vetch	10,10	(6)	12,33	(7)	22,1
Ryegrass + Serradella	12,11	(2)	14,20	(2)	17,3
Ryegrass + Lotus	11,39	(3)	13,67	(3)	20,0

* Values in parentheses represent ranking of treatments within a cutting interval.

clover mixture, while in the 1984 season red clover had the greater influence.

For the mid-winter period in 1981, vetch was the only legume alone treatment which provided harvestable yield for the 3-week cutting interval, and furthermore, this yield was higher than that for ryegrass alone (Table 3.3). Despite this, the ryegrass + clovers treatment again provided the highest yield, followed by ryegrass + white clover and then by ryegrass + vetch. This result is difficult to explain since the ryegrass + vetch treatment yielded less than the sum of yields from ryegrass and vetch alone, while all other ryegrass + legume mixtures except ryegrass + lotus provided higher yields than ryegrass alone, even though these legumes yielded nothing when grown on their own.

At the 6-week cutting interval the yield of vetch had dropped compared to the 3-week interval. However, yield of all other treatments increased from the 3- to the 6-week cutting interval, and in general, this increase was much greater than that observed for total yield (Tables 3.1 and 3.2). These findings therefore support the observation of Smith (1985) that rotational grazing (assumed to correspond with infrequent defoliation) is capable of carrying more stock than continuous grazing (assumed to correspond with frequent defoliation) in mid-winter on irrigated ryegrass. Vetch was again the highest yielding legume treatment but in this case ryegrass alone provided a significantly higher ($p \leq 0,01$) yield. Ryegrass + clovers provided the highest yield followed by ryegrass + white clover, ryegrass + red clover, and then ryegrass + vetch. A possible explanation for the poor performance of ryegrass + vetch relative to the other ryegrass + legume mixtures is that ryegrass and vetch may have competitive growth habits, while the growth habits of the other legumes may be complementary to ryegrass.

TABLE 3.3 The 1981 DM yield from mid-June to mid-August for Italian ryegrass and five pasture legumes grown alone and in selected mixtures.

Grass species	3-week cut t/DM/h		6-week cut t/DM/h		% increase in yield of 6-week over 3-week cutting interval
Midmar Italian Ryegrass	0,959	(7)*	2,687	(5)*	180,2
Kenland Red & Ladino Clover	0,000		0,706	(9)	
Kenland Red (R) Clover	0,000		0,370	(11)	
Ladino White (W) Clover	0,000		0,321	(12)	
Vetch	1,388	(4)	1,223	(9)	-11,9
Serradella	0,000		0,613	(10)	
Lotus	0,000		0,487	(13)	
Ryegrass + R + W Clover	1,733	(1)	3,433	(1)	98,1
Ryegrass + R Clover	1,223	(5)	2,825	(3)	31,0
Ryegrass + W Clover	1,670	(2)	3,387	(2)	102,8
Ryegrass + Vetch	1,581	(3)	2,696	(4)	70,5
Ryegrass + Serradella	1,005	(6)	2,506	(6)	149,4
Ryegrass + Lotus	0,793	(8)	2,360	(7)	197,6

* Values in parentheses represent ranking of treatments within a cutting interval.

In general, yields in 1984 were lower than in 1981, but patterns between treatments were similar (Table 3.4). Vetch was again the highest yielding legume treatment while ryegrass + clovers provided the highest overall yield. The relative increase in yield from the 3- to the 6-week cutting interval was higher than in the 1981 season.

Since ryegrass + clovers appeared to be the best alternative pasture to the currently used ryegrass alone, cumulative yield is presented by harvest (Fig. 3.1) and growth rate by interval between harvests (Fig. 3.2) for these two pastures. In 1981 cumulative yield of ryegrass + clovers was higher for the 6-week than for the 3-week cutting interval between early June and early September, and from mid-October onwards (Fig. 3.1a). For ryegrass alone, cumulative yield for the 6-week cutting interval was higher than that for the 3-week interval throughout the experimental period. However, cumulative yield of both cutting intervals on ryegrass + clovers was above that for both cutting intervals on ryegrass alone. From the end of May to the beginning of July there was no growth at the 3-week cutting intervals on both treatments, as indicated by the zero slope for cumulative yield over this period. In general, growth rate seemed to increase sharply after the beginning of September.

In 1984 cumulative yield showed a smoother pattern than in 1981, with no complete cessation of growth in any of the treatments during mid-winter. However, the yields for the 3-week cutting interval on ryegrass + clovers was almost identical to that of the 6-week cutting interval on ryegrass alone for the whole experimental period. Growth rate, again, showed a marked increase in early September.

Trends in growth rate are better illustrated in Figure 3.2. The variation between cutting intervals in growth rate up to the first harvest cannot be explained, since up to this time no pre-harvest cutting had been

TABLE 3.4 The 1984 DM yield from mid-June to mid-August for Italian ryegrass and five pasture legumes grown alone and in selected mixtures.

Grass species	3-week cut t/DM/h		6-week cut t/DM/h		% increase in yield of 6-week over 3-week cutting interval
Midmar Italian Ryegrass	0,946	(3)*	2,048	(5)*	116,5
Kenland Red & Ladino Clover	0,202	(10)	0,000		
Kenland Red (R) Clover	0,101	(12)	0,000		
Ladino White (W) Clover	0,108	(11)	0,140	(10)	29,6
Vetch	0,856	(6)	1,498	(8)	75,0
Serradella	0,451	(9)	0,905	(9)	100,7
Lotus	0,062	(13)	0,084	(11)	35,5
Ryegrass + R + W Clover	1,308	(1)	3,199	(1)	144,6
Ryegrass + R Clover	0,769	(8)	2,284	(3)	197,0
Ryegrass + W Clover	0,840	(7)	1,940	(6)	131,0
Ryegrass + Vetch	0,946	(3)	1,938	(7)	104,9
Ryegrass + Serradella	0,917	(5)	2,259	(4)	146,3
Ryegrass + Lotus	1,065	(2)	2,572	(2)	141,5

* Values in parentheses represent ranking of treatments within a cutting interval.

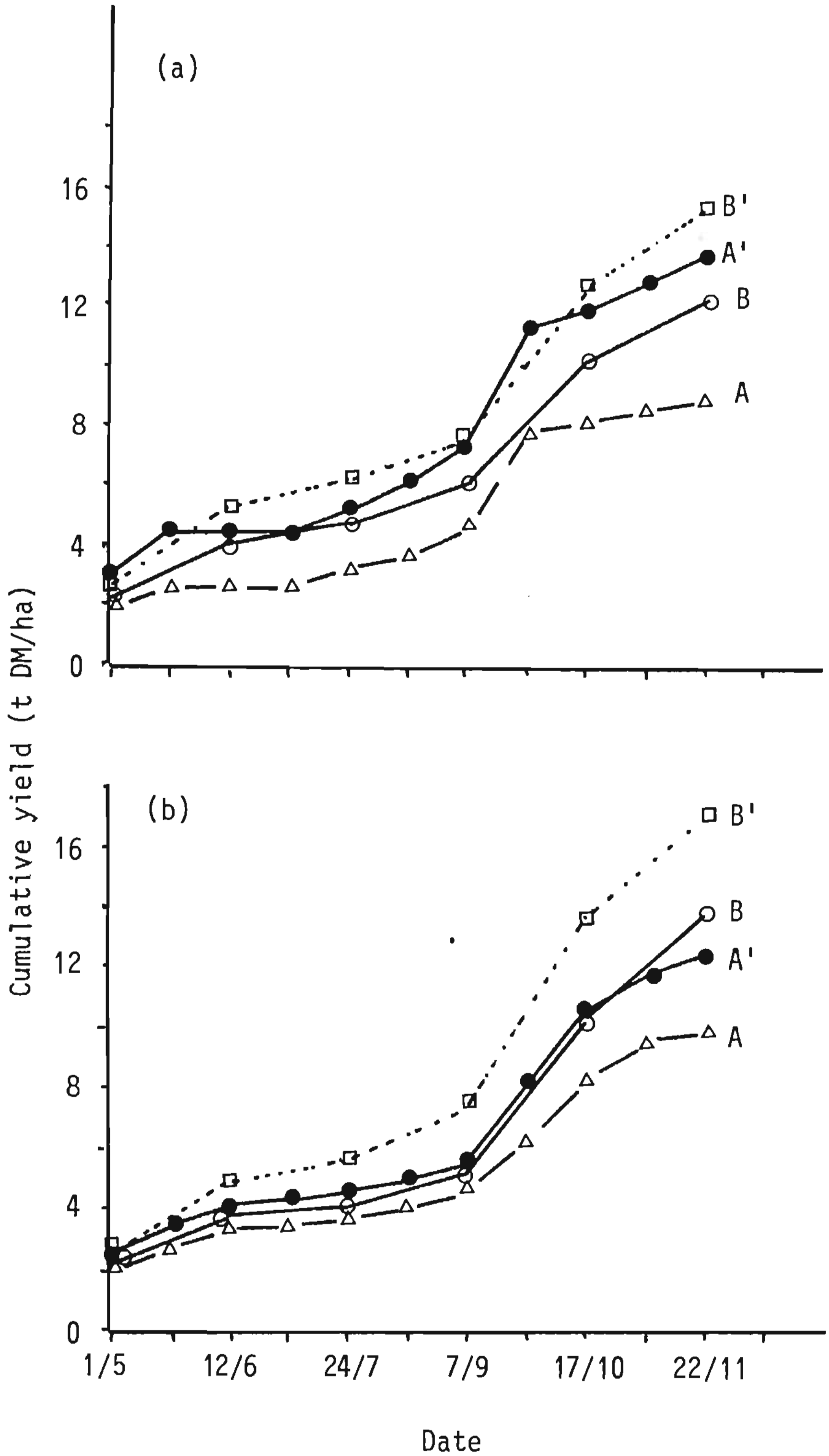


Fig. 3.1 Cumulative yield over the season for ryegrass (A) cut every 3 weeks and (B) cut every 6 weeks, and for ryegrass + clover (A') cut every 3 weeks and (B') every 6 weeks during (a) 1981 and (b) 1984.

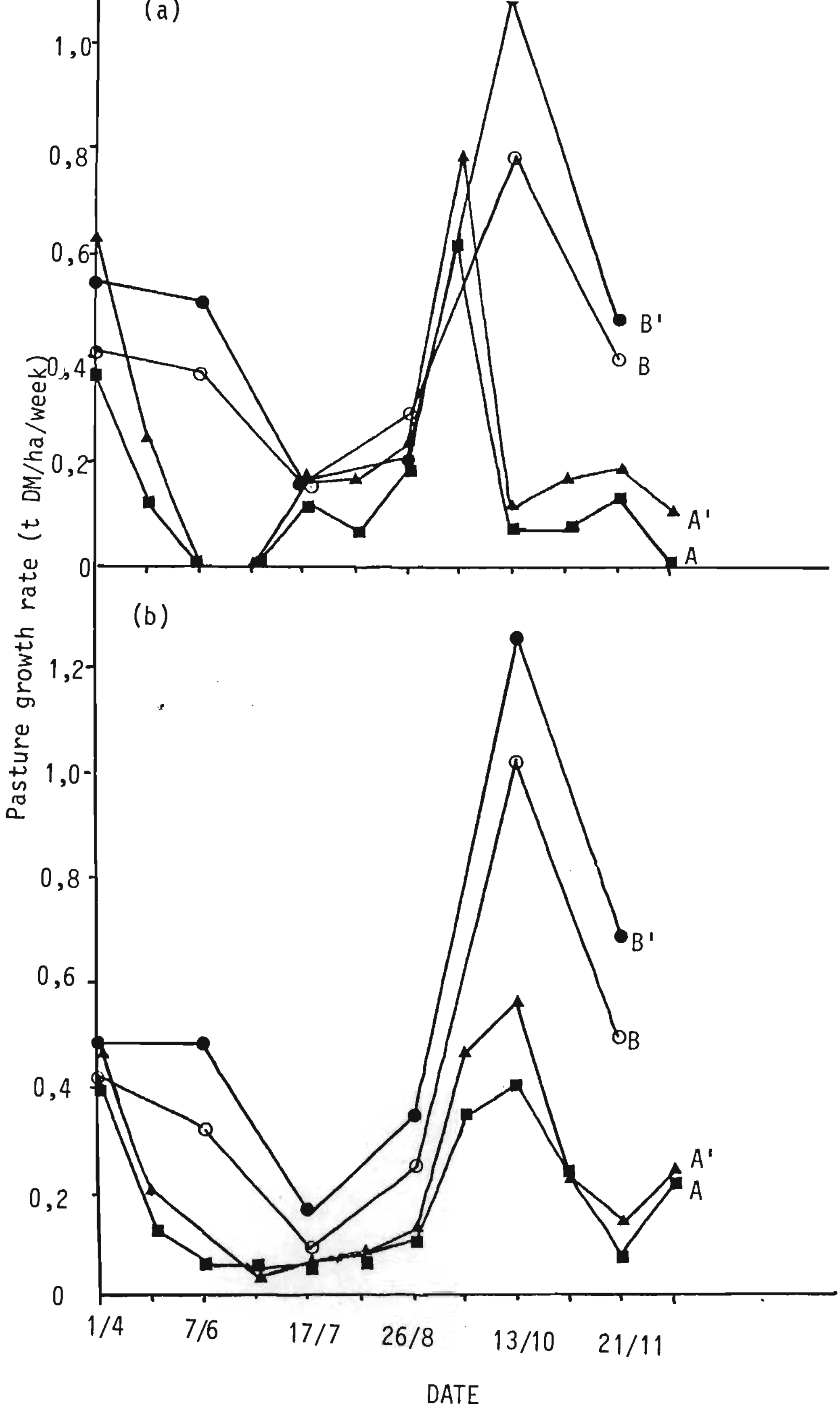


Fig. 3.2 Changes in pasture growth rate over the season for (A) ryegrass alone and (A') ryegrass + clover cut every 3 weeks and for (B) ryegrass and (B') ryegrass + clover, cut every 6 weeks during (a) 1981 and (b) 1984.

applied. The advantage of the 6-week cutting interval in mid-winter is evident, particularly in 1981 (Fig. 3.2b). The very high growth rates of the 3-week cutting interval in September of 1981 are also difficult to explain. However, of most importance is the clear cut periodic nature of the growth curves which obviously present difficulties for livestock enterprises which require a steady supply of feed through this period. As indicated by the responses to cutting interval in this experiment and the grazing work of Smith (1985), a partial solution to this problem lies in applying continuous grazing (frequent defoliation) in autumn and spring/early summer, but applying rotational grazing (infrequent defoliation) in winter.

3.2 Grazing trial

Although the absolute values of results from the small plot species trial in 1980 were considered unreliable (and were therefore not presented), they served as a useful guide for selection of potentially high yielding pastures to test under grazing. This pilot trial had indicated that ryegrass mixed with red and white clover appeared to be the highest yielding pasture combination. In view of the urgent need for grazing data, therefore, the grazing trial (described in section 2.3.2) was established to run concurrently with the second year of the small plot trial in 1981.

Due to the superior yields of ryegrass + clovers in the small plot trial and the widespread use of ryegrass alone on farms (mainly because of concern about legume-induced bloat) the emphasis in this grazing study was on comparing these two pastures for fat lamb production. Results were analysed by testing differences between the two pastures in the regressions of ADG on stocking rate, ADG on disc height (herbage availability) and stocking rate on disc height. This was done separately for ewes and lambs up to weaning, and for lambs from weaning until those on the light stocking rate (the first group to reach 40 kg) were marketed. These time intervals will be referred to as the pre-weaning and post-weaning periods respectively.

On the whole, correlation between ADG and stocking rate was good, except for the ewes on ryegrass + clovers during the pre-weaning period (Fig. 3.3a). However, only a few r values were significant due to low degrees of freedom. There appeared to be a tendency for ADG to be higher for lambs on ryegrass + clovers than for those on ryegrass alone at all stocking rates during the pre-weaning period, and at high stocking rates during the post-weaning period. However, these differences were not significant ($p \leq 0{,}05$). Consequently, data from the two pastures were pooled to compare the ADG vs. stocking rate relationships for lambs before and after weaning and for ewes during the pre-weaning period. (It must be remembered that stocking rate in Figures 3.3, 3.4 and 3.5 is expressed in lambs/ha but actually represents ewe-lamb pairs for the pre-weaning period.)

There was no significant difference in the slope of the ADG vs. stocking rate lines for ewes and for lambs before weaning. Parallel lines were therefore fitted and these lines had significantly different intercepts ($p \leq 0{,}01$) representing a significant main effect (Fig. 3.3b). The slope of the regression line for lambs after weaning, however, was significantly different ($p \leq 0{,}01$) to that for ewes and lambs before weaning, thus representing a significant stocking rate x period interaction. Hence, by using the regression modelling procedure described in section 2.3.2, the six regression lines in Fig. 3.3a were reduced to three lines (Fig. 3.3b) which indicated significant differences only. The coefficient of determination (R^2) for this linear regression model was 0,95

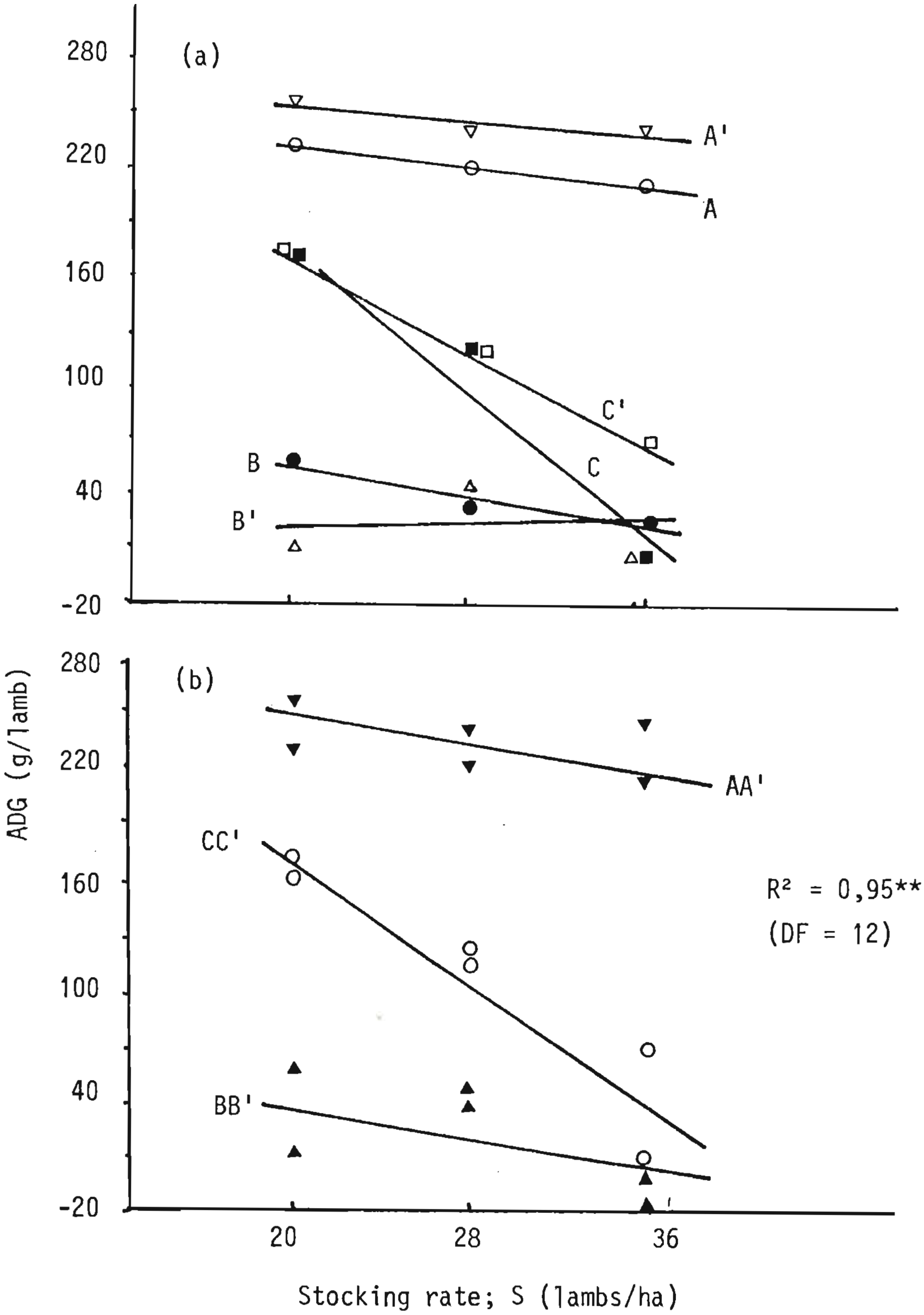


Fig. 3.3(a) Regression relationships between ADG and stocking rate for (A) lambs and (B) ewes before weaning and (C) lambs after weaning on ryegrass, and corresponding regressions (A'; B' and C' respectively) for ryegrass + clovers (Equations : A; ADG = 249 - 1,0S; r = -0,99* : A'; ADG = 26.7 - 0,69; r = -0,71 : B; ADG = 93 - 1,88S; r = -0,99* : B'; ADG = 13 + 0,38S; r = 0,18 : C; ADG = 363 - 9,50S; r = -0,96 : C'; ADG = 293 - 6,25S; r = -0,99*).

(b) Linear regression model developed by eliminating non-significant differences in (a). (Equations : AA'; ADG = 288 - 1,92S : BB'; ADG = 75 - 1,92S : CC'; ADG = 328 - 8,0S).

($p \leq 0{,}01$), thus indicating that 95% of the variation within all the data was accounted for by the three regression lines (DF = 12).

These results suggest that ADG of ewes and lambs before weaning was equally, but not strongly affected by stocking rate. For example, estimated ADG of lambs was 250 and 219g at stocking rates of 20 and 36 ewe - lamb pairs/ha, thus representing only a 12% decrease in ADG for a corresponding 80% increase in stocking rate. Estimated ADG for ewes was positive for stocking rates below 38,8 ewe - lamb pairs/ha, suggesting that ewes were receiving good nutrition. Furthermore, the fact that stocking rate affected ewes no more than lambs suggests that lambs were not gaining at the expense of ewes, or in other words, ewes were not "milking off their backs".

After weaning, lambs appeared to be far more sensitive to stocking rate than before weaning, as indicated by the significantly higher ($p \leq 0{,}01$) decrease in ADG per unit increase in stocking rates. For example, estimated ADG for lambs after weaning was 168 and 40 g for stocking rates of 20 and 36 lambs/ha respectively, thus representing a 76% decrease in ADG for a corresponding 80% increase in stocking rates. Estimated ADG for lambs before weaning was 82; 125 and 179 g higher than after weaning at stocking rates of 20; 28 and 36 ewe-lamb pairs or lambs/ha respectively, thus representing corresponding decreases in ADG of 33; 53 and 82% from before to after weaning. The reasons for the pattern described by this model cannot be determined from these relationships alone. Further interpretation is facilitated by examination of the relations between ADG and disc height, and between stocking rate and disc height.

Despite apparent differences in the ADG vs. disc height relationships for ryegrass alone and ryegrass + clovers, these differences were not significant. However, there was a slight tendency for estimated ADG at equivalent disc height to be higher for lambs on ryegrass + clovers at high stocking rates before weaning, and also for ewes on ryegrass + clovers during this period (Fig. 3.4a). The data from the two pastures were subsequently pooled, and the differences in slopes of the resultant three regression lines for ewes and lambs before weaning and for lambs after weaning were tested. Since these were not significantly different, parallel lines were fitted (Fig. 3.4b). The intercept of the line for lambs before weaning was significantly higher ($p \leq 0,01$) than after weaning, and the intercept for both these lines was significantly higher ($p \leq 0,01$) than that for ewes before weaning. The coefficient of determination for this model was 0,92 ($p \leq 0,01$). However, despite the significant difference in lamb ADG before and after weaning, it is clear that this resulted at least partly from disc height being on average, considerably higher at all stocking rates during the pre-weaning period than during the post-weaning period.

The observations above are supported by the relationships between stocking rate and disc height (Fig. 3.5a). It might be argued that in examining the relationships between stocking rate and disc height, disc height should be the dependent variable since it is influenced by adjusting stocking rate. While this is recognised as a valid argument, in order to derive relationships between gain/ha and disc height it is necessary to have stocking rate expressed in terms of disc height. For this reason stocking rate has been regarded as the dependent variable. Stocking rate on ryegrass + clover was slightly higher at all disc heights after weaning and at disc heights below 9,5 cm before weaning. However, these differences were not significant. Data for the two pastures were subsequently pooled and the difference in slopes of the resultant regression lines for the pre- and post-weaning period was tested. As disc

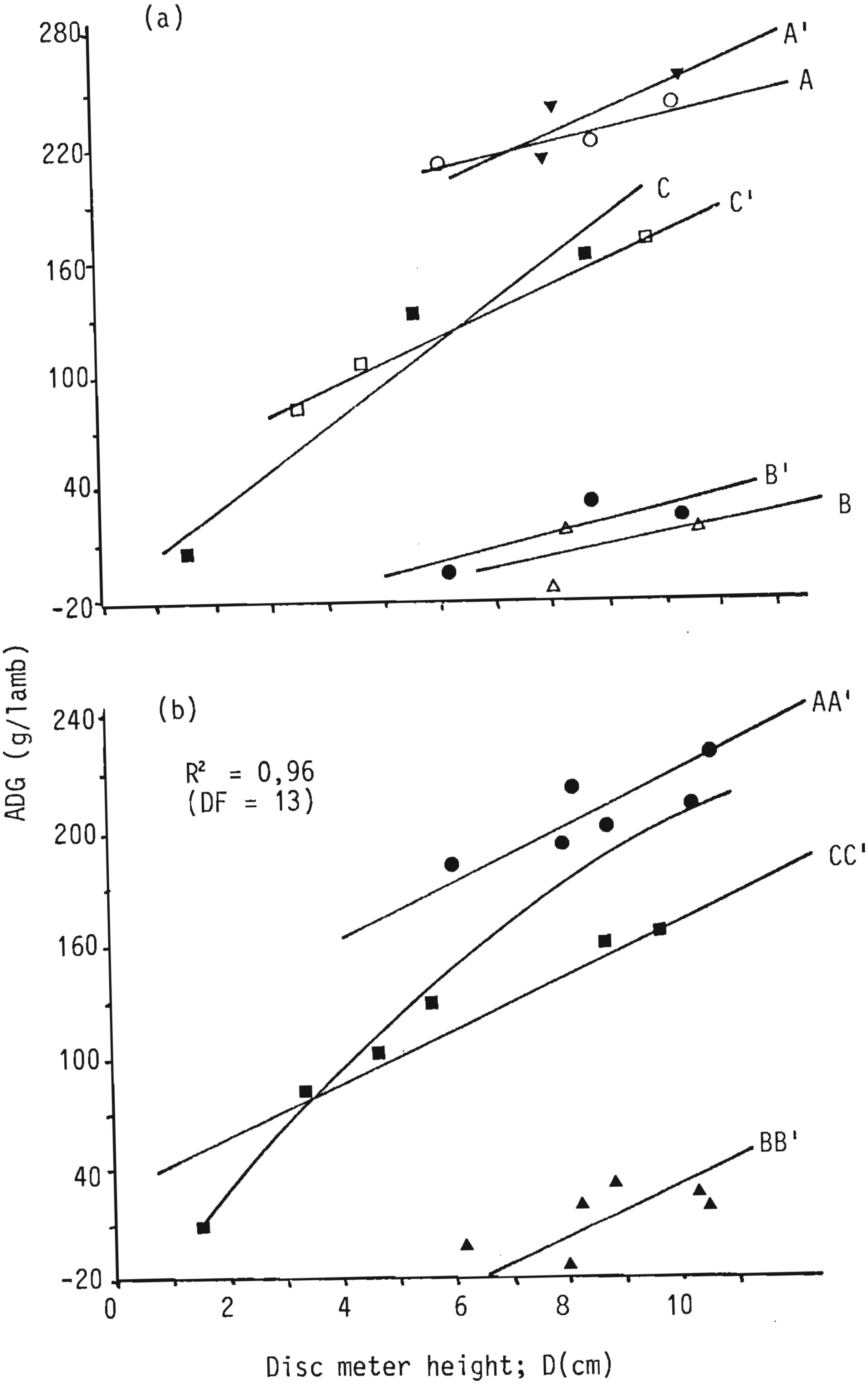


Fig. 3.4 (a) Regression relationships between ADG and disc meter height for (A) lambs and (B) ewes before weaning and (C) lambs after weaning on ryegrass, and corresponding regressions (A'; B' and C' respectively) for ryegrass + clovers. (Equations: A; ADG = 165 + 6,99D; r = 0,95 : A'; ADG = 121 + 12,98D; r = 0,81 : B; ADG = -41 + 5,6D; r = 0,56 : B'; ADG = -34 + 6,25D; r = 0,79 :C : ADG = -14 + 21,6D; r = 0,96 : C'; ADG = 39 + 13,1D; r = 0,99*).
(b) A linear regression model eliminating all non-significant differences in (a). (Equations: AA'; ADG = 106 + 14,4D : BB'; ADG = -113 + 14,4D : CC'; ADG = 28 + 14,4D).

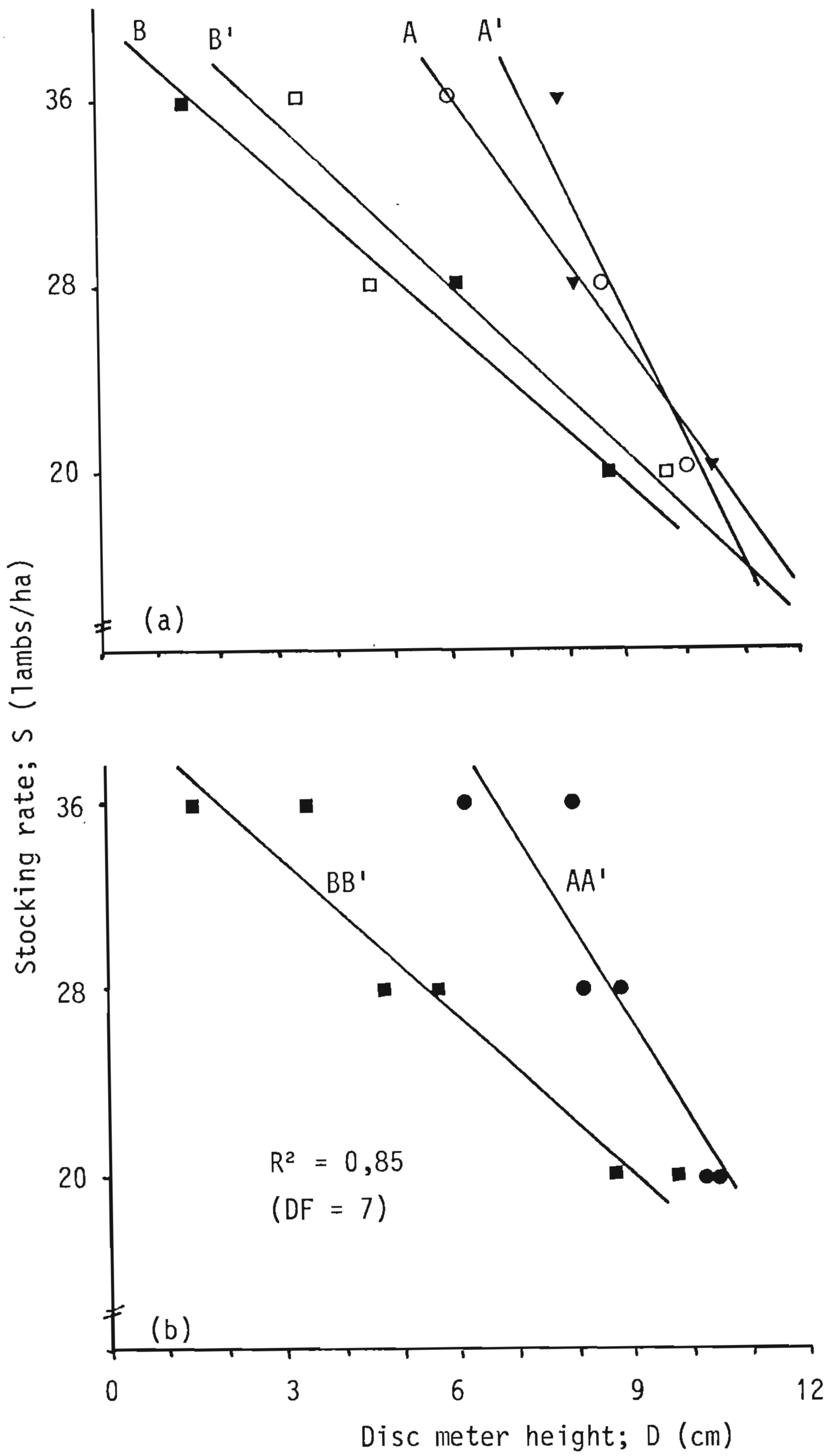


Fig. 3.5 (a) Linear regression relationships between stocking rate and disc meter height for ryegrass (A) before weaning and (B) after weaning and for ryegrass + clover (A') before weaning and (B') after weaning. (Regression equations : A; S = 59,2 - 3,71D; r = -0,99 : B; S = 39,6 - 2,21D; r = -0,99 : A'; S = 74,1 - 5.18D; r = -0,90 : B'; S = 41,5 - 2,28D; r = -0,95).
(b) A linear regression model eliminating all non-significant differences in (a). (AA'; S = 62,9 - 4,03D : BB'; S = 40,4 - 2,21D.)

height increased, stocking rate decreased at a faster rate ($p \leq 0{,}05$) in the pre-weaning period than in the post-weaning period. Due to the inversion of the dependent and independent variables, the practical significance of this result is somewhat difficult to grasp. Alternatively, therefore, it could be said that as stocking rate increased, disc height decreased more rapidly during the post-weaning period than during the pre-weaning period.

Examination of patterns in Fig. 3.4b and 3.5b facilitate further interpretation of results presented in Fig. 3.3b. Firstly, the lower disc heights observed in the post-weaning period (Fig. 3.4b), despite the removal of ewes from the pasture, seemed to be related to the low mid-winter DM production observed in the small plot trial. Since these lower disc heights occurred at the same stocking rates at which higher disc height values were recorded in the pre-weaning period, it is likely that the difference in the slope of the ADG vs. stocking rate relationships observed for lambs in the pre- and post-weaning periods was caused by the differences in pasture availability. For example, if it is assumed that the true relationship between ADG and stocking rate is non-linear, it could be expected that a linear approximation of this curve at high herbage availability would indicate a low negative slope, while if herbage availability was high a steeper slope could be expected (Fig. 3.6). Further, the marginally higher ADG of lambs on ryegrass + clovers in both pre- and post-weaning periods (Fig. 3.3a) could probably be ascribed to slightly higher herbage availability (Fig. 3.5a), and quality (Fig. 3.4a). This latter suggestion is based on the marginally higher ADG of ewes and lambs on ryegrass + clover as disc height increased in the pre-weaning period (Fig. 3.4a), and the assumption that any difference in ADG at equal disc height is a result in a forage quality difference between treatments.

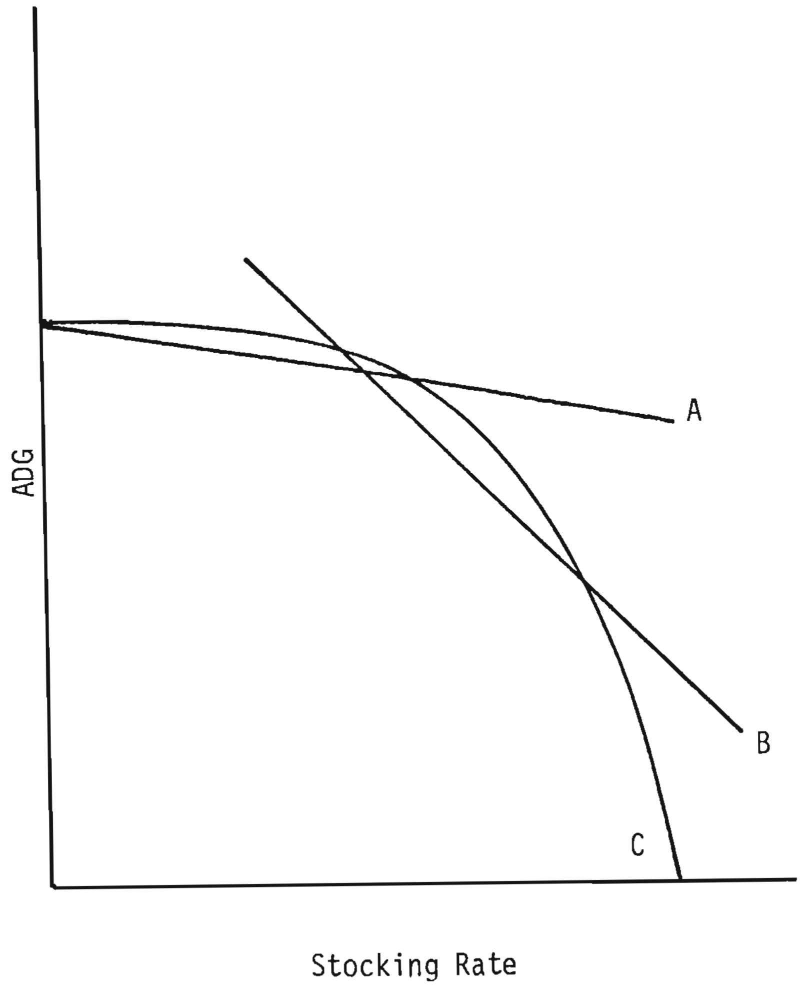


Fig. 3.6 Linear approximations of (A) the upper portion and (B) the lower portion of (C) the hypothetical "true" relationship between ADG and stocking rate.

Consequently, examination of the ADG vs. disc height and stocking rate vs. disc height relationships offered a number of logical explanations for the trends observed in the relationships between ADG and stocking rate, thus supporting the contention of Bransby, Conrad and Dicks (unpublished data).

By multiplying the ADG vs. stocking rate functions for lambs in both the pre- and post-weaning period by stocking rate and the number of days in each period (61 and 79 days respectively), relationships between lamb gain/ha and stocking rate were obtained for each period on both pastures (Fig. 3.7a). These were then added to obtain the relationship between lamb gain/ha for the sum of the two periods for each pasture (Fig. 3.7b). By equating the first derivative of these functions to zero and solving, the stocking rate which maximized lamb gain/ha could be obtained, and by substituting this value back into the original equation, the corresponding maximum gain/ha could be calculated. Gain/ha was maximized at 29,7 and 37,5 lambs/ha with corresponding maximum gain/ha of 672 and 765 kg for ryegrass and ryegrass + clovers respectively. This represented a 26,3% higher carrying capacity and a 13,8% higher gain/ha for ryegrass + clover than for ryegrass alone. It should be remembered that all the results discussed so far were for the period up to when lambs on the low stocking rate reached slaughter mass. However, lambs on ryegrass + clovers at the high stocking rate (36 animals/ha) took another 53 days to reach slaughter mass, and those on ryegrass alone at the same stocking rate weighed only 30 kg by this time, having actually lost weight over the previous three weeks (Fig. 3.8). This was primarily due to low pasture availability on ryegrass at the high stocking rate (a disc height of 1,9 and 9,9 cm for ryegrass and ryegrass + clovers respectively when the trial was terminated).

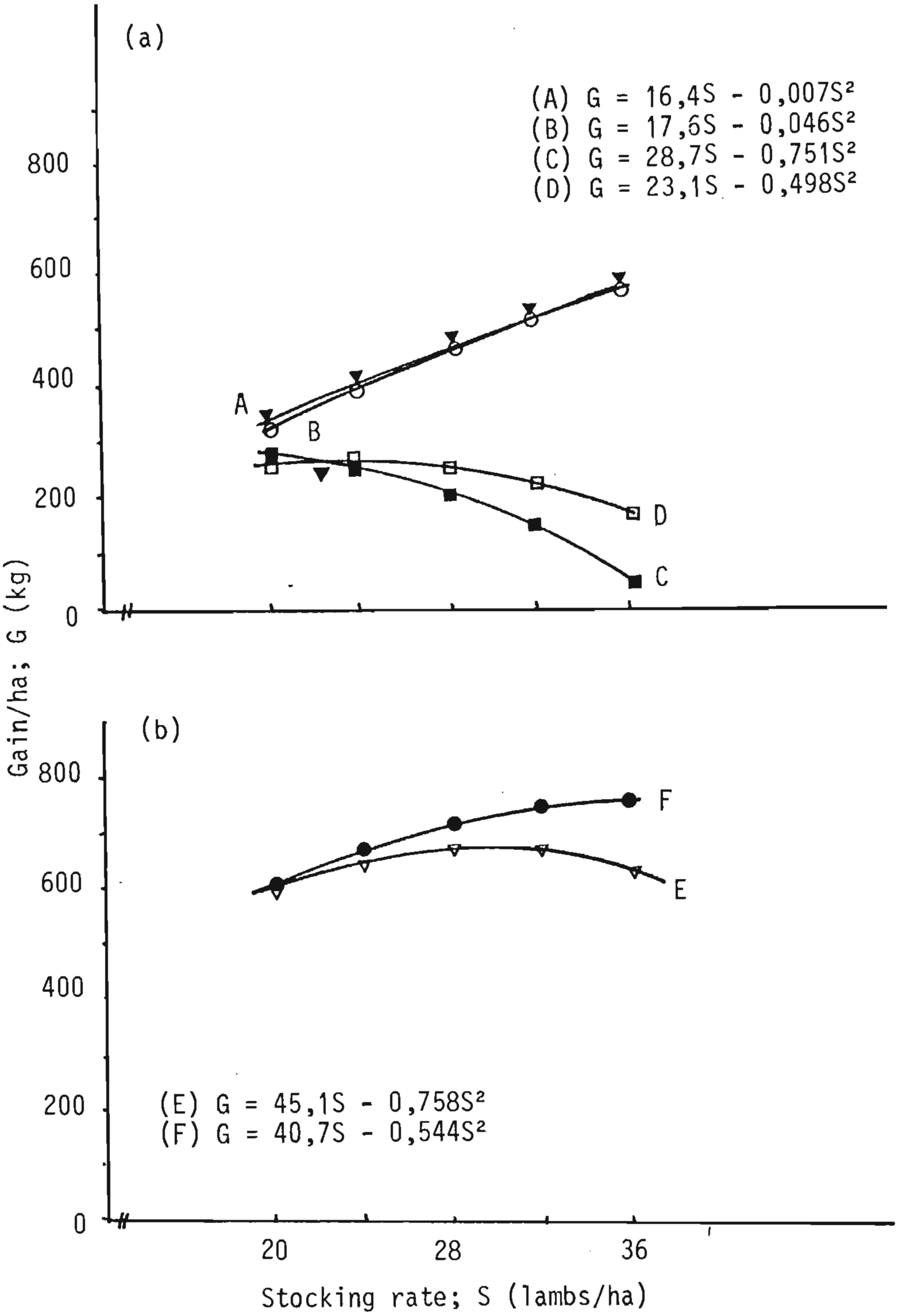


Fig. 3.7 (a) Derived relationships between gain/ha and stocking rate for lambs on ryegrass alone (A) and on ryegrass + clovers (B) in the pre-weaning period and for lambs on ryegrass alone (C) and on ryegrass + clovers (D) for the post-weaning period.
(b) Gain/ha over both pre- and post-weaning periods for lambs on ryegrass (E = A + C) and on ryegrass + clover (F = B + D).

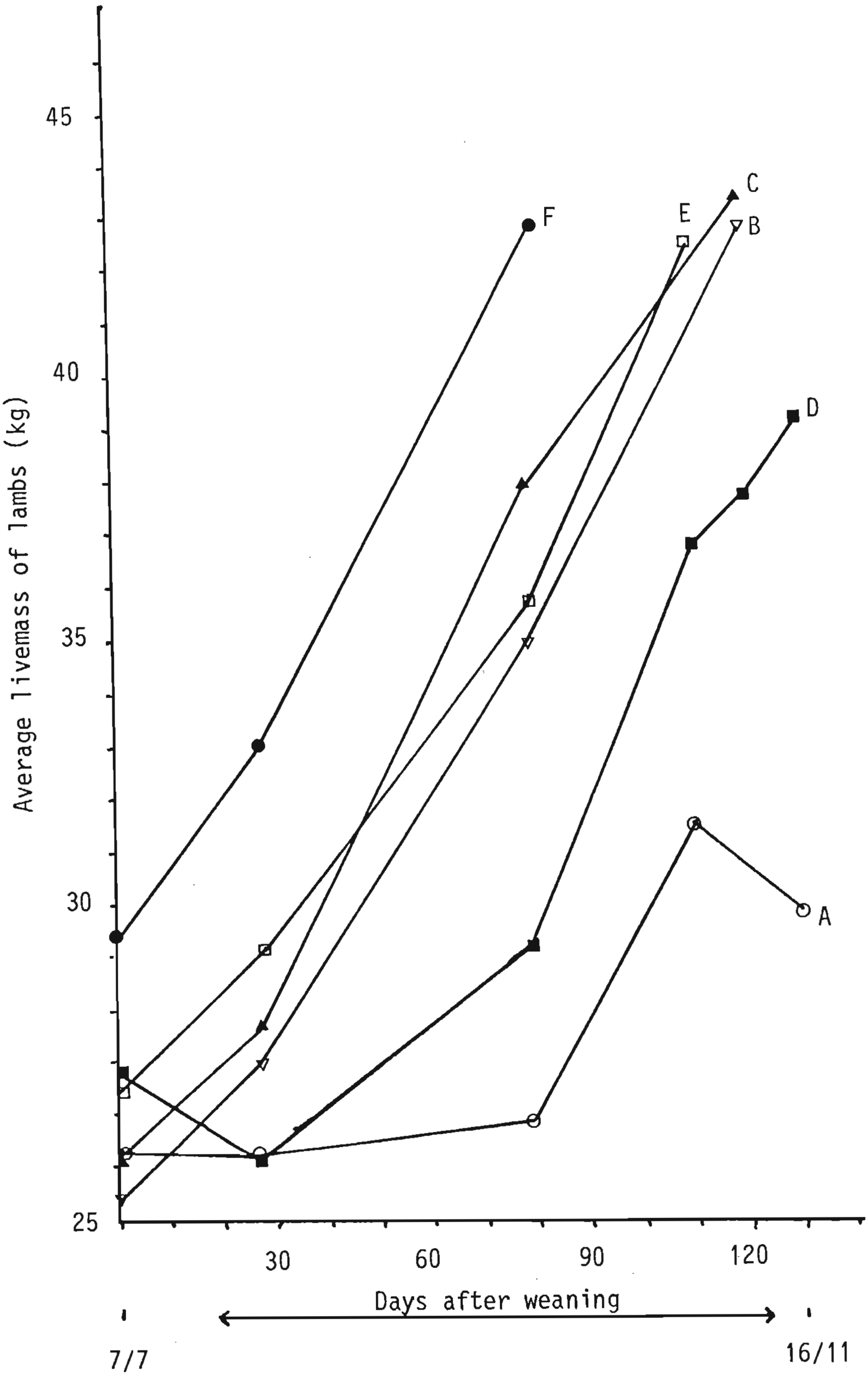


Fig. 3.8 Changes in average livemass of lambs with time after weaning for ryegrass stocked at (A) 20; (B) 28 and (C) 36 lambs/ha and for ryegrass + clover stocked at (D) 20; (E) 28 and (F) 36 lambs/ha.

Consequently, although only minor non-significant advantages were observed for ryegrass + clovers over ryegrass alone in terms of the regression relationships up to when lambs at the low stocking rate were marketed, this advantage was decisive at the high stocking rate during the last two months.

4. PASTURE AND ANIMAL RESPONSES TO NITROGEN FERTILIZATION

In view of the greater ability of ryegrass + clover to carry animals at high stocking rates, final evaluation under grazing was conducted on this pasture only. Furthermore, since nitrogen fertilizer constitutes a major annual production cost, nitrogen was included as a variable. The response to nitrogen was assessed in both small plots under mowing and in a grazing trial. Details of the procedure used in these two experiments appear in sections 2.4.1 and 2.4.2 respectively.

4.1 Small plot trial

Since 75 kg N/ha were applied as a basal or "starter" dressing to all plots, there was in effect, no zero N treatment. Application of 75 kg N/ha at planting only resulted in a yield of 6,66 t DM/ha. Increasing N to 100; 200; 300; 400 and 500 kg/ha over the 75 kg N/ha applied at planting resulted in yield increases of 4,69; 4,77; 5,59; 6,94 and 7,06 t DM/ha respectively (Fig. 4.1).

This represented corresponding increases in yield of 70; 72; 84; 104 and 106%. Yields of all treatments with N applied in addition to the 75 kg N/ha at planting were significantly greater ($p \leq 0,01$) than the treatment which received only 75 kg N/ha at establishment. However, yields from applying 275 and 375 kg N/ha were not significantly greater than that achieved when 175 kg N/ha was applied.

Although the yields from applying 475 and 575 kg N/ha were significantly greater ($p \leq 0,01$) than those achieved when 175; 275 and 375 kg N/ha were applied (but not significantly different from each other) the actual increases in yield were relatively small. For example, the yield from applying 475 kg N/ha was only 2,25 t DM/ha greater than that obtained for an application of 175 kg N/ha, representing an increase of 20%. From

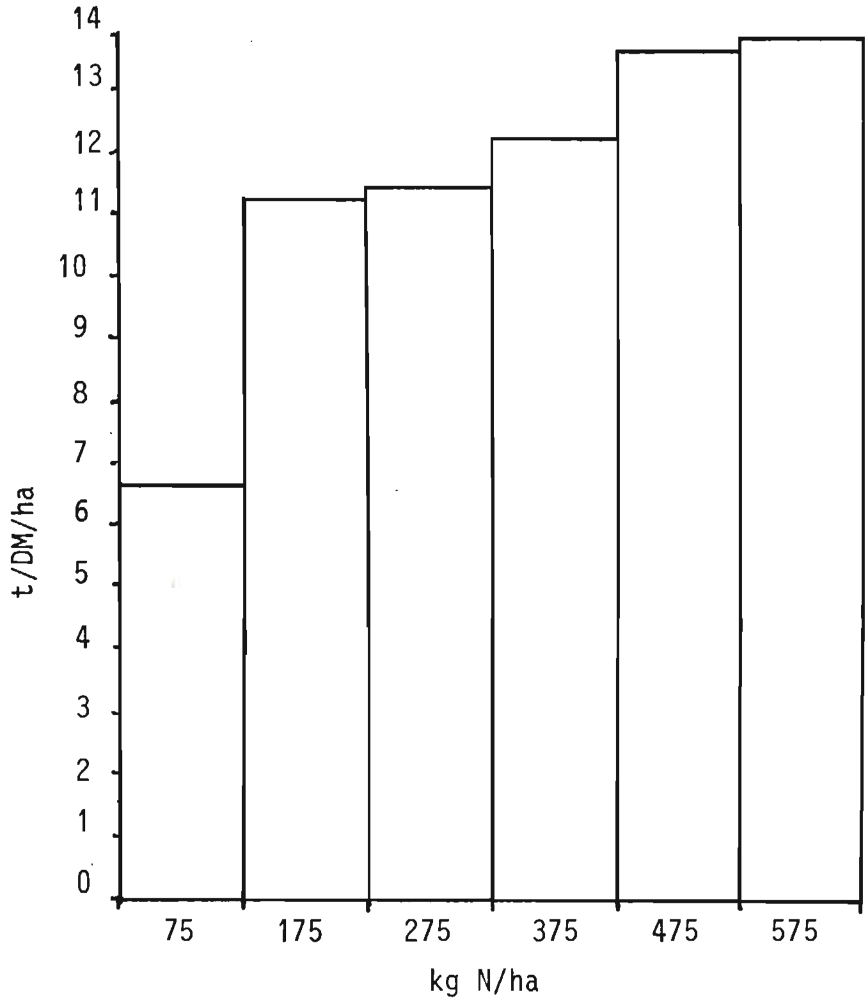


Fig. 4.1 Response of DM yield of ryegrass + clover pasture to increasing levels of N fertilizer.

this small plot trial, therefore, there appeared to be little response to added N above 175 kg N/ha. This result is in agreement with the observations of findings of certain scientists (Anon., 1980) where they demonstrated clearly that ryegrass + clover produced more DM than ryegrass alone at levels of N up to 200 - 300 kg/ha (Table 1.1). This was ascribed to the probable contribution of fixed N provided by the clover.

4.2 Grazing trial

The pre-weaning periods (from the start of grazing until weaning) were 67 and 47 days for 1982 and 1984 respectively, with corresponding post-weaning periods (from weaning until the first groups reached market weight) were 76 and 97 days. In order to assess animal production responses to levels of N, results for ewes and lambs in the pre-weaning period and for lambs in the post-weaning period were considered separately in each season. In addition, results for lambs over both the pre- and post-weaning periods were examined. Differences between levels of N were tested by using the regression modelling procedure described in section 2.3.2 to consider the relationships between ADG and stocking rate, ADG and disc meter height, and between stocking rate and disc meter height.

Except for the 200 kg N/ha treatment in 1982, ewe ADG decreased as stocking rate increased. Although the linear correlation coefficients were mostly fairly high, they were not statistically significant due to low degrees of freedom (Fig. 4.2). Despite apparent differences in these regression lines, the slopes were not significantly different and neither were the intercepts of parallel lines which were fitted to the data from each treatment. Ewe ADG increased as disc meter height increased, with correlation coefficients of a similar order to those for the regression of ADG on stocking rate (Fig. 4.3). However, in this case, correlation was

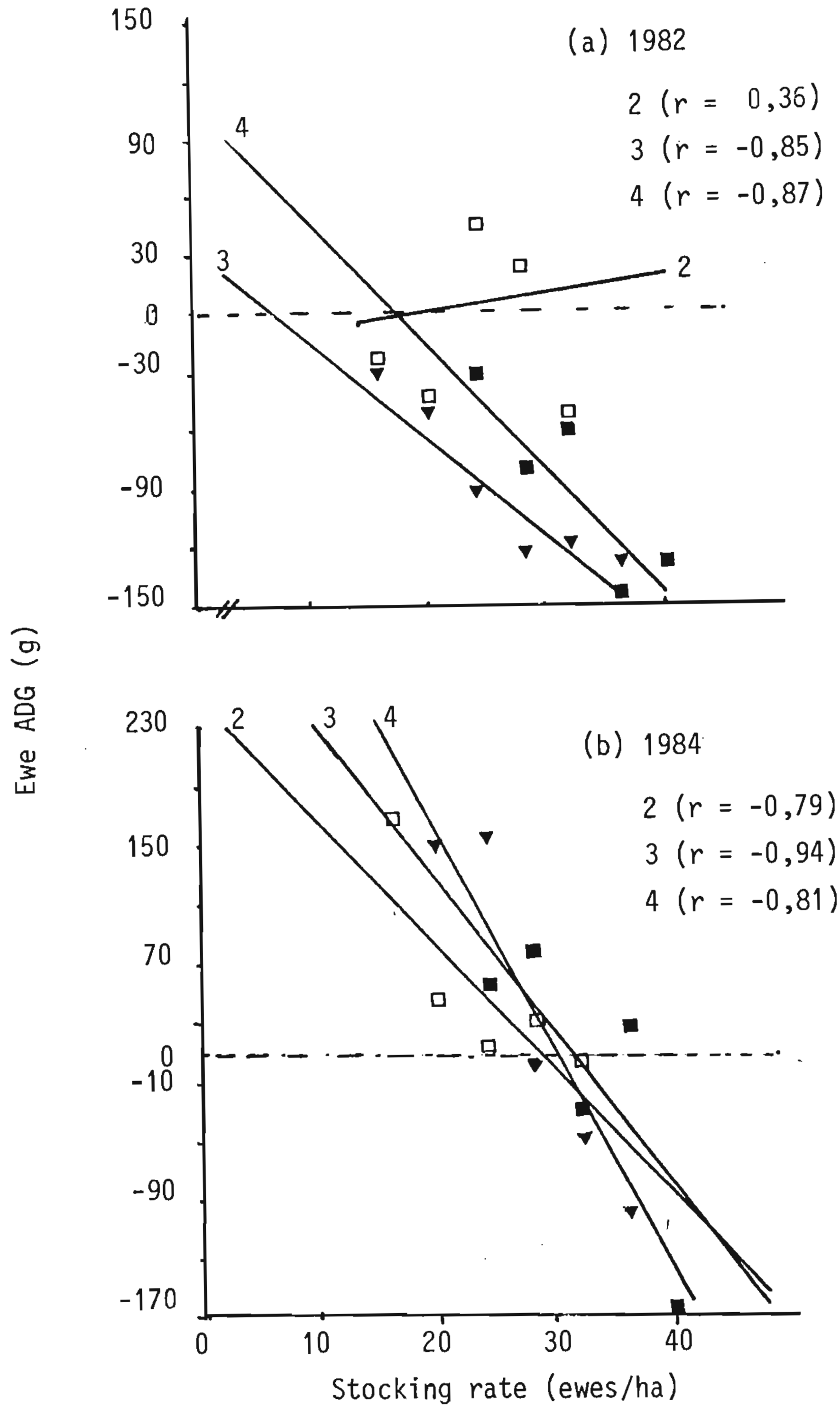


Fig. 4.2 Linear regression relationships between ADG of ewes and stocking rate for (2) 200; (3) 300 and (4) 400 kg N/ha during the pre-weaning period in (a) 1982 and (b) 1984.

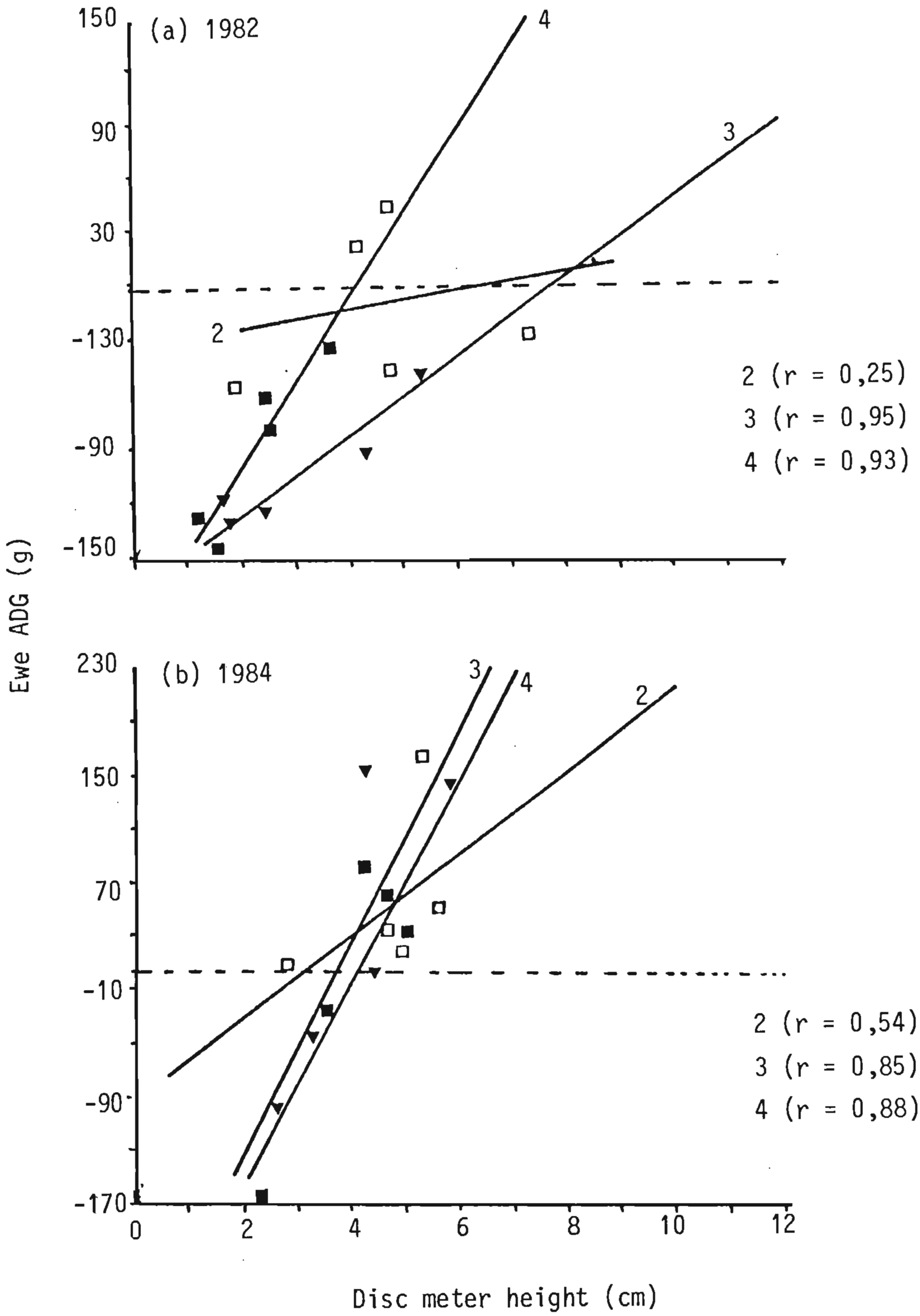


Fig. 4.3 Linear regression relationships between ADG of ewes and disc meter height for (2) 200; (3) 300 and (4) 400 kg N/ha during the pre-weaning period in (a) 1982 and (b) 1984.

poor for the 200 kg N/ha treatment in both the 1982 and 1984 season. There was again no evidence of significant differences between regressions for the different N levels. If it is assumed that different ADG at equal disc meter height reflects different levels of forage quality, then ewe ADG suggests that there was very little difference in forage quality between levels of N.

There was a negative relationship between stocking rate and disc meter height. Correlation was generally good except for the 400 kg N/ha treatment in 1984 (Fig. 4.4). Significant differences were once again not detected, suggesting that there was no significant difference in carrying capacity (and therefore also in pasture DM production) between levels of N.

Similar results with no significant differences between N levels were observed for lambs during the pre-weaning period (Figs. 4.5 and 4.6) and post-weaning period (Figs. 4.7, 4.8 and 4.9), and for the pre- and post-weaning periods combined (Fig. 4.10 and 4.11). Combining the pre- and post-weaning periods resulted in generally higher linear correlation coefficients (Fig. 4.10 and 4.11), suggesting that the animal variation which is commonly observed in relatively short experimental periods (such as that for the pre- and post-weaning periods separately) contributed to the poor correlation observed for certain treatments when results from the pre- and post-weaning periods were examined separately.

It is concluded that, although certain significant increases in yield were observed when N was increased beyond 175 kg/ha in the small plot trial, the absolute differences were relatively small and were most unlikely to be economically worth while. Since the lowest level of N included in the grazing trial was 275 kg N/ha, it is not surprising that animal performance reflected no significant differences between N levels. In order to establish the most economic levels of N fertilization further

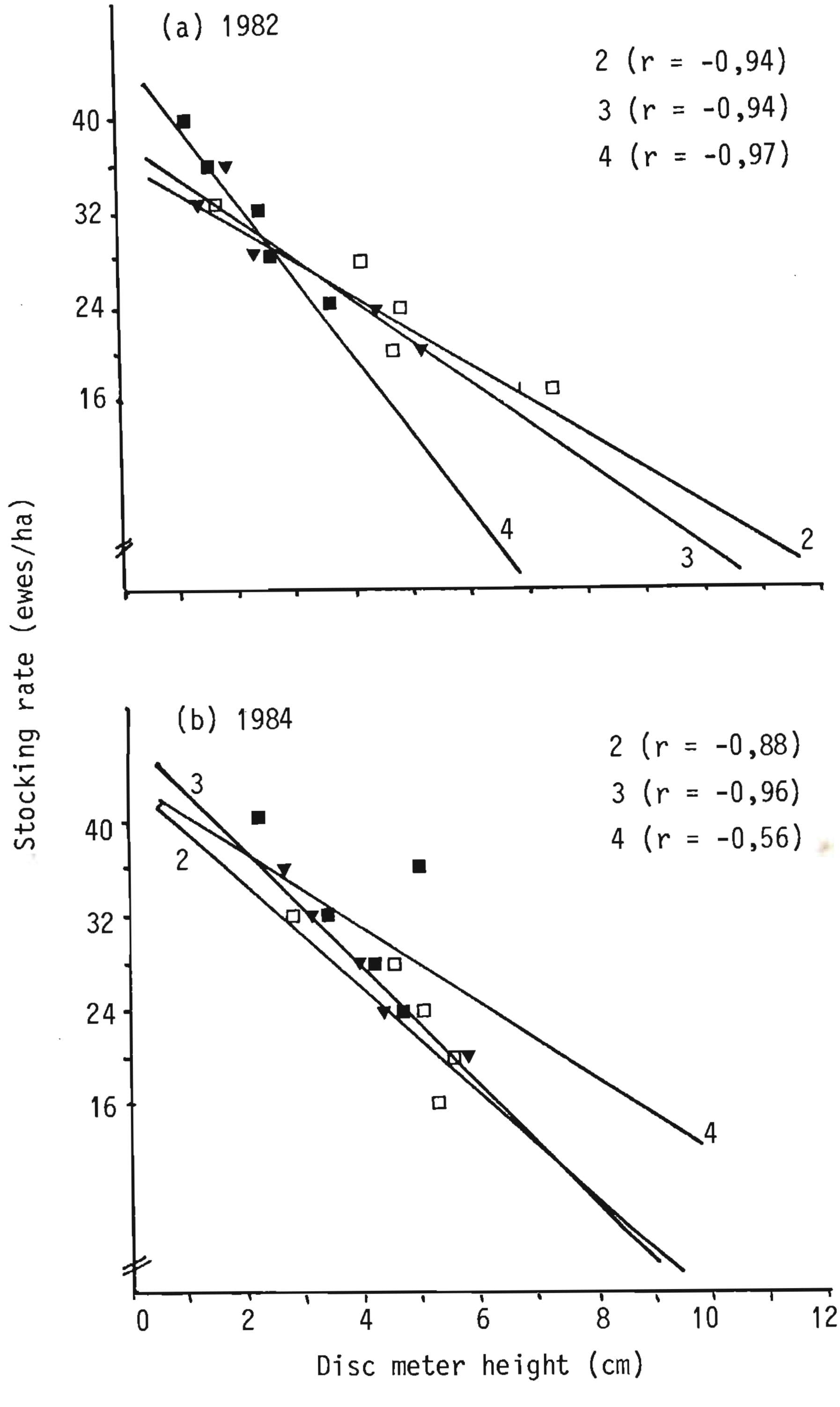


Fig. 4.4 Linear regression relationships between stocking rate and disc meter height for (2) 200; (3) 300 and (4) 400 kg N/ha during the pre-weaning period in (a) 1982 and (b) 1984.

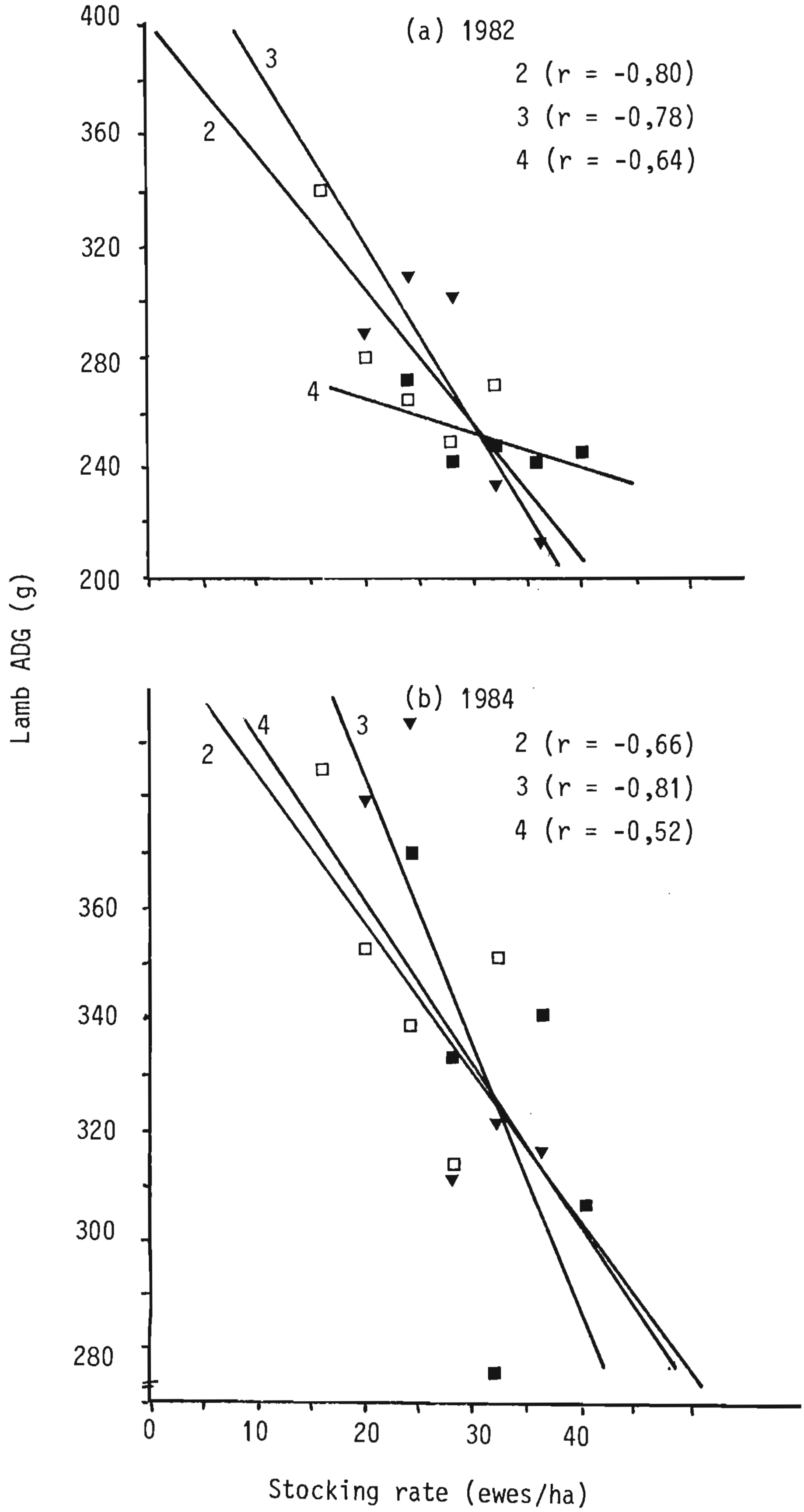


Fig. 4.5 Regression relationships between ADG of lambs and stocking rate for (2) 200; (3) 300 and (4) 400 kg N/ha during the pre-weaning period in (a) 1982 and (b) 1984.

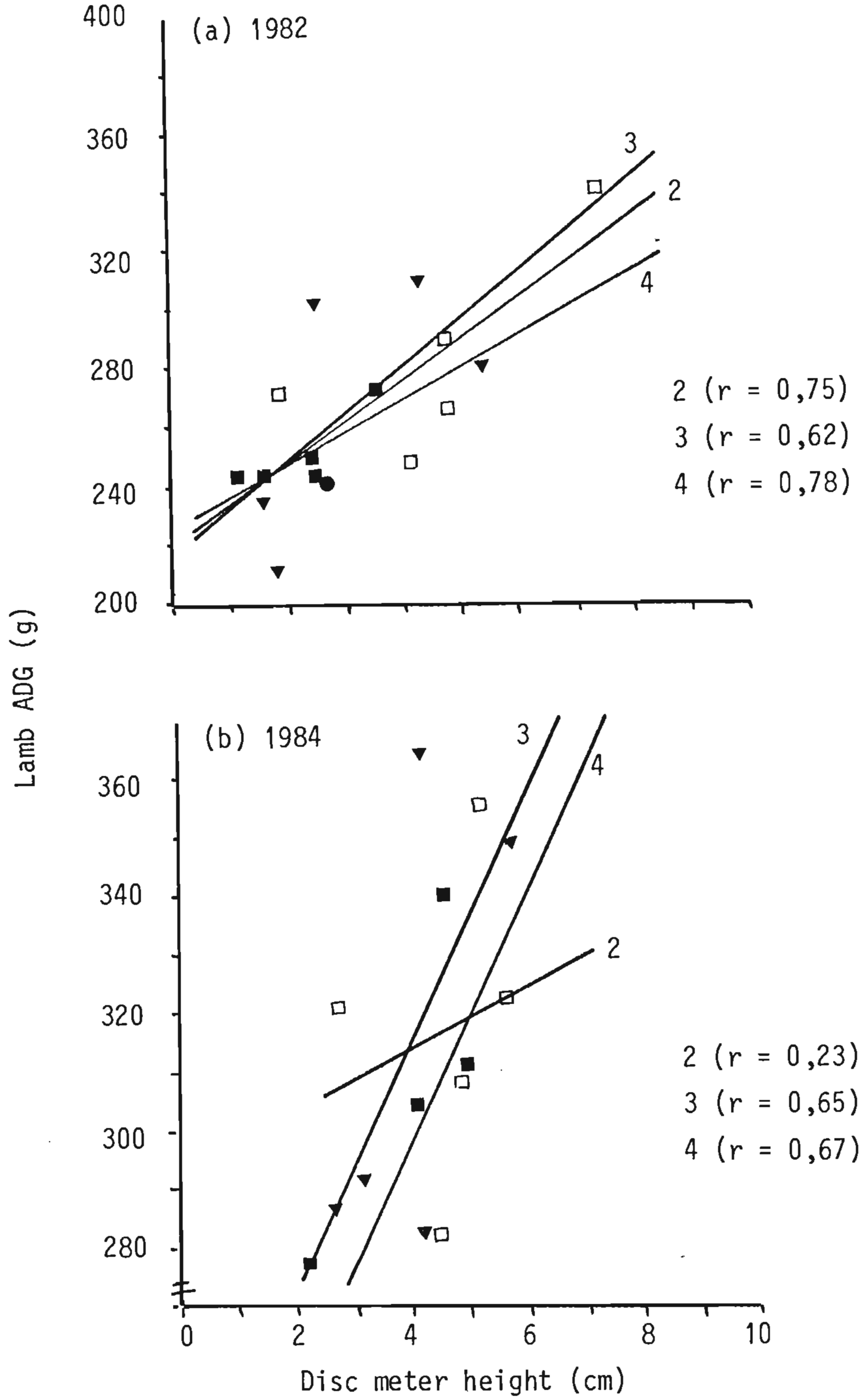


Fig. 4.6 Regression relationships between lamb ADG and stocking rate for (2) 200; (3) 300 and (4) 400 kg N/ha during the pre-weaning period in (a) 1982 and (b) 1984.

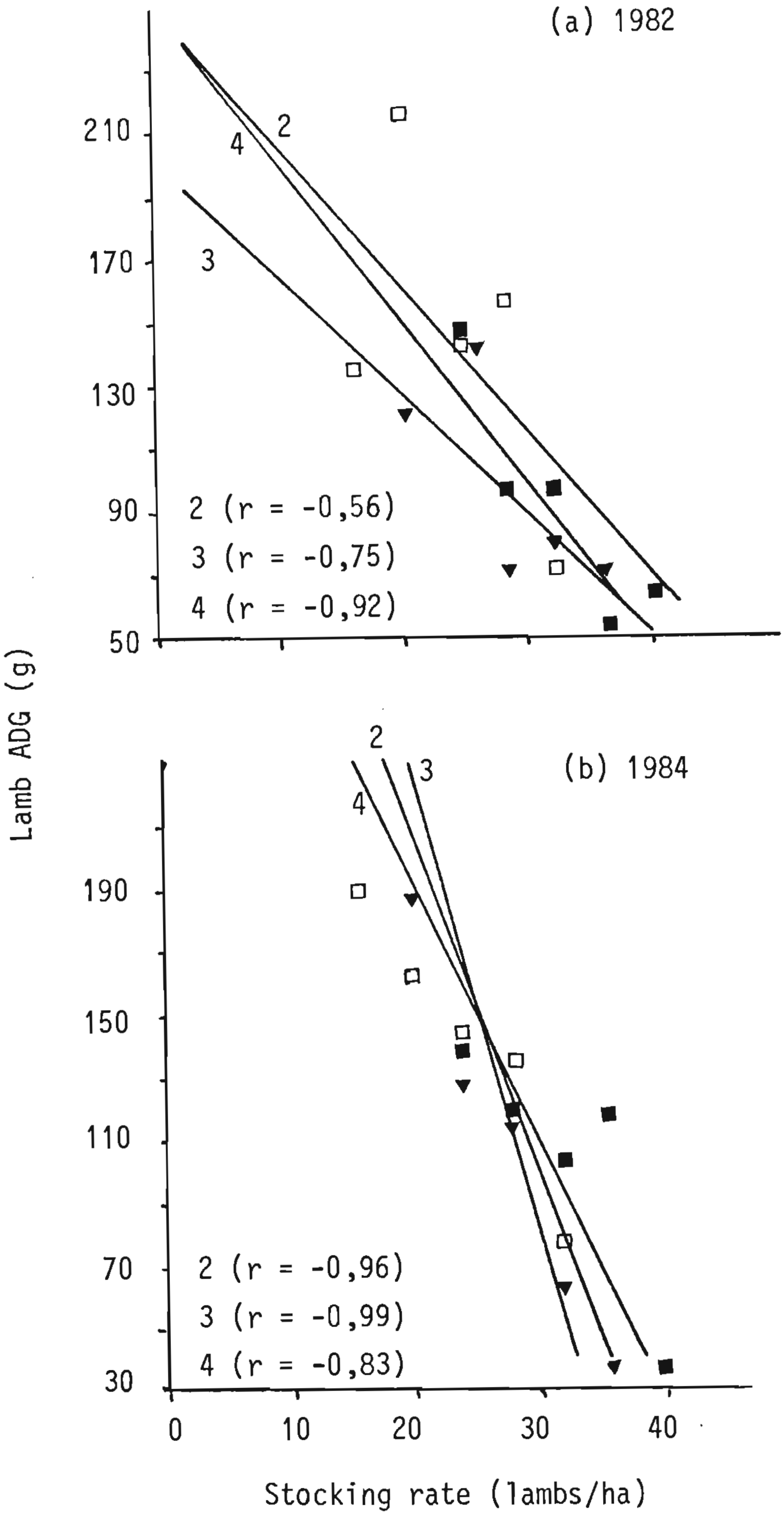


Fig. 4.7 Regression relationships between lamb ADG and stocking rate for (2) 200; (3) 300 and (4) 400 kg N/ha during the post-weaning period in (a) 1982 and (b) 1984.

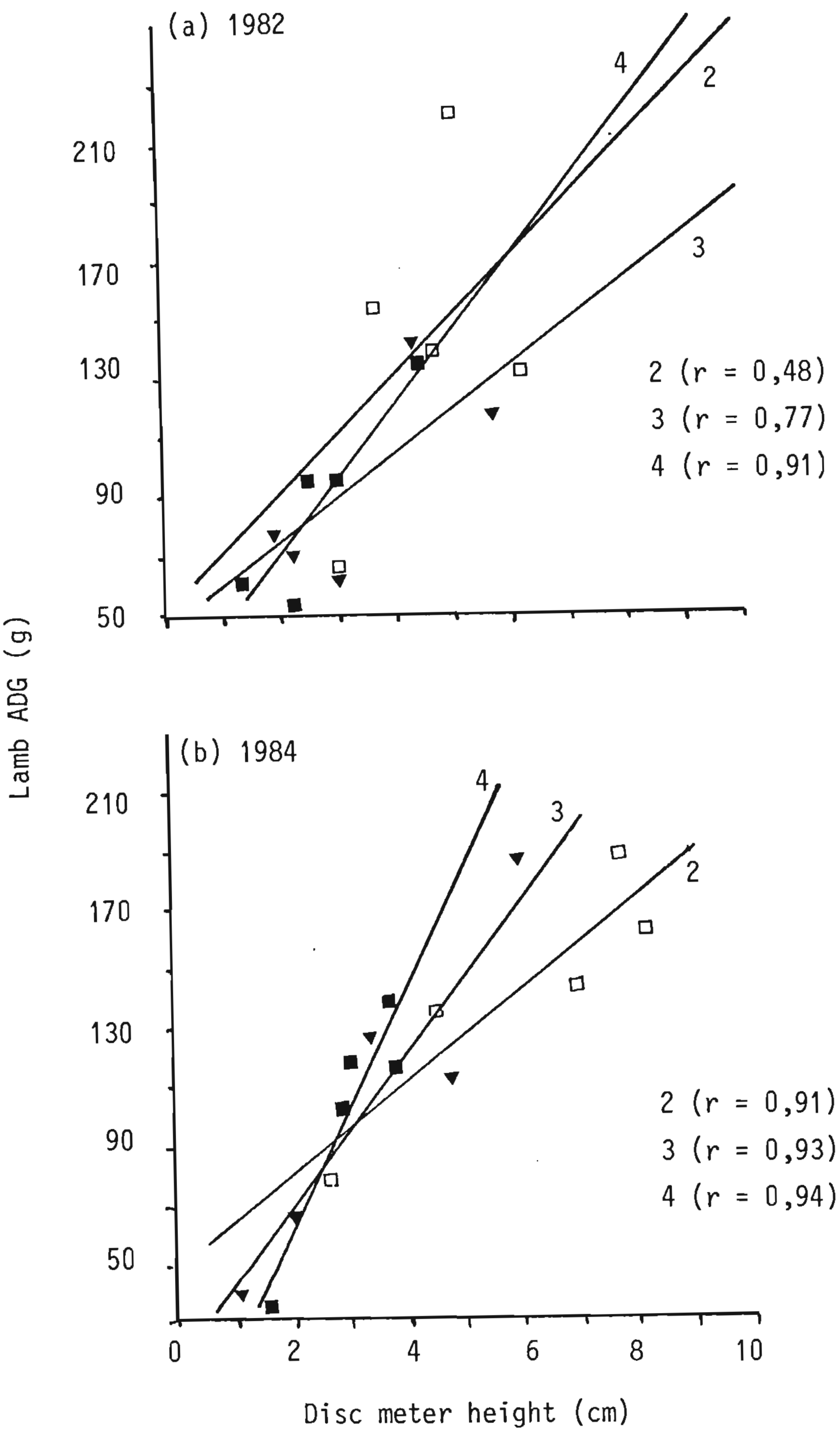


Fig. 4.8 Regression relationships between lamb ADG and disc height for (2) 200; (3) 300 and (4) 400 kg N/ha during the post-weaning period in (a) 1982 and (b) 1984.

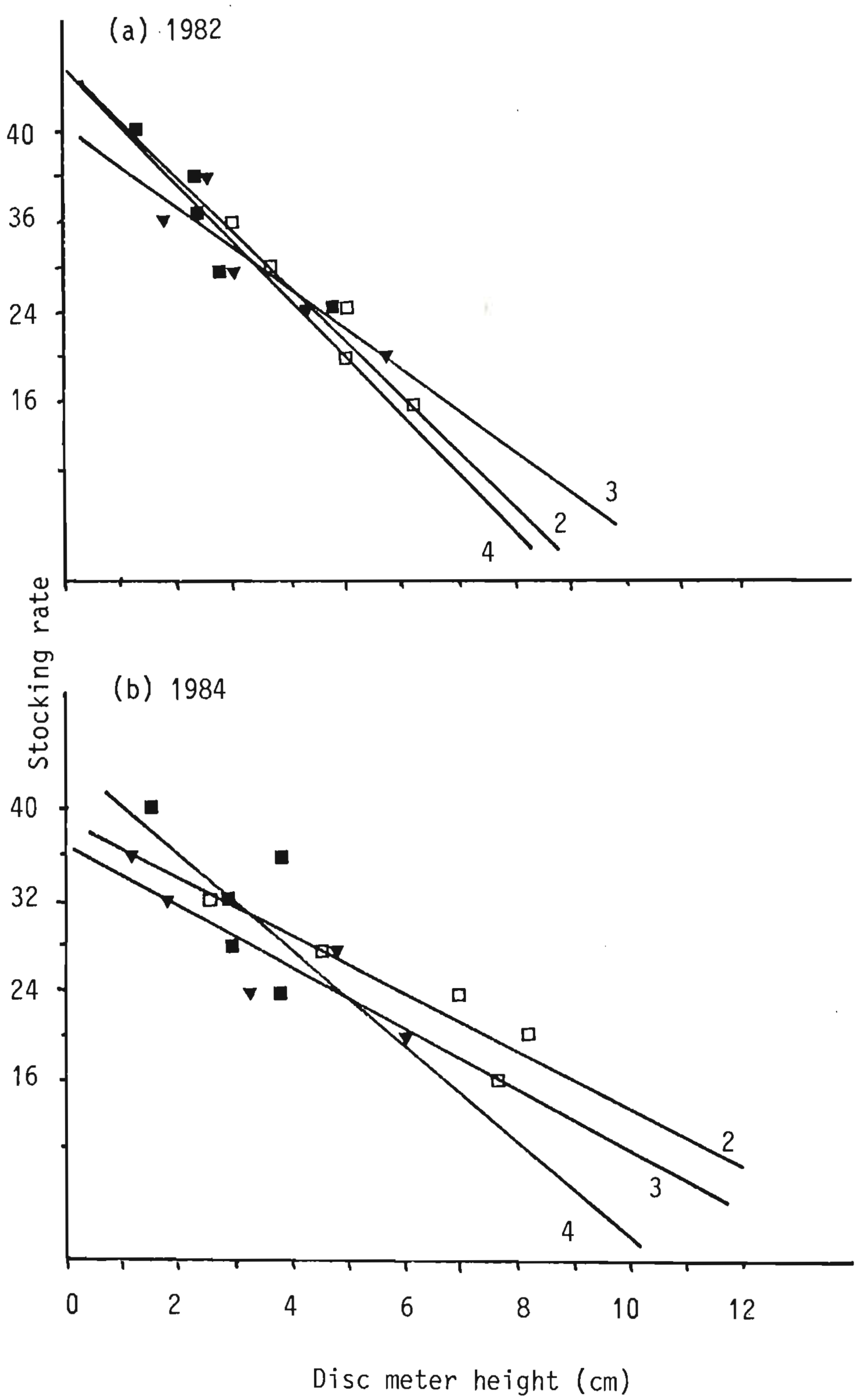


Fig. 4.9 Regression relationships between stocking rate and disc meter height for (2) 200; (3) 300 and (4) 400 kg N/ha during the post-weaning period in 1982 and 1984.

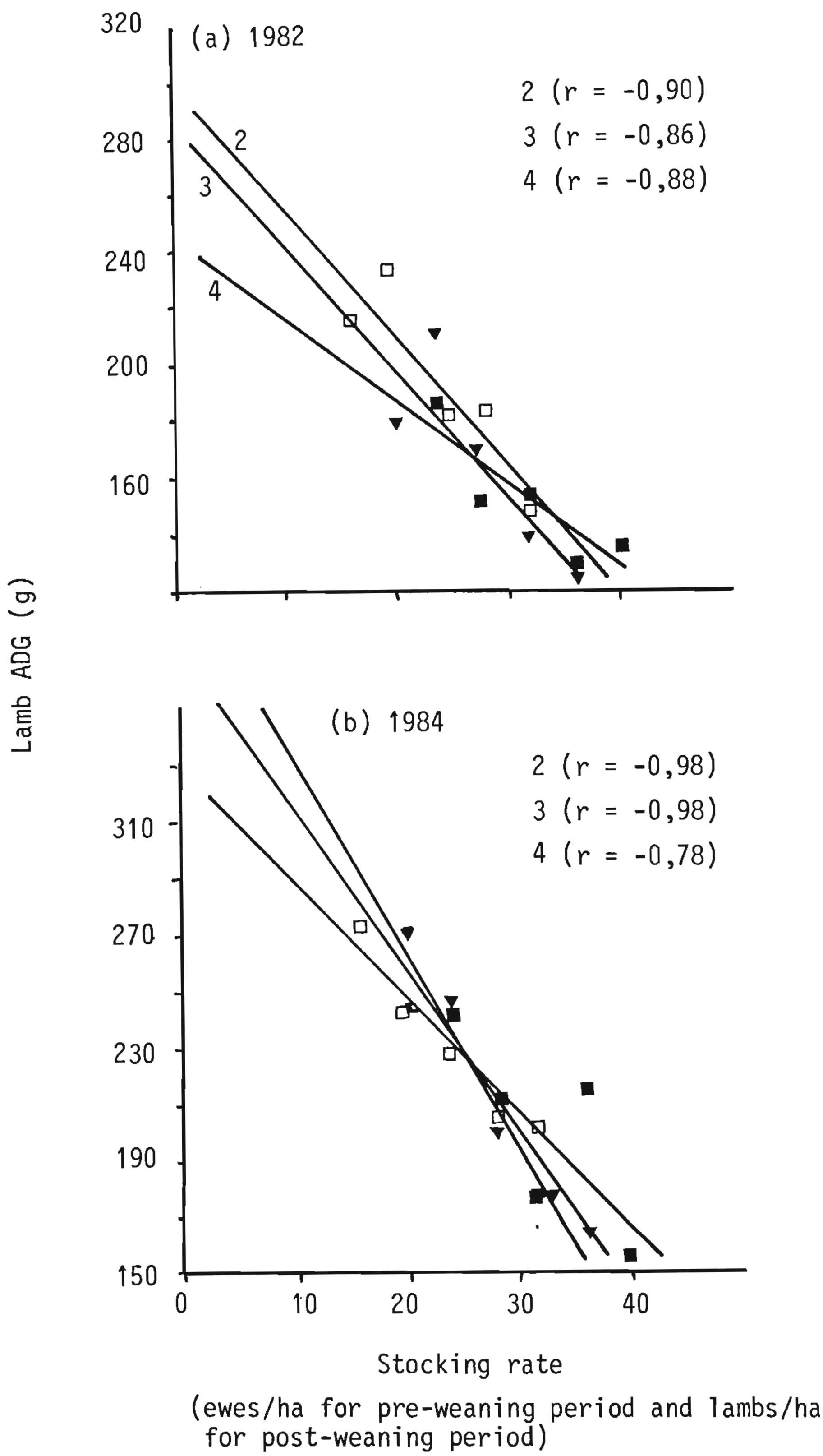


Fig. 4.10 Regression relationships between lamb ADG and stocking rate for (2) 200; (3) 300 and (4) 400 kg N/ha during the pre- and post-weaning periods in (a) 1982 and (b) 1984.

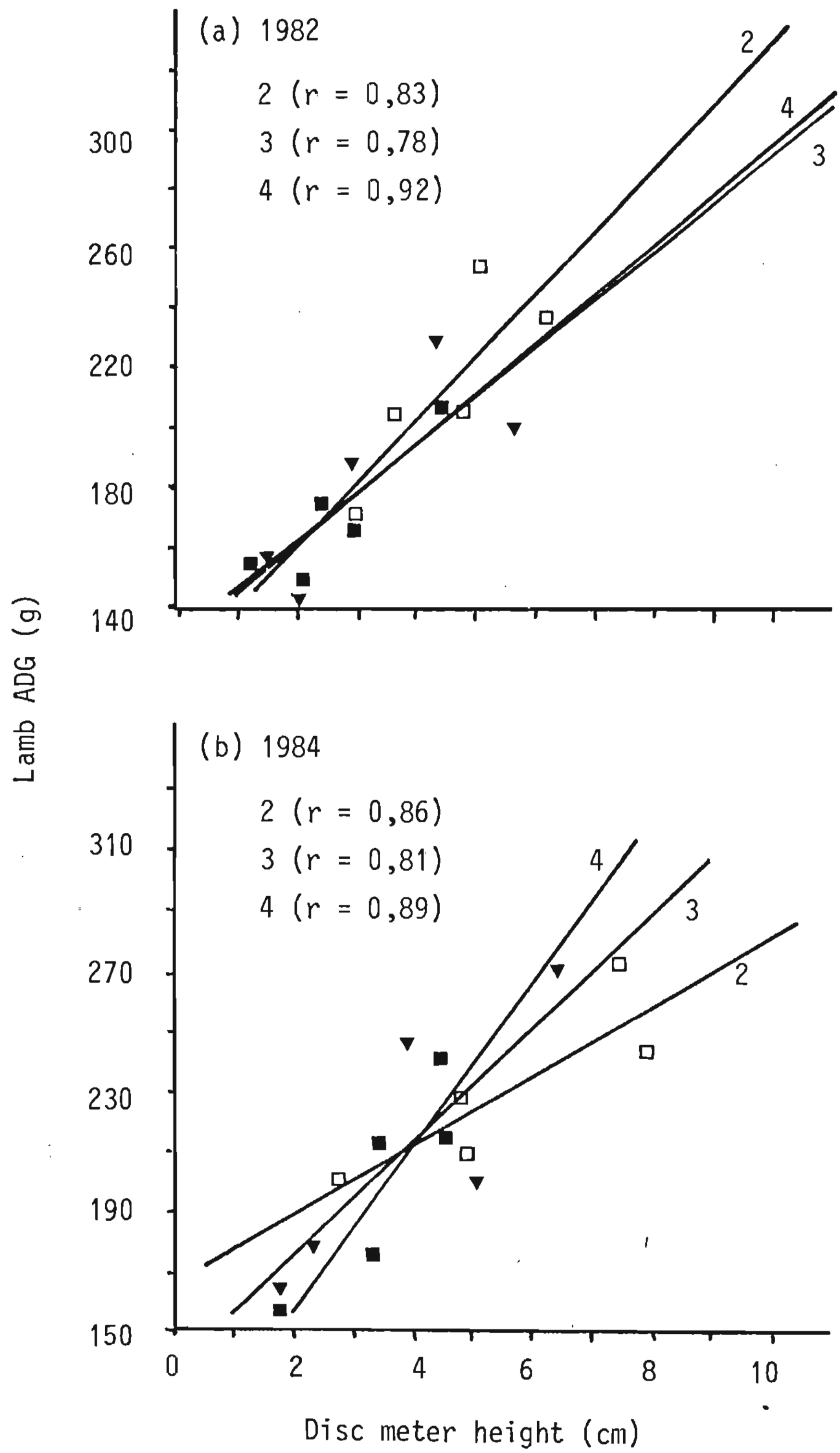


Fig. 4.11 Regression relationships between lamb ADG and disc meter height for (2) 200; (3) 300 and (4) 400 kg N/ha during the pre- and post-weaning periods for (a) 1982 and (b) 1984.

grazing research is required and this should include levels of N from zero to 300 kg/ha. Until such time, a recommendation of no more than 275 kg N/ha for continuously grazed irrigated ryegrass + clover pastures should be appropriate, assuming similar climate and soil conditions to those under which this research was conducted.

5. SIMULATING A FAT LAMB SYSTEM

In order to facilitate economic evaluation of fat lamb production from irrigated ryegrass + clover pastures it is necessary to simulate the fat lamb system under consideration. However, although this was the primary objective in this chapter, a number of secondary issues were also pursued; e.g. a comparison was made between lamb gains before and after weaning, and between single and twin lambs. Since there were no significant differences in animal gains between N levels, data for all N levels were pooled for the analyses, but the results from the 1982 and 1984 seasons were considered separately.

The first step towards development of grazing relationships suitable for incorporation into economic models was the establishment of linear regression models. These linear regression models facilitated statistical comparisons between different components of the system. The regression relationships were then used to derive additional grazing relationships which formed the basis for the economic models and economic analyses in Chapter 6. This chapter is therefore divided into two main sections; one on linear regression models and one on relationships derived from these models, including a simulation of a fat lamb production system.

5.1 Linear regression models

In this section linear regression models were established for ewes and lambs before weaning and for lambs after weaning until the first group was marketed, considering the relationships between ADG and stocking rate, ADG and disc height, and between stocking rate and disc height separately for 1982 and 1984. In addition, the relationships between ADG and stocking rate for single and twin lambs and their mothers in 1984 was examined. The linear regression modelling procedure that was used is described in section 2.3.2.

5.1.1 ADG vs. stocking rate

ADG of lambs and ewes before weaning and of lambs after weaning decreased as stocking rate increased (Fig. 5.1). In 1982 there was no significant difference ($p \leq 0,05$) between the slopes of the regression lines, indicating no significant interactions. Parallel lines were therefore fitted to the data and the intercepts of these lines were significantly different ($p \leq 0,01$) from each other. The three regression lines in this model accounted for 95% of the variation in all three sets of data. Of particular practical significance is the 159g ADG advantage of lambs before weaning over lambs after weaning, which was probably provided mainly by the milk from the dams. At a stocking rate of 30 animals/ha this pre-weaning advantage in ADG represented an increased of 159% over the expected post-weaning ADG of 100g/day. Also of interest is the expected weight loss of most of the ewes within the full range of stocking rates considered. This suggests that ewes were "milking off their backs". However, since the regression lines for ewes and lambs before weaning are parallel, it would appear that lambs did not gain at the expense of ewes any more under high stocking rates than under low stocking rates.

In the 1984 season the slopes of the regression lines for lambs before and after weaning were not significantly different. Parallel lines were therefore fitted and the intercepts of these two lines were found to be significantly different ($p \leq 0,01$) (Fig. 5.1b). Also, the slope of the lines was not significantly different to that of the relationships established in 1982. However, pre-weaning lamb gains were higher ($p \leq 0,05$) in 1984 than in 1982 : at a stocking rate of 30 animals/ha the

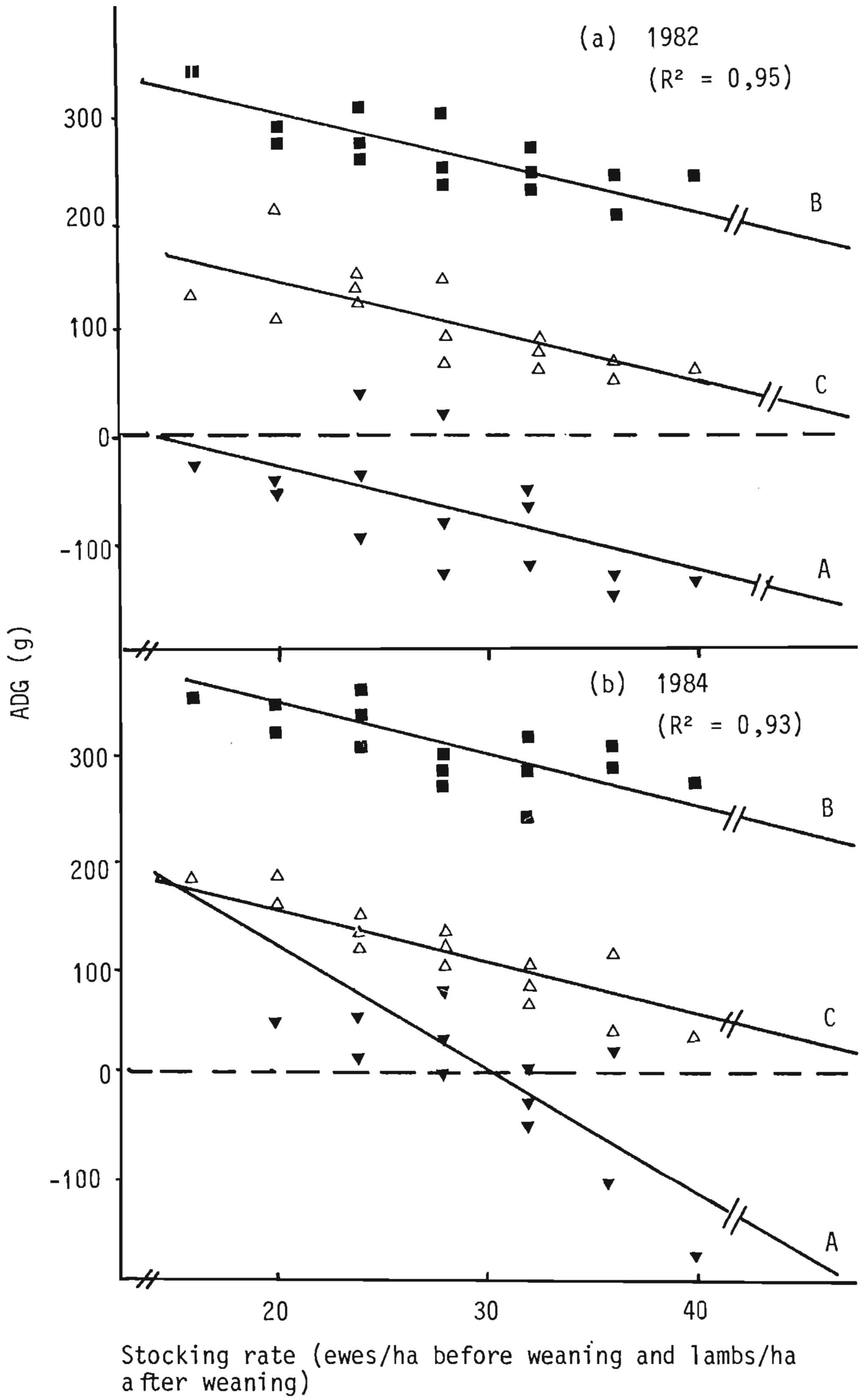


Fig. 5.1 Linear regression models describing the influence of stocking rate on ADG for (A) ewes and (B) lambs before weaning and for (C) lambs after weaning in (a) the 1982 and (b) the 1984 seasons.

Note : Due to 33% twinning in 1984, pre-weaning lamb stocking rate was 33% higher than ewe stocking rate, but post-weaning lamb stocking rates were reduced to the same levels as pre-weaning ewe stocking rate.

advantage in 1984 was 16%. This difference occurred despite half the lambs in 1984 being twins while all the lambs in 1982 were singles, and it is ascribed therefore, mainly to the difference in sheep breeds used in the two years : in 1982 Mutton Merinos were used while in 1984 the breed was Corriedale. Due to almost exactly the same irrigation schedule being applied in each year, between year variation in pasture parameters is likely to have been minimal. The pasture factor most likely to have influenced animal performance was the proportion of clover in the sward, but this appeared to be similar between years, although no quantitative data were collected to support this visual observation.

There was also a significant difference ($p \leq 0,01$) between the slope of the ADG vs. stocking rate regression for ewes in 1984 and the slopes of all other regression lines in both seasons, thus indicating a significant interaction. Expected ewe ADG was positive for stocking rates below 30 animals/ha and negative for higher stocking rates (as opposed to expected ADG being negative for all stocking rates considered in 1982). This difference was probably related again, mainly to between season differences in sheep breed and to twins being included in 1984 but not in 1982. The greater decrease in ewe ADG over lamb ADG as stocking rate increased in the 1984 season suggests that lambs gained at the expense of ewes to a greater extent as stocking rate increased in this season.

If an annual breeding cycle was in operation, the high weight losses of ewes observed in both seasons at a stocking rate of 40 animals/ha would probably not affect reconception, because there was sufficient time after weaning to improve the ewe's condition before the breeding season. However, if the breeding cycle was 8 months (3 lamb crops every 2 years), supplemental feeding would probably be required to prevent decreases in conception rates at high stocking rates.

5.1.2 ADG vs. disc height

Linear regression models for the ADG vs. disc height relationships revealed precisely the same differences as those observed for the ADG vs. stocking rate models. However, the slope of the regression lines in this case was positive (Fig. 5.2). The three regression lines in each of the models accounted for 95% and 91% of the variation in all the data for the 1982 and 1984 seasons respectively.

5.1.3 Stocking rate vs. disc height

Stocking rate decreased as disc height increased (Fig. 5.3). In the 1982 season there was no significant difference in the slope of the stocking rate vs. disc height regressions for the pre- and post-weaning periods. Neither was there any significant difference between the intercepts of parallel lines fitted to these data. It was consequently feasible to represent the two sets of data with one line which accounted for 88% of the variation (Fig. 5.3a). This result is somewhat surprising, since stocking rate was expressed in ewe-lamb pairs/ha for the pre-weaning period and in lambs/ha for the post weaning period. In the 1984 season there was a significant interaction between the two periods, indicated by significantly different ($p \leq 0,05$) slopes of the regression lines. However, in view of expressing stocking rate in different terms for the two periods, between period comparisons have little meaning. The main purpose of establishing these regression relationships, therefore, is to facilitate the derivation of relationships between gain/ha and stocking rate for the two periods in section 5.2.

5.1.4 Single lambs vs. twins

In the 1984 season each stocking rate was represented by two ewes with single lambs and one ewe with twins. Half the lambs were therefore twins. This facilitated a comparison between ewes with single and twin lambs and

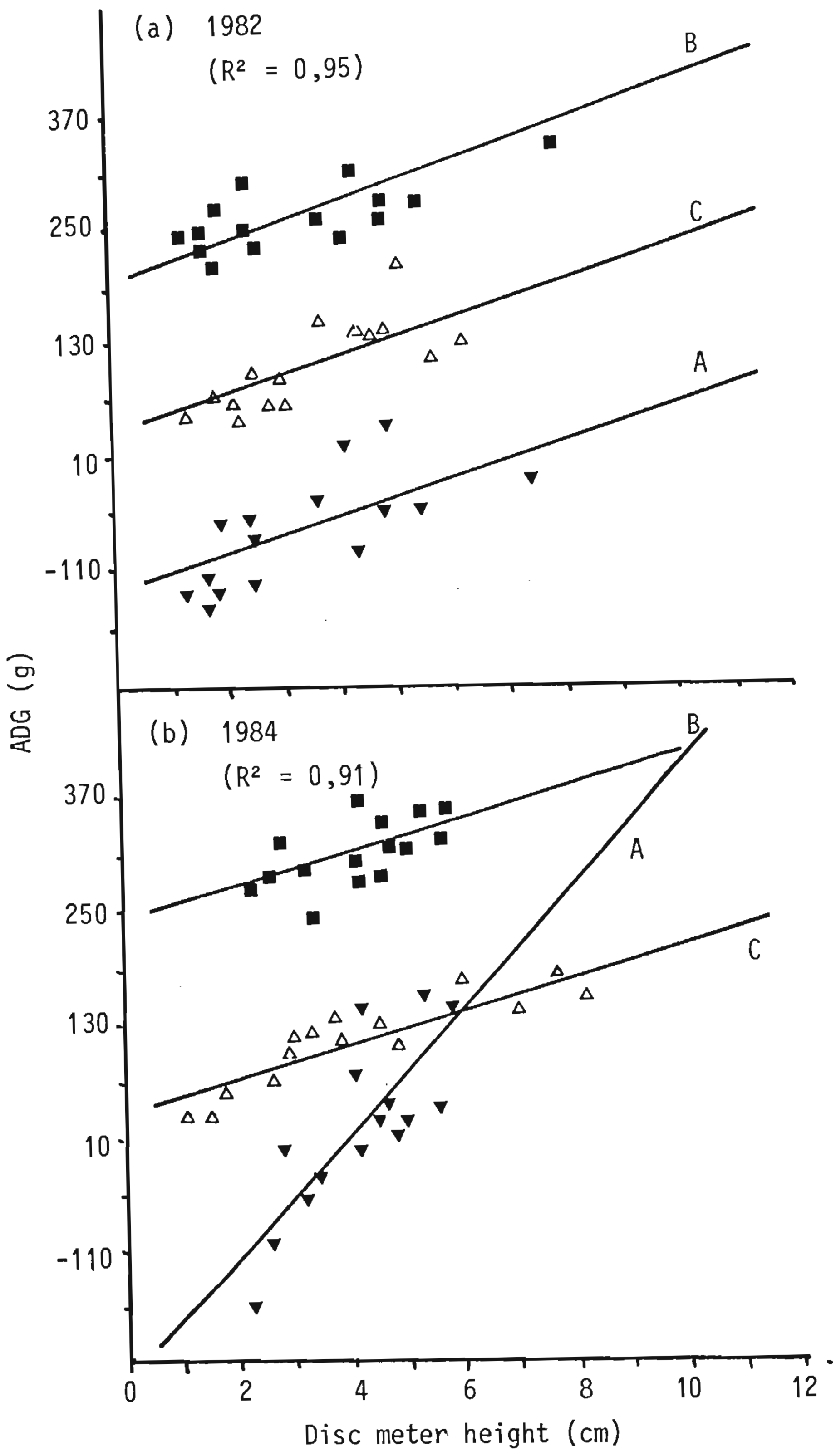


Fig. 5.2 Linear regression models describing the influence of disc meter height on ADG of (A) ewes and (B) lambs before weaning and for (C) lambs after weaning in (a) the 1982 and (b) the 1984 seasons.

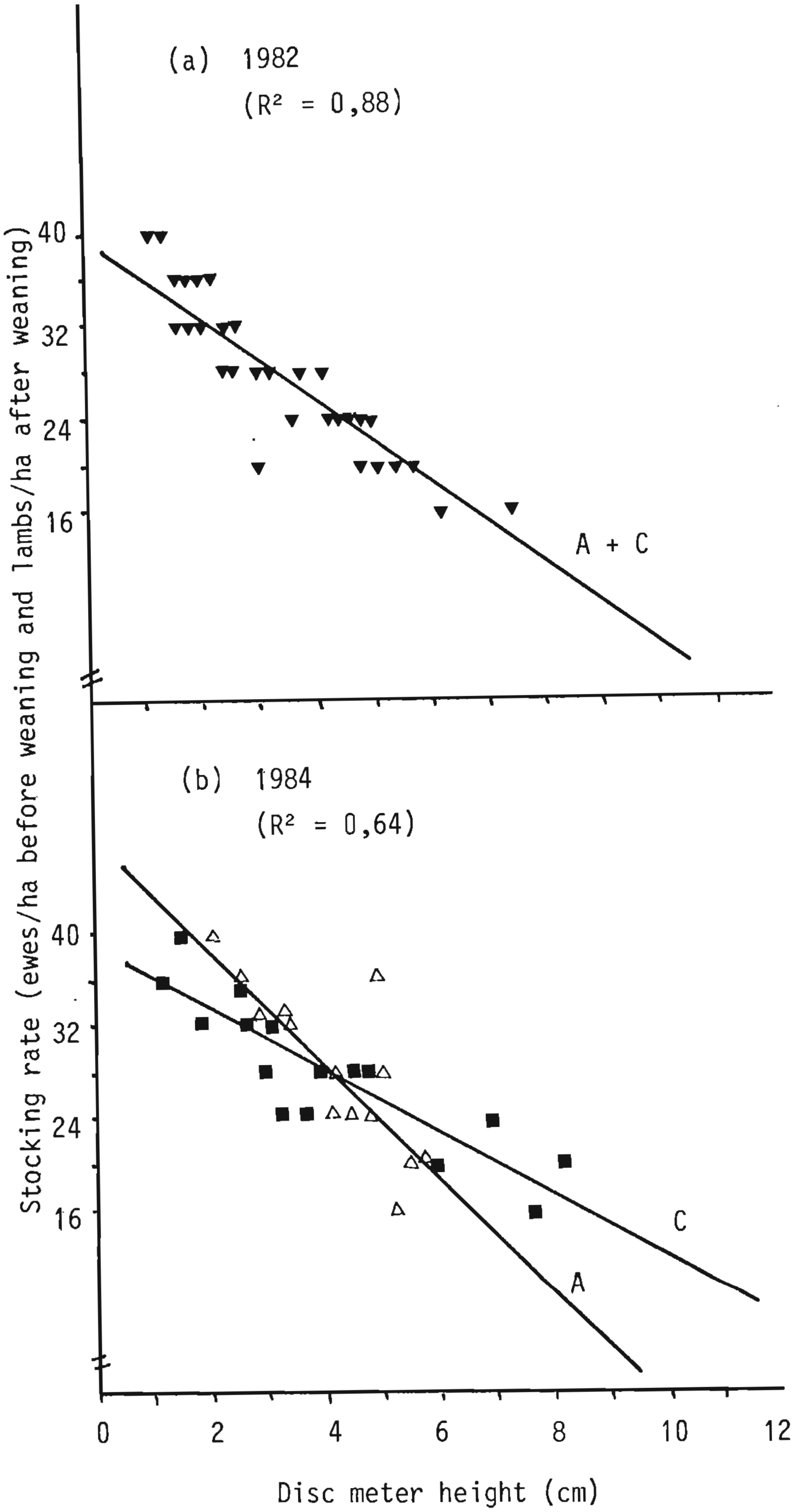


Fig. 5.3 Linear regression models describing the relationship between stocking rate and disc meter height for (A) the pre-weaning and (B) post-weaning periods in (a) 1982 and (b) 1984.

Note : Due to 33% twinning in 1984, pre-weaning lamb stocking rates were 33% higher than ewe stocking rates, but post-weaning lamb stocking rates were reduced to the same levels as pre-weaning ewe stocking rates.

between the single and twin lambs themselves. The linear regression modelling procedure was again employed to consider the ADG vs. stocking rate relationships.

The slopes of the ADG vs. stocking rate regressions for ewes with single and twin lambs differed significantly ($p \leq 0,05$) from each other and from the slopes of the regressions for lambs (Fig. 5.4). No significant difference between slopes of regression lines for single and twin lambs was observed, so parallel lines were fitted and these lines had significantly different ($p \leq 0,05$) intercepts. On average, expected ADG for single lambs was 44,5g more than for twin lambs, which represented a 16% advantage at a stocking rate of 30 ewes/ha. At the same stocking rate, expected ADG for ewes with single lambs was 65,5g/day while that for ewes with twin lambs was -101,2 g/day. These data suggest that ewes with twins have to "milk off their backs" to a greater extent as stocking rate increases than ewes with single lambs. In addition, since the slopes of the lines for single lambs and their mothers were significantly different ($p \leq 0,01$) even single lambs gained at the expense of their mothers to a greater extent as stocking rate increased. This result is in contrast to the 1982 season (when all ewes had singles) in which the lines for lambs and ewes before weaning were parallel (Fig. 5.1a).

5.2 Derived grazing relationships

5.2.1 Gain/ha vs. stocking rate

The linear relationships between ADG and stocking rate (S) can be expressed in general terms as follows :

$$ADG = a - bS \qquad [5.1]$$

Since daily gain/ha (DG/ha) is the product of stocking rate and ADG, then

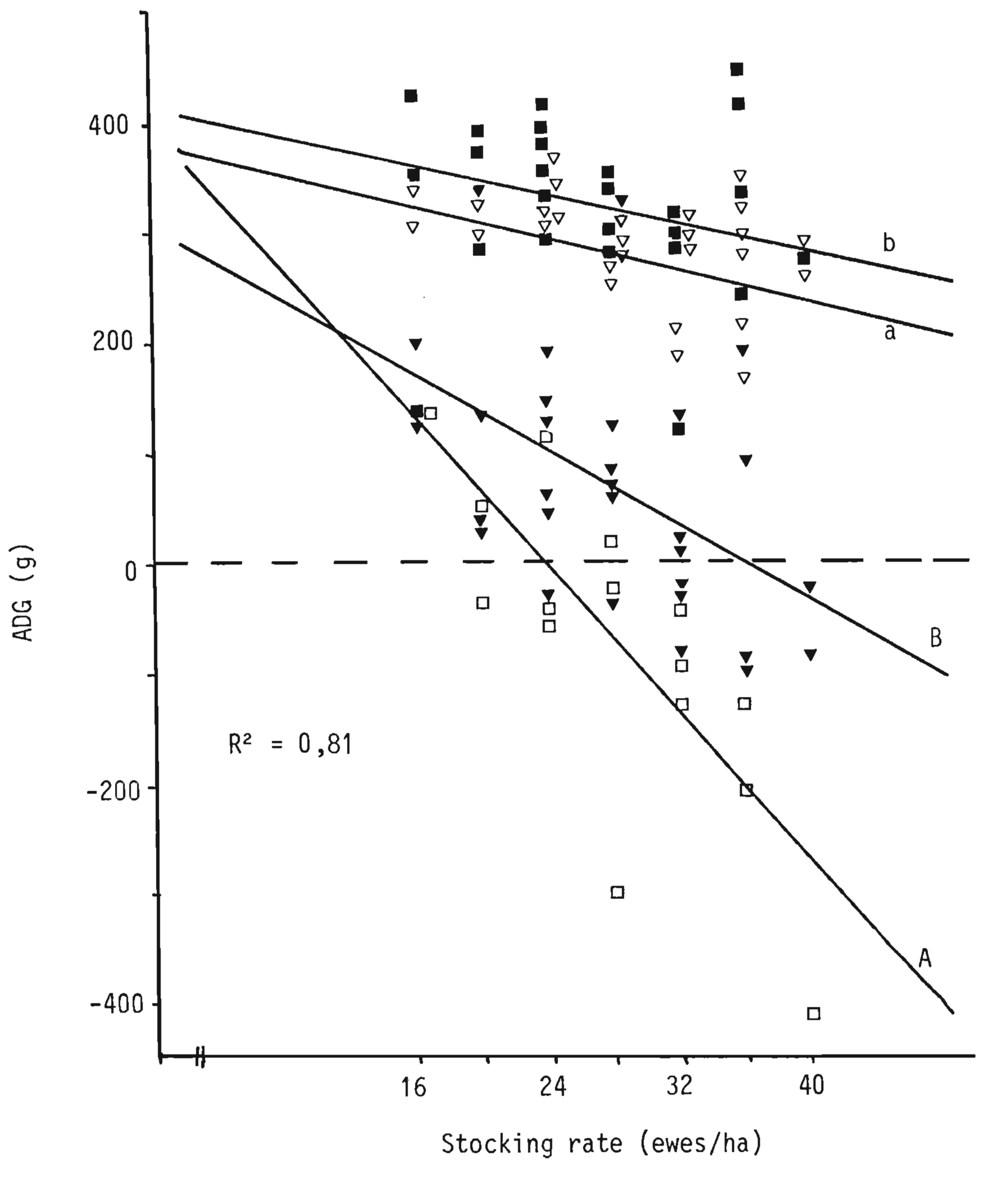


Fig. 5.4 A linear regression model describing the relationships between ADG and stocking rate for (a) twin lambs and (A) their mothers and for (b) single lambs and (B) their mothers in the pre-weaning period of the 1984 season.

$$DG/ha = (a - bS) \times S$$
$$= aS - bS^2 \qquad [5.2]$$

This relationship is presented for ewes and lambs before weaning and for lambs after weaning in both seasons (Fig. 5.5). In order to account for the 33% twinning in 1984, the ADG vs. stocking rate function for lambs before weaning was multiplied by 4/3.

Daily gain/ha was maximized in the pre-weaning period at 42,7 and 45,8 ewes/ha during the 1982 and 1984 seasons respectively, with corresponding maximum daily gains/ha of 8,5 kg and 13,6 kg. For the post-weaning period maximum daily gains/ha of 3,1 and 3,3 kg were obtained at stocking rates of 25,7 and 25,9 lambs/ha for the 1982 and 1984 seasons respectively. The lower lamb stocking rate which maximized daily gain/ha after weaning compared to that which maximized daily gain/ha before weaning was caused mainly by the difference in ADG of lambs before and after weaning. This conclusion is drawn from the fact that there was little difference in the ewe + lamb carrying capacity before weaning and the lamb carrying capacity after weaning, as indicated by the stocking rate vs. disc height relationships in Figure 5.3. The higher maximum daily gain/ha before weaning in 1984 was obviously due partly to twinning. For the post-weaning period the relationships were remarkably similar between seasons.

A matter which required further examination was the apparent excessively high stocking rates which maximized daily gain/ha before weaning. If these are examined in relation to the stocking rate vs. disc height relationships in Figure 5.3, it is evident that the disc meter heights corresponding with maximum gain/ha would have been negative in 1982 and 0,53 cm in 1984. This is clearly unrealistic, and the underlying cause of such a result seemed to be the weight loss of ewes. Consequently, the net ADG and daily gain/ha for the ewe + lamb was related to stocking rate

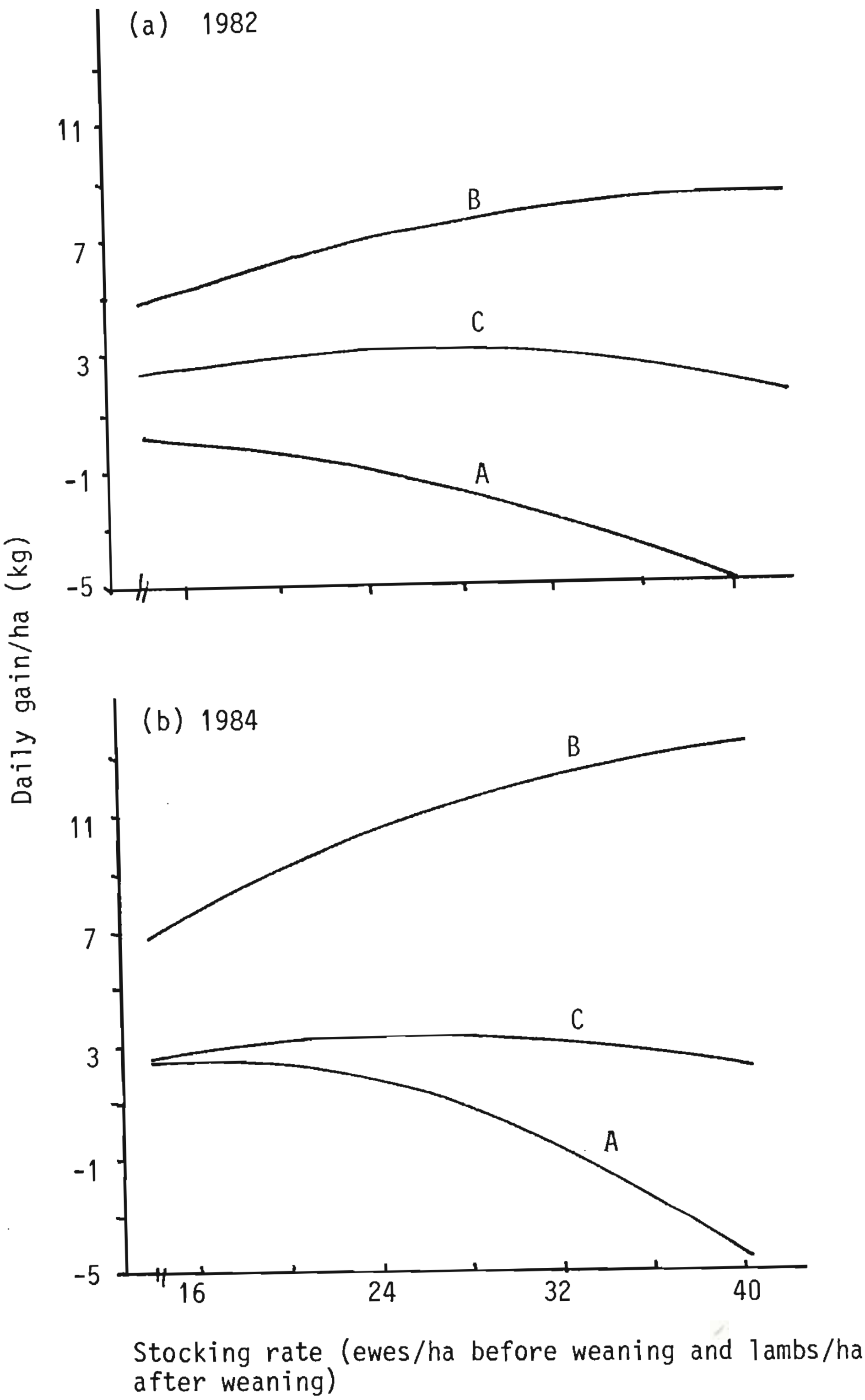


Fig. 5.5 Relationships between daily gain/ha and stocking rate derived from the ADG vs. stocking rate models for (A) ewes and (B) lambs before weaning and for (C) lambs after weaning in the (a) 1982 and (b) 1984 seasons.

for each season (Fig. 5.6). This net ewe + lamb daily gain/ha was maximized at 24,7 and 26,2 ewes/ha in the 1982 and 1984 seasons respectively, with corresponding maximum net daily gains/ha of 5,71 and 12,3 kg. Hence, despite a large difference in maximum net daily gain/ha (which was due mainly to twinning and breed differences between years), the stocking rates which maximized net daily gain/ha before weaning were similar for each year and to those which maximized lamb daily gain/ha after weaning, but only a little more than half of those which maximize lamb daily gain/ha before weaning. Hence, despite net daily gain/ha of ewe + lamb units being of little interest to the producer, relating this parameter to stocking rate served to explain the anomaly of maximum lamb daily gain/ha occurring with no or exceedingly little pasture DM present.

Of more interest to the producer is the stocking rate which maximized gain/ha for the whole grazing period. This was obtained by multiplying the daily gain/ha vs. stocking rate functions for the pre- and post-weaning periods by the number of days in these periods, and then summing the resultant functions (Fig. 5.7). Hence, the pre-weaning functions in Figure 5.5 were multiplied by 67 and 47 days for the 1982 and 1984 seasons respectively, while the corresponding post-weaning functions were multiplied by 80 and 97 days. In 1982 the sum of the pre- and post-weaning functions resulted in a maximum lamb gain/ha of 767 kg which occurred at a stocking rate of 33,4 ewes/ha, with corresponding values of 881 kg and 33,7 ewes/ha in 1984. Again, the stocking rate at which gain/ha was maximized was remarkably similar between years. Despite twinning in 1984, maximum gain/ha was only 15% higher than in 1982. This was primarily due to the shorter pre-weaning grazing period in 1984 (47 days compared to 67 days) which resulted from a delayed start to grazing as a result of a protracted lambing season. Of particular importance is the fact that the stocking

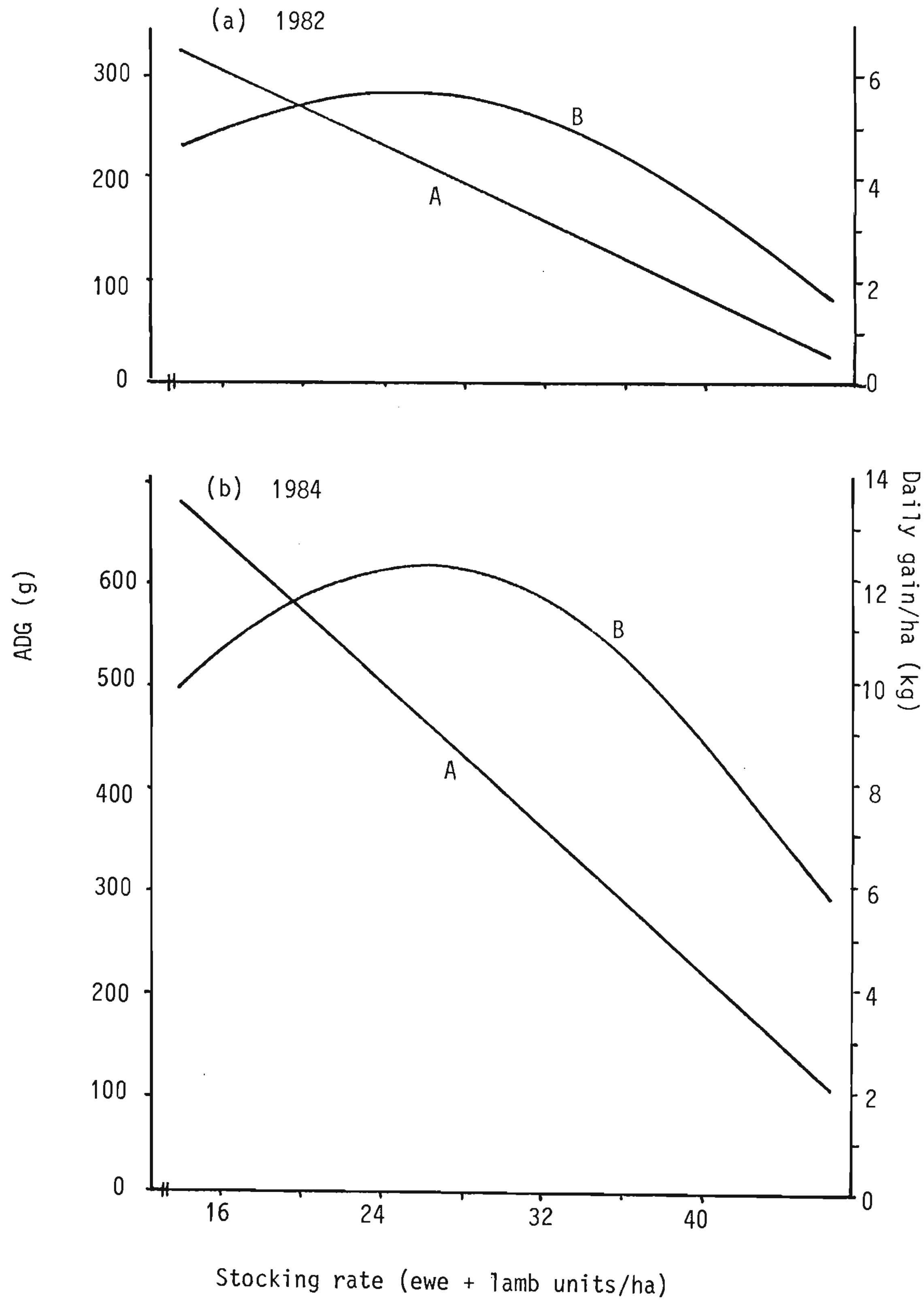


Fig. 5.6 Relationships between net ewe + lamb (A) ADG and (B) daily gain/ha with stocking rate before weaning in (a) 1982 and (b) 1984.

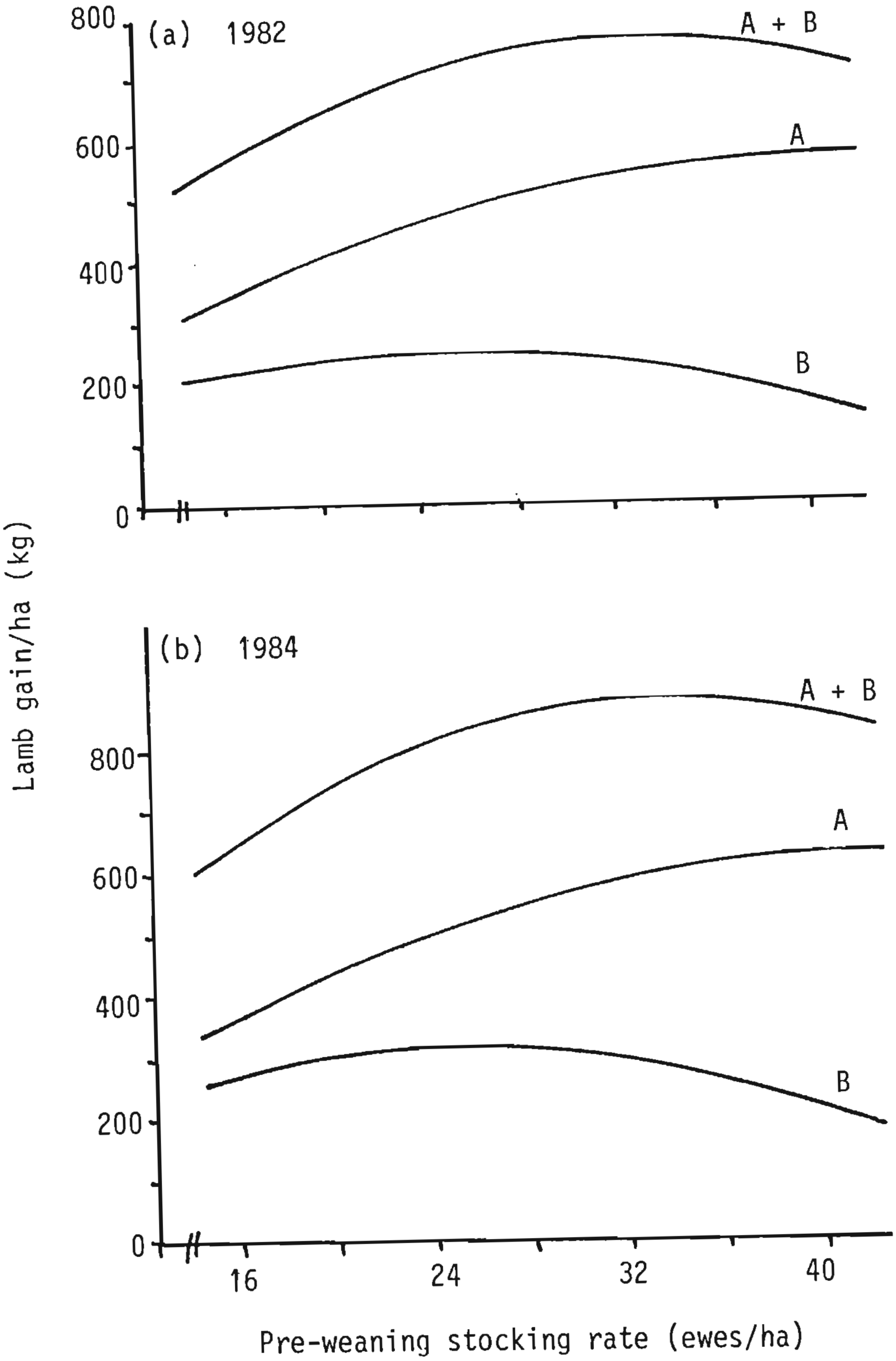


Fig. 5.7 Relationships between lamb gain/ha and pre-weaning stocking rate for (A) the pre-weaning period, (B) the post-weaning period and (A + B) the two periods combined in (a) 1982 and (b) 1984.

rates which maximized gain/ha fell within the limits of the data, thus fulfilling the requirements of this type of experiment prescribed by Connolly (1976).

5.2.2 Gain/ha vs. disc meter height

Stocking rate affects gain/animal and /ha through its effect on the pasture, and in particular, on pasture availability. Consequently, although the relationship between gain/ha and stocking rate is important, it is also useful to relate gain/ha to disc meter height in an attempt to identify the pasture condition which maximizes gain/ha. This was done by multiplying the functions in Fig. 5.2 with those in Fig. 5.3. In other words, functions in Fig. 5.2 relate ADG to disc height and those in Fig. 5.3 relate stocking rate to disc height. Since gain/ha is the product of ADG and stocking rate, the product of functions in Figures 5.2 and 5.3 results in functions which express gain/ha in terms of disc meter height. Furthermore, being the product of two linear functions, the gain/ha vs. disc height relationships are quadratic, and by equating the first derivative of these to zero and solving for disc height it is possible to determine the disc height at which gain/ha is maximized.

Relationships in Fig. 5.8 emphasize the points made in section 5.2.1 viz. pre-weaning lamb gain/ha is maximized at unrealistically low levels of herbage availability because lambs rely heavily on their mothers when stocking rate increases, and consequently their mothers lose weight. For example, the lamb gain/ha/day functions for the pre-weaning period reached maxima at disc meter heights of 0,22 and -1,46 cm in 1982 and 1984 respectively. However, after weaning, daily lamb gain/ha was maximized at a disc meter height of 4,5 cm in 1982 and 6,5 cm in 1984, with corresponding values for ewes before weaning of 9,0 and 6,8 cm.

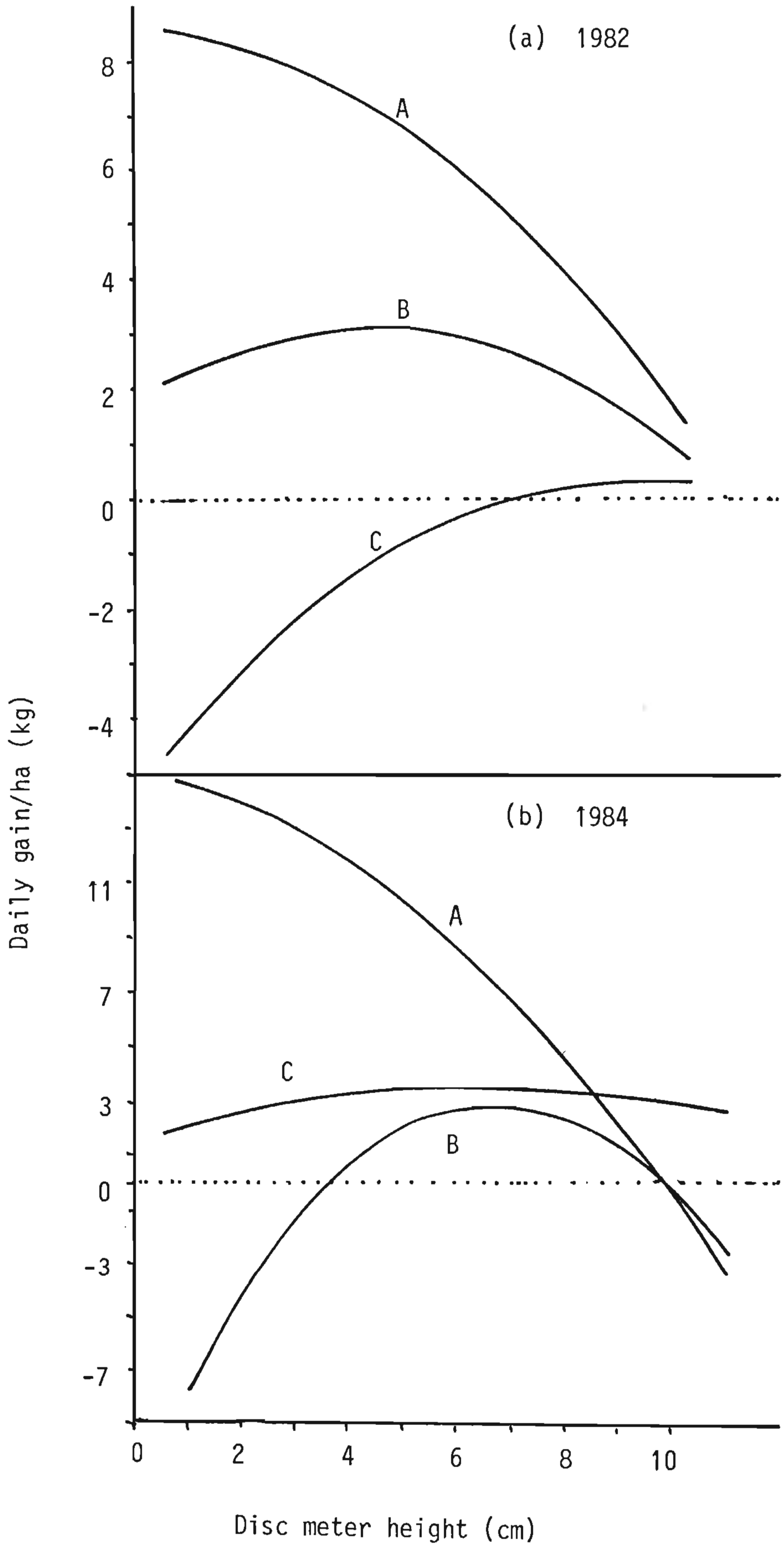


Fig. 5.8 Relationships between daily gain/ha and disc meter height for (A) lambs and (B) ewes before weaning and for (C) lambs after weaning in (a) 1982 and (b) 1984.

When net gain/ha of the ewe + lamb unit was considered, disc meter heights of 4,6 cm and 4,5 cm resulted in maximum production/ha (Fig. 5.9). Consequently, this procedure brought the pattern more into line with post-weaning results and indicated that it is unrealistic to use the gains of offspring alone to determine stocking rates which maximize production, in cases where mothers are still suckling those offspring. A similar response was observed by Bartholomew (1985) with cows that were suckling calves.

Although the disc meter height which maximizes gain/ha in different circumstances has been identified in this section, it should be emphasized that, as for stocking rate, there is a relatively large range in disc meter height within which gain/ha is near maximum. In other words, as pointed out by Bransby _et al._ (1985), gain/ha is well "buffered" against changes in grazing intensity within certain limits. Outside of these limits gain/ha becomes increasingly sensitive to changes in grazing intensity. Furthermore, it should be emphasized that the disc meter heights used to derive the various functions were the average of a number of mean disc meter heights obtained from taking disc meter readings in each paddock on a number of occasions within a given period of time. They therefore include measurements when the sward was tall (especially at the start of grazing in autumn, and in spring when growth started to increase again) and also when it was very short (during mid-winter). This is illustrated well in Fig. 5.10. The important point, therefore, is that these results may well not apply to a situation in which grazing starts when the pasture first reaches 4 - 6 cm, as measured by the disc meter. However, it is quite possible that the extent to which the pasture was allowed to grow out before grazing started, could well have been detrimental to the clover (particularly white clover) which is likely to have been favoured by a shorter and more open canopy.

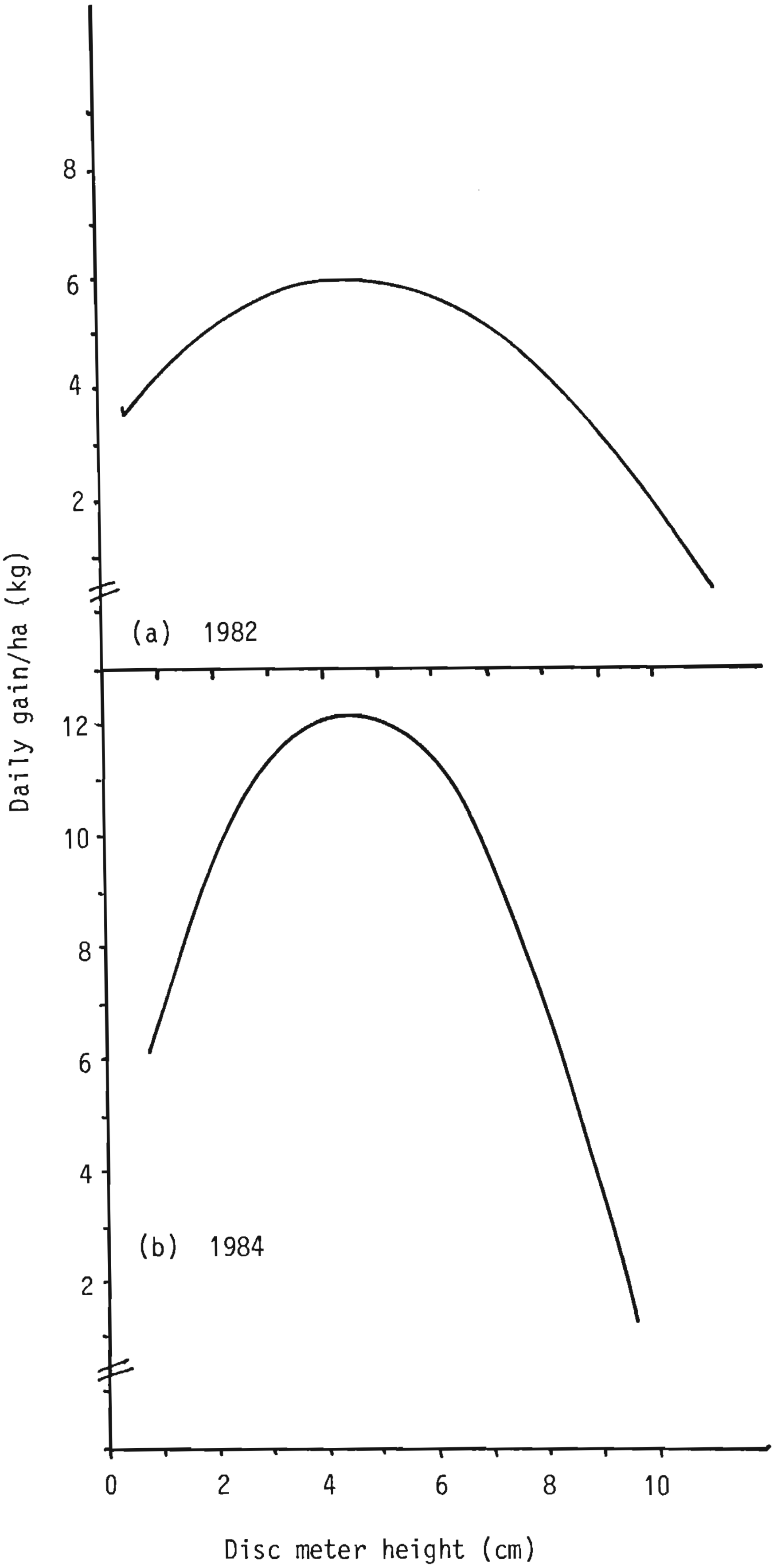


Fig. 5.9 Relationships between net daily gain/ha of ewe + lamb units with disc meter height in the pre-weaning period for (a) 1982 and (b) 1984.

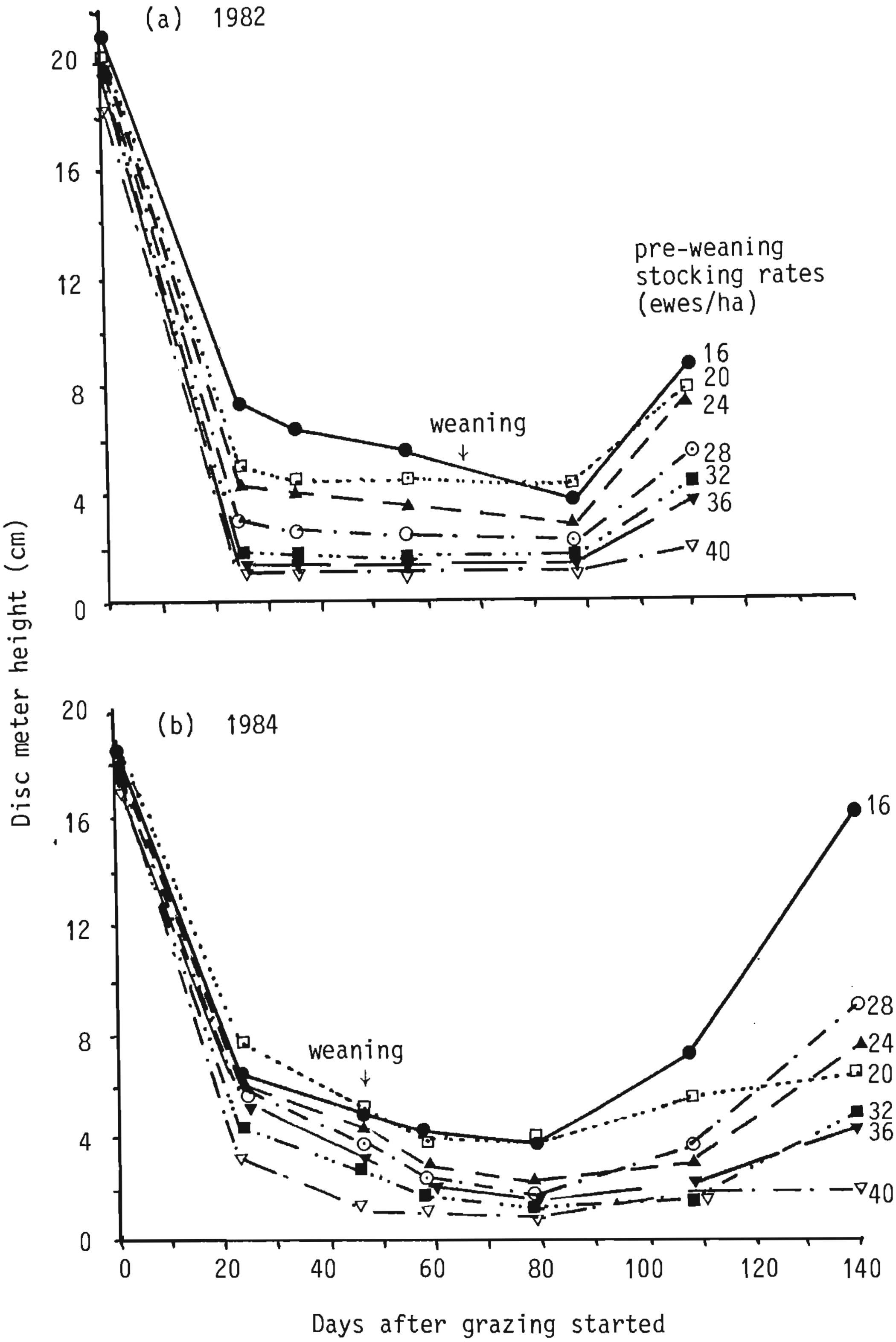


Fig. 5.10 Changes in disc meter heights for different stocking rates with time after commencement of grazing (which was on May 1 in 1982 and May 13 in 1984).

Trends in Fig. 5.10 also suggest that consumption exceeded pasture production by a considerable amount at the start of grazing. The very sharp decline in disc meter height with time over the first three weeks suggests that ewes were primarily eating into an accumulated pool of pasture. However, this response was probably also caused by trampling and it should be emphasized that these patterns do not necessarily reflect patterns of available DM/ha. In addition, it is interesting to note that disc meter height continued to drop even after the ewes were removed at weaning, but started to increase during August. This increase in general, was relatively greater for low stocking rates than for high stocking rates, and appears to reflect the relative excess of production over consumption.

5.3.3 Development of a fat lamb simulation model

So far in this chapter the objective has been to use data to establish an understanding of how stocking rate affects different components of the system in different periods. This has required consideration of data which is common to all stocking rates i.e. from the start of grazing up until the first group (light stocking rate) reached slaughter weight and were marketed. However, lambs on all stocking rate treatments remained on the pasture until they reached slaughter weight, and the required period on pasture consequently increased with increasing stocking rate. Furthermore, data in this study was not collected from birth onwards because it was necessary for all lambs to have been born before they could be allocated to treatments.

In order to perform meaningful economic analysis on biological data it is preferable that the entire production system is simulated. In this case, therefore, it is necessary to start at birth and proceed until some cut off point in summer. It was therefore assumed that lambs were 3 kg at birth and the time taken (T_1) to reach weaning weight (Ww) was calculated as follows :

$$T_1 = (Ww - 3)/ADG_1,$$

where ADG_1 is the ADG from birth to weaning. In Fig. 5.11 this is shown as a function of lamb stocking rate/ha in each season. Hence,

$$ADG_1 = a_1 - b_1S$$

and

$$T_1 = (Ww - 3)/(a_1 - b_1S) \qquad [5.3]$$

Since all lambs were weaned when the lightest was 18 kg, the heaviest lambs were between 26 and 28 kg at weaning. Consequently, it was considered valid to include weaning weight (and therefore the time which it would take to weaning) as a variable in the simulation model. The importance of doing this lies in the fact that lamb ADG was much higher before weaning than after weaning, with the obvious practical implication that the longer weaning is delayed, the shorter is the time required for lambs to reach a slaughter weight.

Although there was no significant difference in slopes between the two lines in Fig. 5.11, the equations were used as they stood for the simulation model. In other words, parallel lines were not fitted. The reason for this was that, although the difference in slopes was not significant, each line fitted independently to each set of data will give the best single description of that data alone.

In order to estimate the time from weaning (T_2) required to reach slaughter weight (40 kg) the following formula was used :

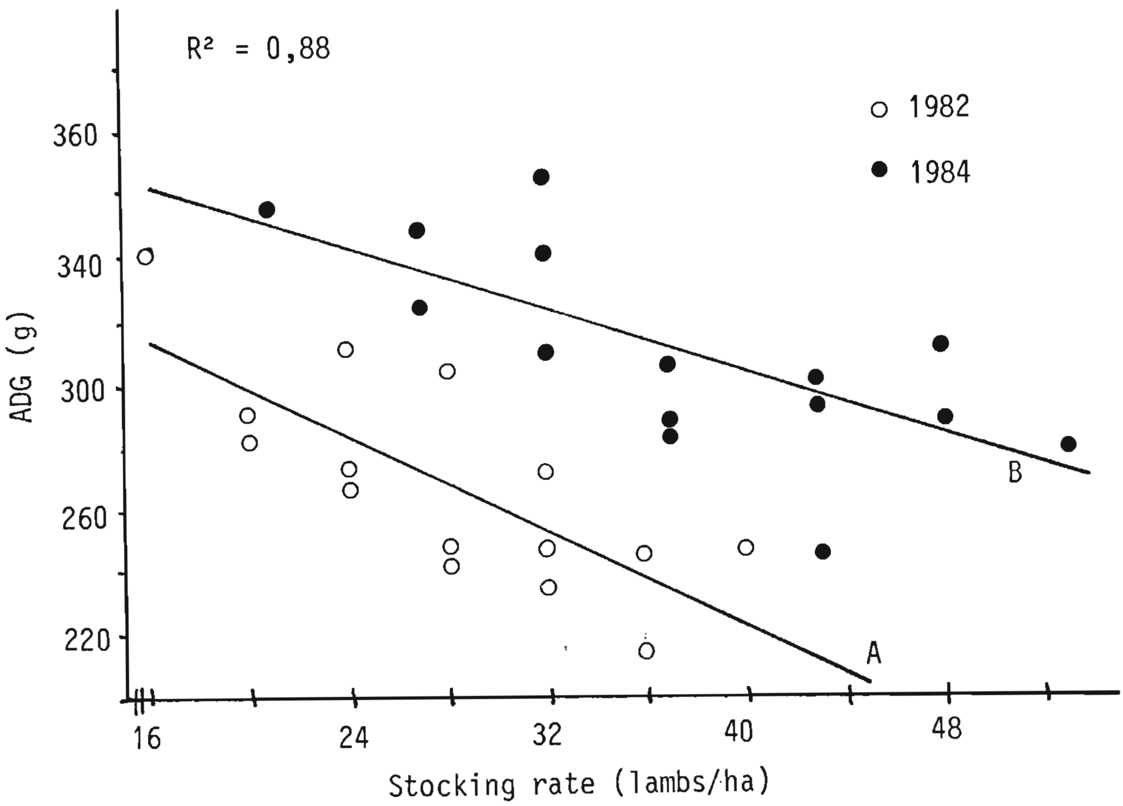


Fig. 5.11 A linear regression model for the relationship between lamb ADG and stocking rate in the pre-weaning period during (A) 1982 and (B) 1984. (A; $y = 374 - 3.8x$: B; $y = 404 - 2,5x$).

$$T_2 = \frac{40 - Ww}{ADG_2}$$

where ADG_2 is the ADG from weaning until slaughter weight was reached. This ADG can be expressed in terms of stocking rate by fitting a regression of ADG (from weaning to when slaughter weight was reached), on stocking rate. Bearing in mind that this period increased with increased stocking rate, such a relationship has little biological meaning. However, it is a useful means of determining the time required to reach slaughter weight for the purpose of simulation and is presented in Fig. 5.12. Consequently,

$$ADG_2 = a_2 - b_2S$$

and therefore

$$T_2 = (40 - Ww)/(a_2 - b_2S) \qquad [5.4]$$

It also follows that the time taken from birth to slaughter (T_3) is easily calculated :

$$\begin{aligned} T_3 &= T_1 + T_2 \\ &= (Ww - 3)/(a_1 - b_1S) + (40 - Ww)/(a_2 - b_2S) \qquad [5.5] \end{aligned}$$

Hence, equation 5.5 is an expression of the time taken from birth to reach slaughter weight in terms of both stocking rate and weaning weight. Considering stocking rates of 16; 20; 24; 28; 32; 36 and 40 lambs/ha, and weaning weights of 18; 20; 22; 24 and 26 kg, the time from birth to slaughter was calculated and presented in graph form (Fig. 5.13 and 5.14).

From the 1984 simulation, lambs at low stocking rates could be expected to finish in a slightly shorter period than when the 1982 simulation was used. This is primarily due to the slightly higher ADG observed at low stocking rates during both pre- and post-weaning periods in realistic estimates because they were obtained from a large number of lambs which grazed the whole experiment at a relativly low grazing pressure after the initial treatment lambs were marketed.

The simulation which follows assumes that grazing starts at lambing on 1 April, and continues for 260 days, with the first group of lambs being followed by a second group which are finished in December. This assumption again represents minor extrapolation from experimental data, since grazing in the grazing trials only started in May. However, this extrapolation is considered completely feasible because many farmers currently establish ryegrass pastures early enough to enable grazing to start on 1 April. In addition, an earlier start to grazing should lead to earlier weaning and removal of ewes from the pasture, thus reducing the grazing pressure on the pasture before the critical mid-June to early August period during which very little pasture growth takes place. Consequently, an earlier start to grazing is likely to be more lenient on the pasture.

In order to establish what the initial weight of the second group of lambs should be to ensure that they finish in December, it is first necessary to establish how much time is available after the first group of lambs has been marketed. This is determined by subtracting T_3 (or $T_1 + T_2$) from 260 days, the outcome being dependent on stocking rate and weaning weight of the initial group of lambs. The relationship between the number of days available to finish the second group of lambs and stocking rate, is presented in Fig. 5.15. Since the total number of days in the grazing season is constant, the time available to finish the second group of lambs is inversely related to the time taken to finish the first group. This trend is clearly evident when Figure 5.15 is compared to Figure 5.13.

The total production system can be represented diagrammatically as follows :

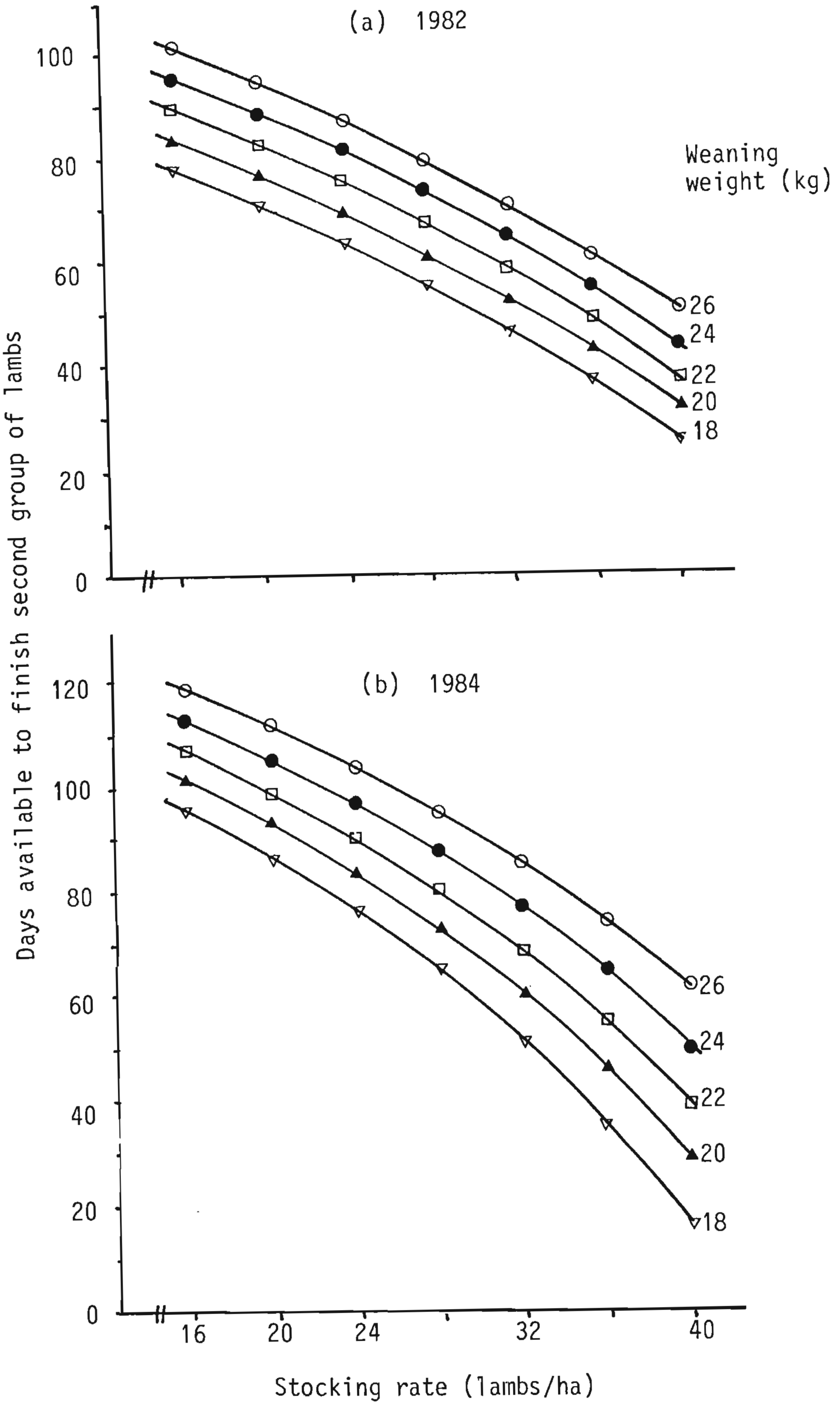
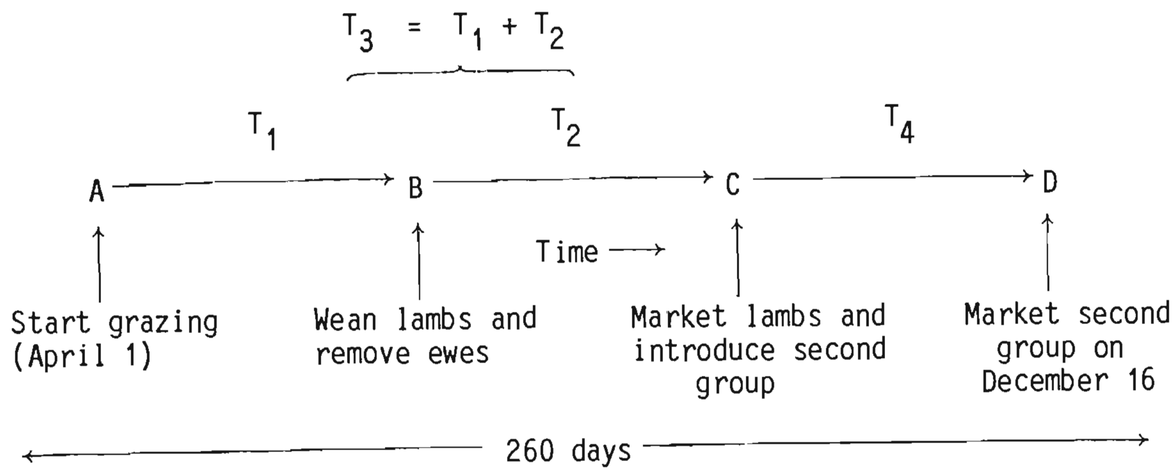


Fig. 5.15 Simulated relationships between the number of days available to finish a second group of lambs and stocking rate, for different weaning weights in (a) 1982 and (b) 1984.



While A and D remain fixed at April 1 and December 16 respectively, B and C, and therefore T_1; T_2; T_3 and T_4 all vary with stocking rate and weaning weight.

To estimate the initial lamb weight required in order to reach market weight of 40 kg by December 16, the following formula applies :

$$W_i = 40 - (T_4 \times 0{,}17) \qquad [5.6]$$

where W_i is the required initial weight, 40 kg is the finished weight, T_4 is the number of days available to finish the second group of lambs (which is a function of stocking rate and weaning weight) and 0,17 kg is the expected ADG of the second group of lambs from the time they start grazing until they are finished.

The W_i values are presented in Table 5.1 for different stocking rates and weaning weights. This initial weight required of the second group of lambs in order to finish them at 40 kg by December 16 increased with increasing stocking rate and decreasing weaning weight. The reason for this is that high stocking rates and low weaning weights for the first group of lambs resulted in these lambs taking longer to finish, thus leading to a shorter period available for grazing the second group which

TABLE 5.1 The estimated initial weight of the second group of lambs required in order to finish animals at 40 kg on December 16, expressed as kg for different stocking rates and weaning weights in 1982 and 1984.

YEAR	STOCKING RATE (LAMBS/HA)	WEANING WEIGHT (kg) 18	20	22	24	26
1982	16	26.76	25.77	24.79	23.80	22.80
	20	27.93	26.96	25.94	24.94	23.94
	24	29.21	28.20	27.18	26.18	25.14
	28	30.62	29.56	28.54	27.52	26.50
	32	32.10	31.08	30.04	28.98	27.95
	36	33.74	32.62	31.67	30.63	29.60
	40	35.58	34.54	33.51	32.50	31.42
1984	16	23.73	22.76	21.81	20.84	19.87
	20	25.26	24.21	23.15	22.10	21.03
	24	27.01	25.84	24.68	23.51	22.34
	28	28.97	27.66	26.38	25.09	23.78
	32	31.23	29.78	28.34	26.88	25.43
	36	33.83	32.20	30.58	28.95	27.34
	40	36.92	35.09	33.23	31.40	29.55

Note : Values below solid lines in the body of the table represent lamb weights which are unlikely to be obtainable (see Chapter 6).

consequently had to be heavier in order to attain slaughter weight by December 16.

Although economic analysis depends indirectly on the information derived from the simulations performed so far, lamb gain/ha is the variable to which economic analysis can be directly applied. The ultimate aim of this chapter, therefore, is to relate lamb gain/ha to stocking rate and weaning weight. This was done by using the following equation :

$$G = 40S + (60 \times 0{,}17)\ T_4$$
$$= 40S + 10{,}2\ T_4 \qquad [5.7]$$

where G = gain/ha;

40 kg = slaughter weight of lambs;

S = stocking rate of first group of lambs;

60 = lambs/ha for second group of lambs;

0,17 = ADG of second group of lambs;

and T_4 = number of days the second group of lambs spent on the pasture.

Lamb gain/ha is expressed in terms of stocking rate and in terms of weaning weight in Figures 5.16 and 5.17 respectively. In 1982 gain/ha increased with stocking rate and did not reach a maximum below 40 lambs/ha (Fig. 5.16). For an increase in stocking rate from 16 to 40 lambs/ha, gain/ha for a weaning weight of 18 kg increased from 1432 to 1862 kg, representing a 30% improvement in production. By increasing weaning weight, predicted lamb gain/ha increased on average by 249 kg and this figure showed little variation as stocking rate changed. On average, it represented a 15% increase in production. It is interesting to note that the highest predicted gain/ha was 2121 kg, which occurred when weaning weight was 26 kg and at a stocking rate of 40 lambs/ha.

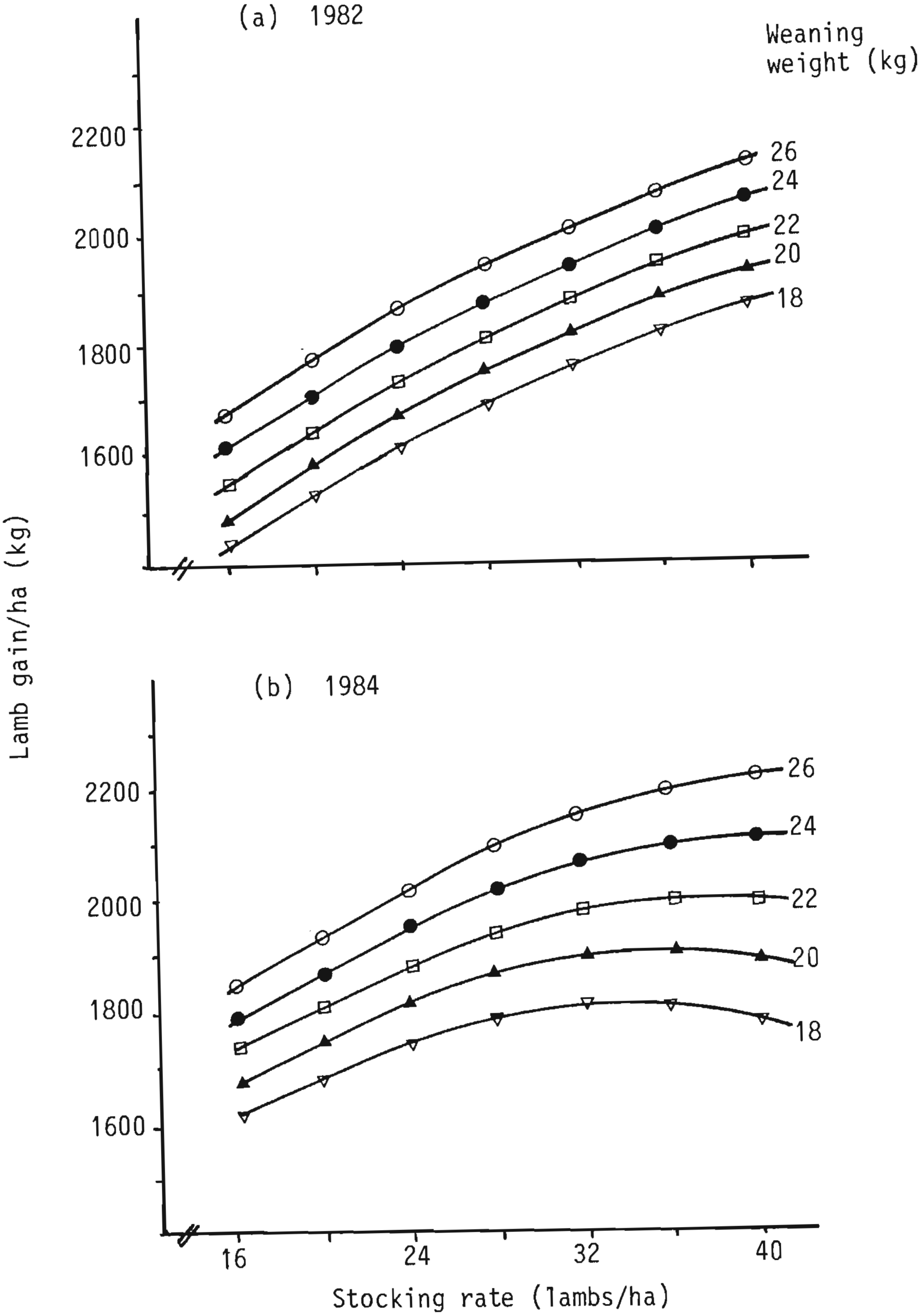


Fig. 5.16 Simulated relationships between lamb gain/ha and stocking rate for different weaning weights in 1982 and 1984.

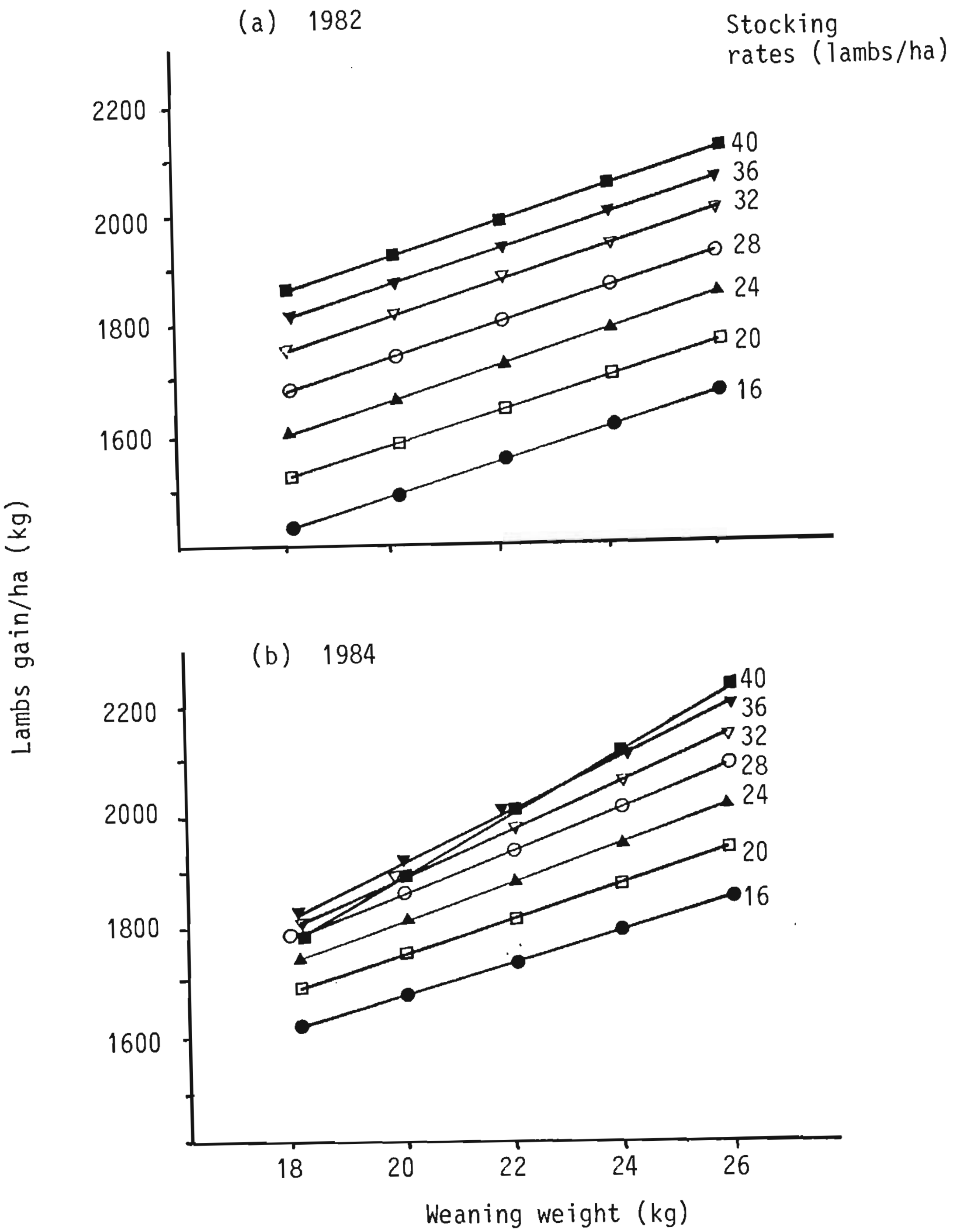


Fig. 5.17 Simulated relationships between lamb gain/ha and weaning weight for different stocking rates in 1982 and 1984.

In contrast to the 1982 simulation, results for 1984 showed maximization of gain/ha below 40 lambs/ha when weaning weight was between 18 and 22 kg, but not for weaning weights of 24 and 26 kg. Also, at a stocking rate of 16 lambs/ha weaning at 26 kg resulted in an increase in gain/ha of 240 kg over weaning at 18 kg, while at a stocking rate of 40 lambs/ha this difference was 439 kg/ha. Consequently, gain/ha showed a relatively greater response to higher weaning weights at high stocking rates compared to low stocking rates. It follows, therefore, that there was a greater response of gain/ha to stocking rate for high weaning weights than for low weaning weights. For example, when weaning weight was set at 26 kg, gain/ha increased by 377 kg with an increase in stocking rate from 16 to 40 lambs/ha, while for the same change in stocking rate and a weaning weight of 18 kg this difference was only 177 kg. The highest gain/ha of 2227 kg was again obtained when weaning weight was 26 kg and stocking rate 40 lambs/ha.

Gain/ha increased linearly with weaning weight (Fig. 5.17). The patterns here represent the same trends evident in Fig. 5.16, but presented in a different way. For example, in 1982 the parallel lines (equal spacing) reflect the parallelism evident in Fig. 5.16a, and the closer proximity of the lines to one another at high stocking rates reflect the decrease in slopes of lines at high stocking rates in Fig. 5.16a. Similarly, in 1984 the change in slopes (at high stocking rates in particular) of lines in Fig. 5.17b reflects the divergence of lines at high stocking rates in Fig. 5.16b. Also, the gain/ha maxima observed for weaning weights between 18 and approximately 23 kg in Fig. 5.16b are reflected in the intersection of lines at a weaning weight of 23 kg in Fig. 5.17b. In combination, therefore, these two figures (Fig. 5.16 and 5.17) represent a response surface with lamb gain/ha as the dependent variable and stocking rate and weaning weight as the independent variables.

Despite difference between seasons in breed of experimental sheep, the gain/ha was remarkably similar in the two years. This is probably because stocking rate was expressed, for the purpose of the simulation, as lambs/ha and not ewes/ha, thus eliminating to a certain extent, the benefits of twinning. The reason for doing this was that the number of lambs that can be carried through the critical winter period is the major constraint to increasing stocking rate on the farm, and therefore it is this figure rather than any other factor that should determine the pre-weaning ewe stocking rate. In practice, all this means is that twinning leads to fewer ewes/ha during the pre-weaning period than no twinning, but gain/ha is not likely to be affected much. However, costs are likely to be reduced and profit/ewe should be markedly affected by the percent twinning achieved. The economic benefits of twinning will be discussed in the next chapter.

For the farmer who is interested in producing one crop of lambs only (i.e. the first group), gain/ha for this phase alone is of interest. Since lambs at all stocking rates remained on pasture until they reached 40 kg, gain/ha for the first group of lambs is simply a linear function ($G = 40S$; where G = gain/ha and S = stocking rate) and is not dependent on weaning weight. However, should a farmer wish to produce a ryegrass seed crop after marketing these lambs, he will have to finish them by a specified time. Weaning weight, once again, then becomes important, and by using the information in Fig. 5.13 he will be able to select a suitable combination of stocking rate and weaning weight to ensure that his lambs are marketed early enough to allow his seed crop to grow out.

Having developed relationships for gain/ha against stocking rate, the stage has now been set to perform economic analysis by building on to this model in the next chapter. This procedure, of course, will include both stocking rate and weaning weight as variables.

6. AN ECONOMIC MODEL

Since the study described in this thesis was oriented primarily towards the producer, it would not be complete without economic analysis. In addition, greater confidence would be engendered in these results if they were verified on a farm scale, bearing in mind the relatively small scale of individual paddocks in the grazing trials. Economic analysis is therefore performed on the data by developing an economic model from the grazing simulation model described in Chapter 5. Subsequently, results from a pilot evaluation on a farm scale are presented in Chapter 7.

Initially, the breeding phase alone was considered in respect of expenditure, income and profit/ha and /ewe for different stocking rates and weaning weights. Thereafter, the second group of lambs was considered and finally, a production system incorporating both the breeding phase and second group of lambs was assessed.

6.1 The breeding phase

6.1.1 Expenditure

Total expenditure (E) for the breeding phase of production (from birth until the first group of lambs were marketed) can be divided into two main categories : pasture costs (M) e.g. fertilizer, establishment and irrigation costs, and animal costs (A) which include the expenses directly associated with keeping animals, such as dosing and labour costs. Hence

$$E = M + A \qquad [6.1]$$

Pasture costs were made up as follows, based on figures obtained in November/December, 1985 :

	Rand/ha
Land preparation and planting	91,62
500kg superphosphate/ha	118,09
280kg N/ha @ R1,15/kg	322,00
30kg/ha Midmar ryegrass seed	65,00
4kg/ha Kenland red clover seed	40,00
3kg/ha Ladino white clover seed	52,00
Irrigation (ESCOM power + plant depreciation)	34,29
	723,00

In view of there being no response to N fertilization in the grazing trial a level of N application close to the lowest level (275 kg N/ha) was chosen for the purpose of economic analysis. However, since this input is not related to stocking rate or weaning weight, allowance can easily be made for higher levels of N by simply subtracting R1,15/additional kg of N applied/ha from profit/ha determined in later sections of this chapter. This, of course, is valid only because there was no production response to increased N fertilization.

Animal costs were made up of dosing, labour and marketing costs. During the pre-weaning period both ewes and lambs were dosed for internal parasites every 18 days. Ewes were dosed with a broad spectrum worm remedy at a cost of 0,88 cents/head/day, while lambs received both a tapeworm and a broad spectrum worm remedy at an average cost of 1,00 cents/head/day. Labour was costed on the basis of one labourer spending an average of half a day (4 hours) caring for 300 lambs and their mothers, and earning a salary of R130 per month. These figures were considered realistic from agricultural extension experience in the Underberg district. Hence, daily labour costs/ewe-lamb unit during the pre-weaning period came to 0,72 cents, and total costs/ewe-lamb unit were 2,6 cents/day. To obtain total labour + dosing costs/ha for different stocking rates and weaning weights during the pre-weaning period, this figure was multiplied by stocking rate and by the number of days in the pre-weaning period (estimated using equation 5.3) for corresponding stocking rates and weaning weights. For the purpose of economic analysis, stocking rate was expressed in lambs/ha in both the pre- and post-weaning periods. The reason for this was that in a farm production system the winter period, when pasture growth is slow, is the main limitation to carrying more animals/ha, and during this period only lambs were on the pasture. The feeling was, therefore, that if the lamb stocking rate was to remain constant over the production period from birth to slaughter, then the pre-weaning stocking rate must be set on the basis of lambs/ha and not ewes/ha (since a variable percentage of twinning can be expected between farms and between years). However, it is recognized that some producers may wish to lamb a pre-determined number of ewes down on pasture and, if they achieve a high level of twinning, remove some of the lambs when ewes are withdrawn at weaning, but this strategy was not considered.

Total labour + dosing costs/ha appear in Table 6.1. Since these costs were directly related to stocking rate, they rose sharply as stocking rate increased. Another contributing factor to this response was the increased length of the pre-weaning period with increased stocking rates. As weaning weight increased, these costs also increased due to the corresponding increase in the pre-weaning period. In 1984 the dosing + labour costs/ha for the pre-weaning period were lower than in 1982. This was due to the lower ewe : lamb ratio as a result of twinning in 1984, as well as the slightly higher lamb gains (Fig. 5.11) in this season.

During the post-weaning period it was again assumed that a labourer could handle 300 lambs and their mothers. However, dosing costs for the ewes were no longer allocated to the pasture phase of the production system, but accounted for in a manner to be described further on in this chapter. Lambs were dosed as for the pre-weaning period, but daily dosing costs/lamb rose to 1,22 cents/lamb/day due to the larger dose required as lambs increased in weight.

Dosing and labour costs/ha were obtained by multiplying the daily cost/lamb by stocking rate and the number of days in the post-weaning period, calculated for different stocking rates and weaning weights by means of equation 5.4. Once again, due to the direct link between dosing and labour costs and stocking rate, and due to the increased length of the post-weaning period as stocking rate increased (as a result of lower weight gains with increased stocking rates), these values increased with stocking rate (Table 6.2). However, since the pre-weaning period increased with increased weaning weight, it follows that the post-weaning period showed a corresponding decrease. This was because, as weaning weight increased, less weight gain was required to reach the slaughter weight of 38-40 kg. Hence, total labour and dosing costs/ha for the post-weaning period decreased with increased weaning weight. At low stocking rates these costs were slightly higher in 1982 than in 1984, while at high stocking rates the reverse was observed. This appeared to be associated with the stocking rate x year interaction in post-weaning ADG (Fig. 5.12).

The final portion of expenditure which needed to be considered was marketing costs. This was made up as follows :

TABLE 6.2 Total costs/ha (R) for labour and dosing lambs, considering different stocking rates and weaning weights during the post-weaning period.

YEAR	STOCKING RATE (LAMBS/HA)	LAMB WEANING WEIGHT (KG) 18	20	22	24	26
		R				
	16	42	38	34	30	27
	20	54	49	44	39	34
	24	67	61	55	49	43
1982	28	81	73	66	59	51
	32	96	87	78	70	61
	36	112	102	91	81	71
	40	129	117	106	94	82
	16	38	35	31	28	24
	20	51	46	42	37	32
	24	65	59	53	47	41
1984	28	82	74	67	59	52
	32	101	91	82	73	64
	36	123	112	100	89	78
	40	149	136	122	109	95

	Rand
Abattoir fee	3,00
Slaughter fee	0,60
Levies	1,20
Agents fee	2,40
Insurance	0,64
Transport to abattoir	1,90
	9,74

Marketing costs/ha (K) are therefore a linear function of stocking rate (S):

$$K = 9,74S$$

Total expenditure/ha (E) therefore included pasture costs (Q), pre-weaning dosing and labour costs (N), post-weaning dosing and labour costs (M) and marketing costs (K) :

$$E = Q + N + M + K$$

These total costs/ha (Table 6.3) increased with stocking rate but showed virtually no change as weaning weight increased. This latter result was caused by the increase in animal costs/ha with increased weaning weights for the pre-weaning period (Table 6.1) being more or less balanced by the corresponding decrease in animal costs/ha with increased weaning weights in the post-weaning period (Table 6.2). Differences between years in total expenditure/ha was minimal.

Total expenditure/ewe was obtained by simply dividing expenditure/ha by ewe stocking rate. This value decreased as stocking rate increased (Table 6.4) primarily because pasture costs were being divided by correspondingly more animals. As a result of twinning, expenditure/ewe in

1984 was considerably higher than in 1982; at a stocking rate of 40 lambs/ha and a weaning weight of 18kg this difference was 33%.

6.1.2 Income and profit

Income (I) was also a linear function of stocking rate. Taken that the live slaughter weight was 40kg and a price of R2/kg live weight was obtained (since the current price of dressed super lamb was R4+, and 97% of the 90 lambs slaughtered were graded super) income/ha was calculated as follows :

$$I = 40 \times 2 \times S$$
$$= 80S$$

For a stocking rate of 16 lambs/ha, income/ha was therefore R1280 and for 40 lambs/ha it was R3200. This represented a ~~150%~~ 250% increase.

Profit/ha (P) was obtained by subtracting expenditure from income :

$$P = I - E$$

Alternatively, profit/ha could be expressed as a function of stocking rate as follows :

$$P = 80S - (M + N + Q + 9{,}74S)$$

Despite the increase in expenditure/ha with increased stocking rate, profit/ha also increased with stocking rate (Table 6.5). The suggestion, therefore, is that income increased more rapidly with stocking rate than did expenditure. This trend is clearly illustrated in figure 6.1. For a weaning weight of 18 kg, profit at a stocking rate of 40 lambs/ha was 455% higher than profit at 16 lambs/ha in 1982, whereas the corresponding difference in income was only 150%. This was a result of subtracting expenditure (and particularly the "fixed" pasture cost/ha) from income to

TABLE 6.5 Profit/ha for different stocking rates and weaning weights in the breeding phase.

YEAR	STOCKING RATE (LAMBS/HA)	LAMB WEANING WEIGHT (KG) 18	20	22	24	26
		R				
	16	340	341	342	343	344
	20	602	604	605	606	608
	24	863	865	867	868	870
1982	28	1123	1125	1127	1128	1130
	32	1380	1382	1384	1387	1389
	36	1636	1638	1640	1642	1645
	40	1888	1890	1893	1895	1898
	16	347	349	350	351	353
	20	611	613	615	617	619
	24	873	876	878	881	884
1984	28	1133	1136	1140	1143	1146
	32	1389	1394	1398	1403	1407
	36	1643	1648	1654	1660	1665
	40	1891	1898	1906	1913	1920

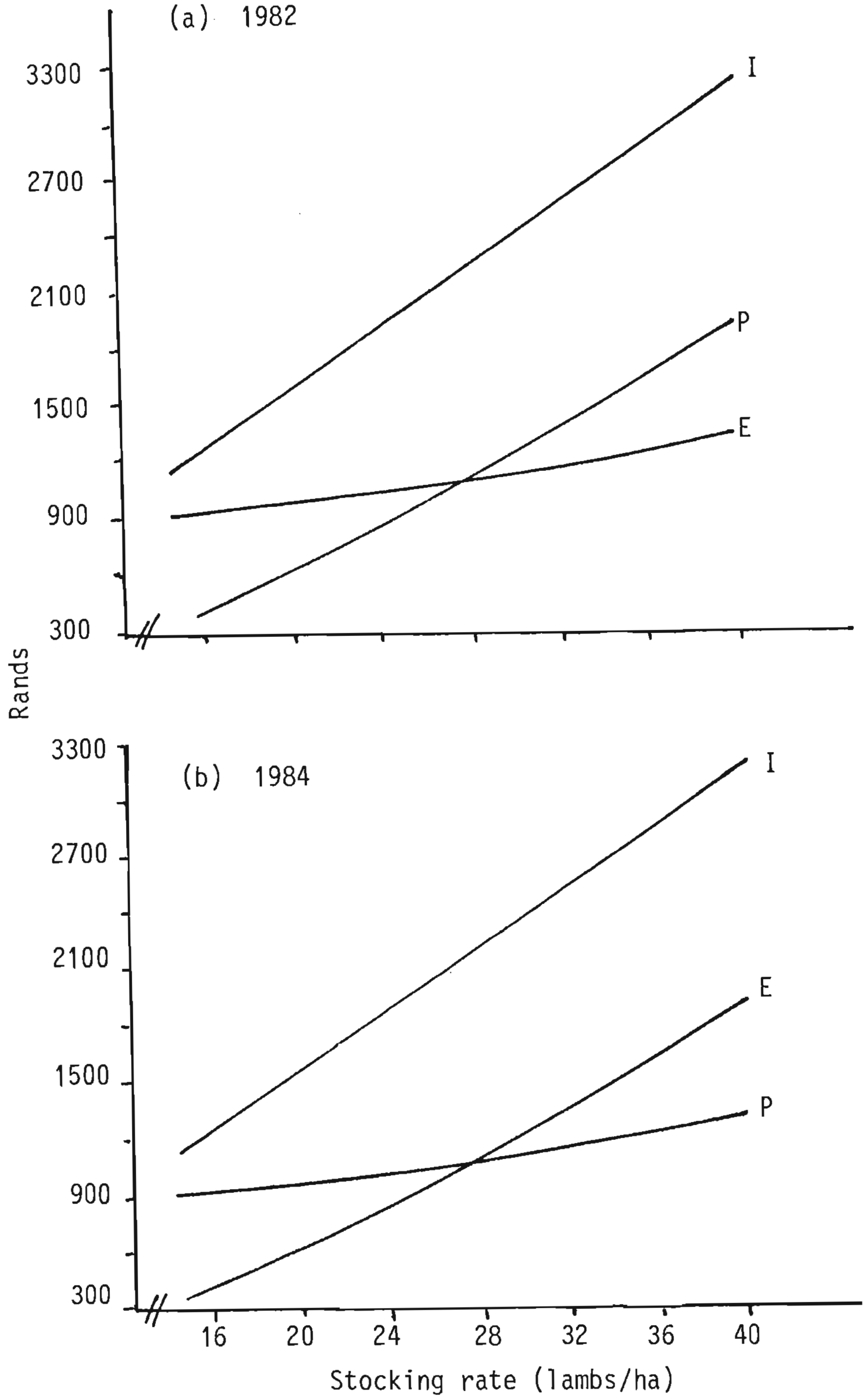


Fig. 6.1 Changes in income (I), expenditure (E) and profit (P)/ha with stocking rate for the breeding phase only, in 1982 and 1984.

obtain profit. There was little difference in profit/ha between years and across stocking rates.

To obtain profit/ewe, profit/ha was divided by ewe stocking rate. This value increased with stocking rate, but showed little change as weaning weight increased (Table 6.6). Assuming a weaning weight of 18 kg, estimated profit/ewe at a stocking rate of 40 lambs/ha was 122 and 177% higher than for a stocking rate of 16 lambs/ha in the 1982 and 1984 seasons respectively. In 1984, profit/ewe was higher than in 1982, clearly as a result of twinning : assuming a weaning weight of 18 kg and a stocking rate of 40 lambs/ha, the profit advantage of twinning in 1984 was 33%.

Return on annual expenditure was obtained by expressing profit/ha as a percentage of expenditure/ha (Table 6.7). These values showed an extremely sharp response to increasing stocking rate, and for a weaning weight of 18 kg, return on costs/ha was nearly 4 times higher at a stocking rate of 40 lambs/ha than at 16 lambs/ha. This is clearly a result of the sharp increase in income with stocking rate and a relatively gentle increase in costs/ha, primarily as a result of no change in pasture costs/ha as stocking rate increased.

6.2 Speculation phase

As indicated at the end of Chapter 5, once the first group of lambs were marketed it was still possible to obtain further production from the pasture by introducing weaned lambs. These lambs could either be bought in, or alternatively, they might be lambs that were off the same farm as those already marketed from ryegrass + clover, but having been fed on a lower plane of nutrition as a result of inadequate ryegrass + clover pasture for all the sheep on the farm during winter. For the purpose of this study it will be assumed that the lambs were bought in, and this

TABLE 6.6 Profit/ewe for different stocking and weaning weights in the breeding phase.

YEAR	STOCKING RATE (LAMBS/HA)	LAMB WEANING WEIGHT (KG)				
		18	20	22	24	26
				R		
	16	21	21	21	21	22
	20	30	30	30	30	30
	24	36	36	36	36	36
1982	28	40	40	40	40	40
	32	43	43	43	43	43
	36	45	46	46	46	46
	40	47	47	47	47	47
	16	29	29	29	29	29
	20	41	41	41	41	41
	24	48	49	49	49	49
1984	28	54	54	54	54	55
	32	58	58	58	58	59
	36	61	61	61	61	62
	40	63	63	63	64	64

TABLE 6.7 Profit/ha as a percent of costs/ha for the breeding phase, considering different weaning weights and stocking rates.

YEAR	STOCKING RATE (LAMBS/HA)	LAMB WEANING WEIGHT (KG) 18	20	22	24	26
		R				
	16	36	36	37	37	37
	20	60	61	61	61	61
	24	82	82	82	83	83
1982	28	101	101	101	101	102
	32	117	117	118	118	119
	36	131	132	132	133	133
	40	144	144	144	145	146
	16	37	38	38	38	38
	20	62	62	62	63	63
	24	83	84	84	85	85
1984	28	102	103	104	104	105
	32	119	120	120	121	122
	36	132	134	135	136	137
	40	145	146	147	149	150

second phase of production will therefore be referred to as the speculatory phase.

6.2.1 Expenditure

From experience in the Underberg area, weaned lambs could be obtained for about R1,50/kg liveweight, and so this was the purchase price adopted for this study. The reason why this value is lower than the price for slaughter lambs is that the weaned lambs were not in slaughter condition. A daily dosing cost of 0,19 cents/lamb was assumed and a stocking rate of 60 lambs/ha, irrespective of previous stocking rates. The number of days in the speculation phase (Fig. 5.15) and the required purchase weight of lambs (Table 5.1) to ensure marketing at 40 kg by December 16 using an estimated ADG of 170 g was calculated previously. Expenditure for the speculation phase (E_1) was therefore calculated as follows :

$$E_1 = (1,5W_p + 0,0019T_4 + K)60$$

where W_p represents the purchase weight of weaned lambs, T_4 the number of days in the speculation phase, and K, the marketing cost/lamb.

Expenditure/ha for the speculation phase was high compared to the previous (breeding) phase of production due to the high cost of purchasing weaned lambs. These values increased slightly with stocking rate in the breeding phase, due to heavier lambs being required as a result of fewer days being available for the speculation phase, as stocking rate increased in the breeding phase (Table 6.8). The change in expenditure/ha with weaning weight and between years was very small.

6.2.2 Income and profit

Income of the speculation phase (I_1) was obtained as follows :

$$I_1 = 40 \times 60 \times 2$$
$$= 4800$$

TABLE 6.8 Expenditure/ha for the speculation phase for different weaning weights and stocking rates (values below solid lines indicate situations for which lambs are unobtainable in respect of each year).

YEAR	BREEDING PHASE STOCKING RATE (LAMBS/HA)	BREEDING PHASE LAMB WEANING WEIGHT (KG) 18	20	22	24	26
				R		
	16	3886	3863	3841	3818	3796
	20	3912	3889	3847	3844	3822
	24	3941	3918	3815	3872	3848
1982	28	3973	3949	3925	3902	3880
	32	4006	3983	3959	3935	3912
	36	4043	4018	3997	3973	3950
	40	4085	4061	4039	4017	3991
	16	3817	3795	3774	3752	3730
	20	3851	3808	3804	3780	3757
	24	3897	3865	3838	3812	3786
1984	28	3936	3906	3877	3848	3818
	32	3987	3953	3921	3889	3856
	36	4045	4009	3971	3935	3899
	40	4115	4074	4081	3989	3949

assuming a slaughter weight of 40 kg, a stocking rate of 60 lambs/ha and a price of R2,00/kg. Consequently, profit/ha for the speculation phase (P_1) was calculated as R4800 minus expenditure/ha :

$$P_1 = 4800 - E_1$$

Profit/ha decreased with increased stocking rate, but showed little variation between years and across weaning weights (Table 6.9). The decrease in profit/ha for the speculation phase as stocking rate increased was primarily due to fewer days and therefore less gain in the speculation phase, as stocking rate in the breeding phase increased (Fig. 5.15). When expressed as a percent of costs, profit for the speculation phase suggested that this operation was economically worthwhile (Table 6.10).

Clearly, the positive price margin (selling price minus buying price) played a major role in the profitability of the speculation phase : e.g. if it is assumed that the purchase weight of animals was 25 kg, buying price R1,50/kg, selling price R2,00/kg and the stocking rate 60 lambs/ha, the difference in the buying and selling price of the initial weight/ha would be R750. In other words, R750 of the profit/ha was due to selling the initial weight of lambs at R0,50/kg more than what was paid for it. From Table 6.9 it is obvious that this represents a major proportion of the profit in the speculation phase, suggesting that for equal buying and selling price this phase may well not be profitable. However, the model enables the effect of price margin on profit to be examined by varying buying and selling price, although it was considered unnecessary to pursue this issue here. Another important point is that farmers are unlikely to sell weaned lambs that are above 30 kg, since relatively little feed would be required in order to finish them. Consequently, it was considered that weaned lambs of 30 kg or more would not be obtainable, thus excluding all

TABLE 6.9 Profit/ha for the speculation phase, taking into account different stocking rates and weaning weights during the breeding phase (values below solid lines indicate situations for which lambs are unobtainable in respect of each year).

YEAR	BREEDING PHASE STOCKING RATE (LAMBS/HA)	BREEDING PHASE WEANING WEIGHT (KG) 18	20	22	24	26
		R				
	16	914	937	959	982	1004
	20	880	911	933	956	978
	24	859	882	905	928	952
1982	28	827	851	875	898	920
	32	794	817	841	865	887
	36	757	782	803	827	850
	40	715	739	761	783	809
	16	983	1005	1026	1048	1070
	20	949	972	996	1020	1043
	24	903	935	962	988	1014
1984	28	864	894	923	952	982
	32	813	847	879	911	944
	36	755	791	829	865	901
	40	685	726	769	810	851

TABLE 6.10 Profit/ha as a percent of expenditure/ha for the speculation phase, considering different stocking rates and weaning weights in the breeding phase (values below solid lines indicate situations for which lambs are unobtainable in respect of each year).

YEAR	BREEDING PHASE STOCKING RATE (LAMBS/HA)	BREEDING PHASE WEANING WEIGHT (KG) 18	20	22	24	26
		R				
	16	24	24	25	26	26
	20	23	23	24	25	26
	24	22	23	23	24	25
1982	28	21	22	22	23	24
	32	20	21	21	22	23
	36	19	20	20	21	22
	40	18	18	19	20	20
	16	26	27	27	28	29
	20	25	25	26	27	28
	24	23	24	25	26	27
1984	28	22	23	24	25	26
	32	20	21	22	23	25
	36	19	20	21	22	23
	40	17	18	19	20	22

conditions for which such lambs would be required. In the bodies of Tables 6.8 to 6.14 these situations fall below the solid line.

6.3 Breeding and speculation phases combined

6.3.1 Expenditure

Despite a decrease in expenditure/ha with increased stocking rate in the speculating phase, this did not completely balance the corresponding increase in costs with stocking rate during the breeding phase. Consequently, there was still a slight increase in expenditure/ha with stocking rate when both breeding and speculation phase were considered together (Table 6.11). These values varied little between years and across stocking rates.

6.3.2 Profit

Profit/ha for the breeding and speculation phase combined showed little variation across weaning weights in the breeding phase and between years, but still increased with stocking rate (Table 6.12). However, if only the situations for which lambs are available (values above the solid line for each year in Table 6.12) are considered, relatively few options provide higher profit/ha than the breeding phase alone stocked at 40 lambs/ha (Table 6.5). In 1982 these options are a stocking rate of 28 lambs/ha and weaning weights of 20-26 kg, and weaning weights of 24-26 kg at a stocking rate of 32 lambs/ha. For the 1984 season these options included weaning weights of 18-26 kg, 20-26 kg and 24-26 kg at stocking rates of 28, 32 and 36 lambs/ha respectively. Assuming that a stocking rate of 40 lambs/ha in the breeding phase is sustainable under farm conditions, therefore, there would seem to be little advantage in using a lower stocking rate and including a speculation phase. However, should a producer decide to use a stocking rate of 28 lambs/ha in the breeding phase, further use of the pasture by means of a speculation phase would

TABLE 6.11 Total expenditure/ha for the breeding and speculation phase combined, considering different stocking rates and weaning weights during the breeding phase (values below solid lines indicate situations for which lambs are unobtainable in respect of each year).

YEAR	BREEDING PHASE STOCKING RATE (LAMBS/HA)	BREEDING PHASE WEANING WEIGHT (KG) 18	20	22	24	26
				R		
	16	4286	4803	4779	4756	4732
	20	4910	4886	4862	4838	4814
	24	4998	4973	4948	4924	4898
1982	28	5090	5064	5039	5014	4989
	32	5186	5161	5135	5109	5084
	36	5287	5260	5237	5210	5185
	40	5397	5371	5346	5322	5294
	16	4750	4726	4704	4680	4657
	20	4840	4815	4789	4763	4738
	24	4944	4909	4880	4852	4123
1984	28	5013	5010	4977	4945	4912
	32	5158	5120	5083	5046	5012
	36	5283	5240	5198	5155	5114
	40	5424	5376	5326	5277	5229

TABLE 6.12 Profit/ha for the breeding and speculating phases combined, considering different stocking rates and weaning weights in the breeding phases (values below solid lines indicate situations for which lambs for the speculation phases are unobtainable in respect of each year).

YEAR	BREEDING PHASE STOCKING RATE (LAMBS/HA)	BREEDING PHASE WEANING WEIGHT (KG) 18	20	22	24	26
		R				
1982	16	1254	1277	1301	1325	1348
	20	1490	1514	1538	1562	1586
	24	1722	1747	1772	1796	1822
	28	1950	1976	2001	2026	2051
	32	2174	2199	2225	2251	2276
	36	2393	2420	2443	2470	2495
	40	2603	2630	2654	2678	2706
1984	16	1330	1356	1376	1400	1423
	20	1560	1585	1611	1637	1662
	24	1776	1811	1840	1869	1898
	28	1997	2030	2063	2095	2129
	32	2202	2240	2277	2314	2349
	36	2397	2440	2482	2525	2566
	40	2576	2624	2674	2723	2771

make a marked difference to profit/ha. The relationships between income, expenditure and profit/ha (for both breeding and speculation phases combined) is shown in figure 6.2. From these data it is clear that profit/ha increases with stocking rate, because income/ha increases more rapidly with increased stocking rate than expenditure/ha. It is interesting to note that even though gain/ha for both breeding and speculation phases reaches a maximum within the range of stocking rates considered and assuming a weaning weight of 18 kg (Fig. 5.16), this did not occur for profit/ha. (Because lambs were sold at a constant mass !!)

Although the speculation phase is not directly linked with the number of ewes in the breeding phase, profit was also expressed for the two phases combined, on a per ewe basis (Table 6.13). This was done because ewes can be regarded as the capital investment in the enterprise. Land values were not considered since it was assumed that the producer did not want to sell his land. However, it was assumed that if sheep were not profitable he would sell his ewes and use the land for some other enterprise. Consequently, accepting a value of R100/ewe, the figures in Table 6.13 represent the percent return on capital tied up in ewes. From this point of view then, the fat lamb production system described here appears to be highly profitable.

An alternative way of assessing profitability is to express profit as a percent of costs for both phases combined (Table 6.14). In terms of these figures this production system also appeared to be highly profitable. However, profit/ewe increased with decreasing stocking rate, while return on costs increased with increasing stocking rates. Consequently, the stocking rate to be applied in practice would depend on the objectives of the producer, but it could be assumed that most producers would wish to maximize profit. This points to using just the breeding phase at a very

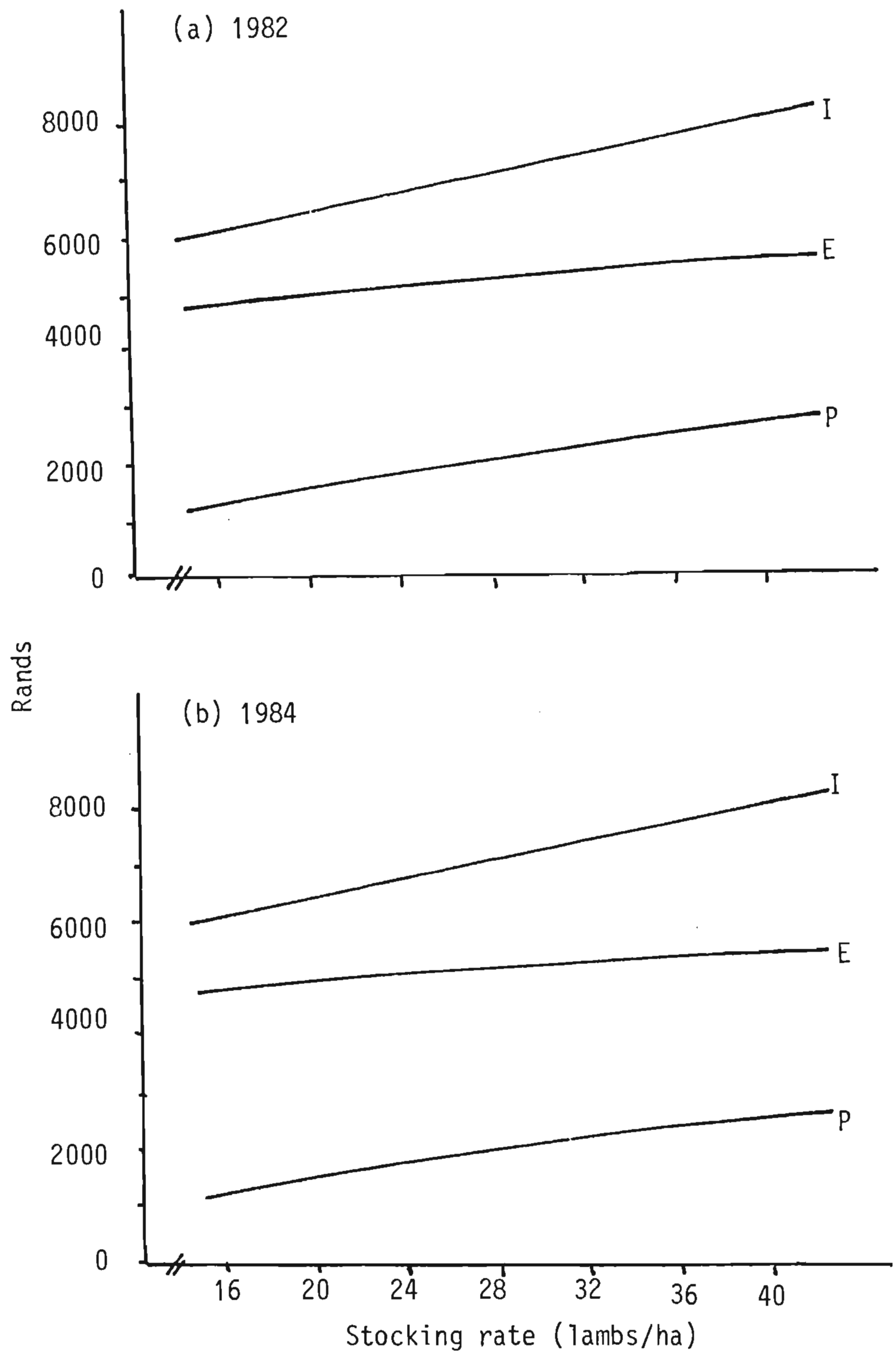


Fig. 6.2 Changes in income (I), expenditure (E) and profit (P)/ha with stocking rate for both breeding and speculation phases combined in the 1982 and 1984 seasons.

TABLE 6.13 Profit/ewe for the breeding and speculating phases combined, considering different stocking rates and weaning weights in the breeding phase (values below solid lines indicate situations for which lambs for the speculation phase are unobtainable in respect of each year).

YEAR	BREEDING PHASE STOCKING RATE (LAMBS/HA)	BREEDING PHASE WEANING WEIGHT (KG) 18	20	22	24	26
		R				
1982	16	78	80	81	83	84
	20	75	76	77	78	79
	24	72	73	74	75	76
	28	70	71	72	72	73
	32	68	69	70	70	71
	36	67	67	68	69	69
	40	65	66	66	67	68
1984	16	83	85	86	88	89
	20	78	79	81	82	83
	24	74	76	77	78	79
	28	71	73	74	75	76
	32	69	70	71	72	73
	36	67	68	69	70	71
	40	64	66	67	68	69

TABLE 6.14 Profit/ha for the breeding and speculation phases combined, expressed as a percent of total expenditure for different stocking rates and weaning weights in the breeding phase (values below solid lines indicate situations for which lambs for the speculation phase are unobtainable in respect of each year).

YEAR	BREEDING PHASE STOCKING RATE (LAMBS/HA)	BREEDING PHASE WEANING WEIGHT (KG) 18	20	22	24	26
				R		
	16	26	27	27	28	29
	20	30	31	32	32	33
	24	35	35	36	37	37
1982	28	38	39	40	40	41
	32	42	43	43	44	45
	36	45	46	47	47	48
	40	48	49	50	50	51
	16	28	29	29	30	31
	20	32	33	34	34	35
	24	36	37	38	39	39
1984	28	40	41	42	42	43
	32	43	44	45	46	47
	36	45	47	47	49	50
	40	48	49	50	52	53

high stocking rate, or both a breeding and speculation phase at a medium stocking rate. The high return on costs/ha for the breeding phase (Table 6.7) relative to the two phases combined (Table 6.14) also favours this option.

6.4 Discussion

The economic model and analysis presented in this chapter is essentially based on the gross margin theory, provided labour is considered to be a variable cost. Consequently, the profits/ha and /ewe presented can be regarded as gross margins and as such, serve as a useful basis for comparing fat lamb production from irrigated ryegrass + clover pastures with alternative enterprises. Clearly, what is not considered here is the cost of carrying the ewes for the 10 months when they are not on pasture, and net profit i.e. gross margin less fixed costs.

Assuming that the dual purpose ewe will provide 4 kg of wool, it is widely recognised in the sheep farming community that the income from this should be adequate to cover the costs of keeping her for the rest of the year, provided she is grazed on rangeland with the necessary supplementation in winter. In fact, with current wool prices, this level of production can even lead to a small profit. However, if the ewes were run on pastures, the income from wool alone would not be enough to cover costs for 10 months.

To facilitate use of the model, a farmer clearly needs to be able to provide his own actual or expected figures for the input variables, and to obtain net profit, all that is required is the deduction of fixed costs/ha or /ewe. It should be emphasized that differences in net profit would once again be relatively greater than differences in gross margin, thus further emphasizing the advantage of the higher stocking rates.

7. EVALUATION ON A FARM SCALE

Having established a grazing and an economic model for fat lamb production from irrigated ryegrass + clover from research data, the obvious next step would be to evaluate these models in the production environment. In particular, it is necessary to establish whether results obtained on a grazing trial which employed only a few animals on a small area would apply to a farm scale operation. An attempt was therefore made to do this on a single farm for only one season.

7.1 Production inputs and procedure

The farm evaluation took place in 1985 on "Hebron", the farm of Mr. Andrew Scott, which was located approximately 100 km southeast of Underberg. A 5,6 ha area was established to ryegrass + clover in late February. The nature of the site was similar to that used to collect the experimental data near Underberg, but the soil was classified as the Clovelly form (MacVicar et al., 1977). The annual rainfall, soil depth and soil pH were all similar to the Underberg site. Following soil analysis, 90 kg P/ha was applied before planting and 20 kg P/ha was applied at planting. Seeding was carried out as for the Underberg trial and irrigation was applied to ensure 25 mm to the whole area every ten days. Nitrogen was applied at 63; 37; 89; 92 and 36 kg/ha in March, April, May, August and September respectively, giving a total of 317 kg N/ha. An additional 70 kg N/ha was applied in the speculation phase, and some N went on in combination with K (as 1:0:1) at establishment. Total applied N therefore slightly exceeded the upper level of 400 kg/ha used in the trial, but this was probably necessary due to the lower proportion of clover in the pasture.

The pasture was grazed by Mutton merino x Corriedale x Ile de France crossbred ewes and lambs, starting on April 3. At this time the pasture had grown out to a stage which was considered to be too long for sheep grazing. Consequently, as ewes lambed they were introduced to the pasture until the stocking rate exceeded the desired 30 ewe-lamb pairs/ha in an attempt to graze the pasture down to the desired level. Once this had been achieved (after 16 days) the stocking rate was reduced to approximately 36 ewe-lamb pairs/ha.

At weaning on June 3, when lambs were on average 18 kg, ewes were removed from the pasture and 180 lambs remained for the winter period, thus representing a stocking rate of 32 lambs/ha. The first group of 80 lambs reached market weight (40 kg) on September 28 and the second group of 80 lambs reached this weight on October 8. The remaining 20 lambs took longer to reach market weight, with 6 of them in fact, not even reaching this goal by November 30. Once the first group of 80 lambs was marketed, lighter lambs that had been born later and over-wintered on inferior pasture were introduced to increase the stocking rate to approximately 60 lambs/ha. Thereafter, as lambs were marketed more were added, but stocking rate fluctuated somewhat until suspension of grazing on November 20, due to very low lamb ADG after mid-November. The probable cause of this low ADG was the onset of seeding in ryegrass and very low levels of clover in the sward. The disappearance of clover was most likely caused by inadequate irrigation at certain times in the season, and inadequate grazing pressure in the first 4 - 5 weeks of grazing, resulting in an overgrown pasture. Dosing procedure was the same as for the Underberg trial.

7.2 Grazing results

7.2.1 Stocking rate

Grazing records for the pre-weaning period appear in Table 7.1 and Fig. 7.1 and 7.2. Due to the put-and-take nature of stocking, average stocking rate was obtained by dividing animal grazing days/ha by the days in the grazing period. This resulted in stocking rates of 37,7 ewes/ha and 41,1 lambs/ha, implying 9% twinning. The stocking rate achieved on the farm was therefore close to the upper limit (40 ewes + lambs/ha) used in the grazing trial at Underberg. For the post-weaning period from June 3 to September 28 (118 days) the stocking rate was maintained at 32 lambs/ha, while during the subsequent phase the average stocking rate was 76 lambs/ha, which was higher than that applied in the grazing trial and used in the model. The fluctuation in stocking rate for this phase is shown in Table 7.3 and Fig. 7.3, and the average stocking rate was obtained by dividing 22 431 grazing days by 5,6 ha and 53 days.

7.2.2 Lamb gains

During the pre-weaning period the lamb ADG achieved on the farm was 246 g/day. Predicted values at the equivalent ewe stocking rate were 231 g/day and 278 g/day for the 1982 and 1984 seasons in the grazing trials. Consequently, the number of days in the pre-weaning period observed on the farm (61 days) fell between that predicted by the model using the 1982 (65 days) and 1984 (54 days) data.

The first 80 lambs marketed achieved ADG's of 197 g for their 117 day post-weaning period, and 213 g for the 178 day period from birth to slaughter (Table 7.3). The second 80 lambs marketed achieved ADG's of 170 g for their 128 day post-weaning period and 195 g for the 189 day period from birth to slaughter. On average, all 180 lambs took 186 days to reach a mean market weight of 40,1 kg, thus representing a mean ADG of 199 g from birth to slaughter. Corresponding predicted values for the same

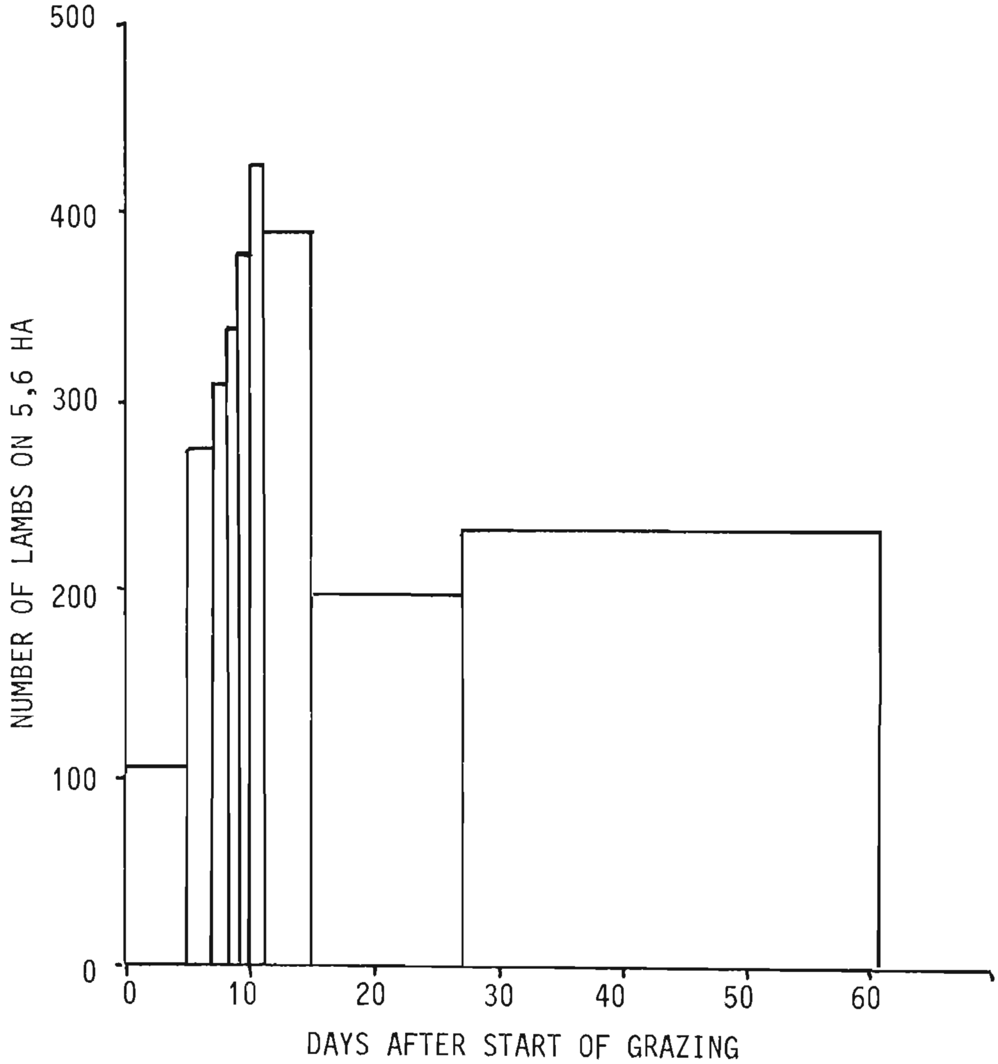


Fig. 7.1 Changes in stocking rate of lambs on the 5,6 ha block of pasture at "Hebron" for the period April 3 to June 3.

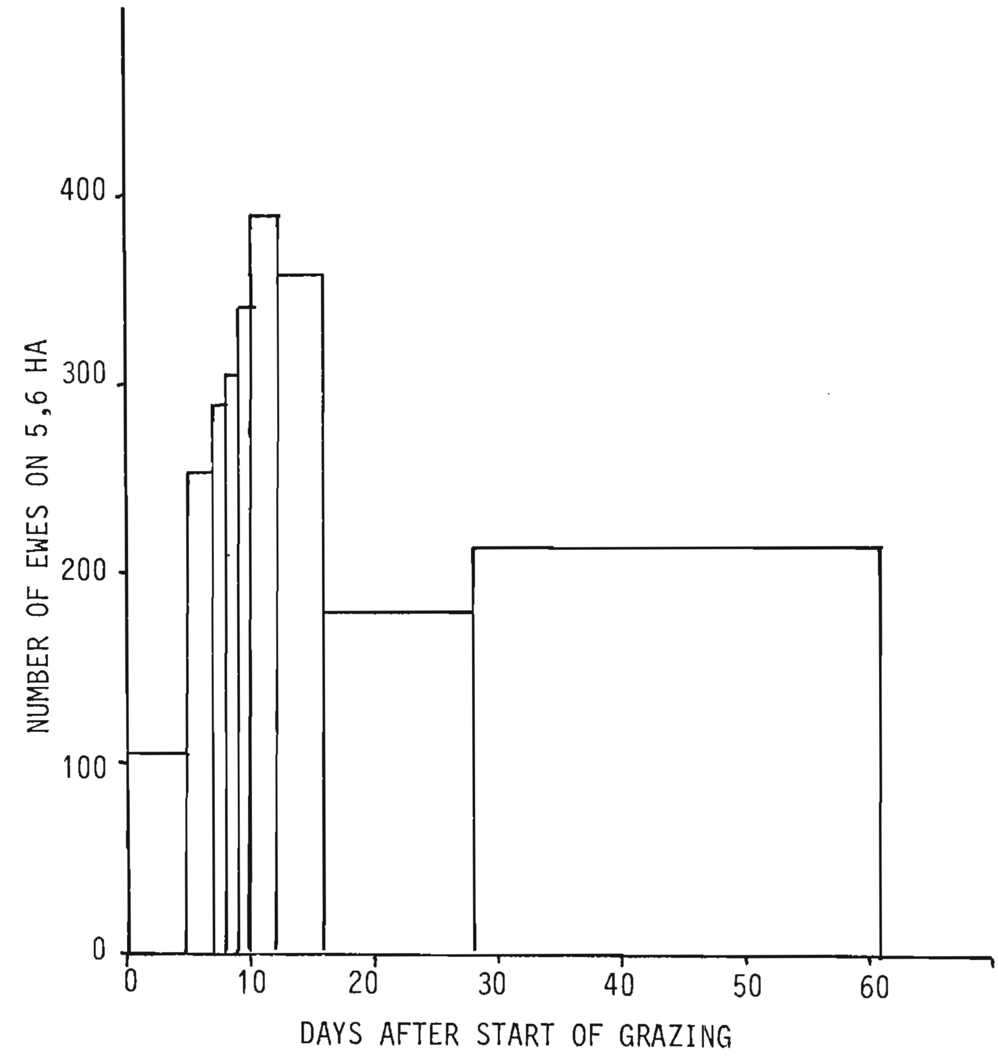


Fig. 7.2 Changes in ewe stocking rate on the 5,6 ha block of pasture at "Hebron" for the period April 3 to June 3.

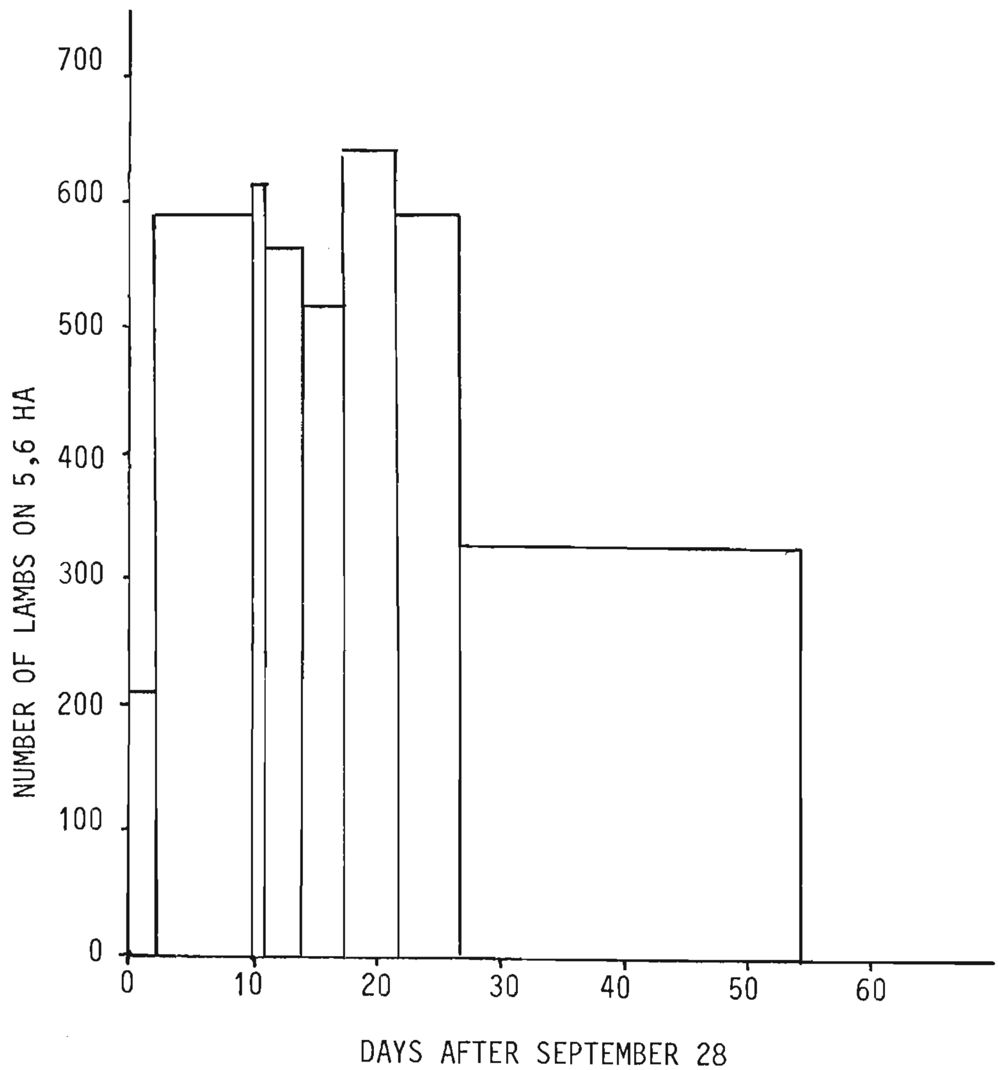


Fig. 7.3 Changes in lamb stocking rate on the 5,6 ha pasture block at "Hebron" after the first 80 lambs from the breeding phase were marketed on September 28.

TABLE 7.1 Grazing records for the pre-weaning period expressed in terms of the 5,6 ha pasture.

EWES			LAMBS		
Number of Animals	Days	Animal Grazing days	Number of Animals	Days	Animal Grazing days
105	5	525	107	5	535
253	2	506	273	2	546
285	1	285	311	1	311
305	1	305	335	1	335
340	1	340	375	1	375
388	2	776	425	2	850
258	4	1432	391	4	1564
178	12	2136	197	12	2364
213	33	7029	232	33	7656
	61	13334		61	14536

Average stocking rate was calculated as follows :

$$\text{Animal grazing days} \div 5{,}6 \div 61 \text{ days}$$

This worked out to be 37,7 ewes/ha and 41,1 lambs/ha.

TABLE 7.2 Grazing records from 28 September (when the first 80 lambs from the breeding phase were marketed) to 20 November when grazing was suspended.

1985 Time of Year	Number of Days	Number of Sheep	Grazing Days
28 Sept. - 30 Sept.	2	208	416
30 Sept. - 8 Oct.	8	465	3720
8 Oct. - 9 Oct.	1	614	614
9 Oct. - 12 Oct.	3	564	1692
12 Oct. - 15 Oct.	3	514	1542
15 Oct. - 19 Oct.	4	640	2560
19 Oct. - 24 Oct.	5	590	2950
24 Oct. - 30 Nov.	27	331	8937
TOTAL	53		22431

Average stocking rate

$$= 22431 \div 53 \div 5{,}6 \text{ ha}$$

$$= 76 \text{ lambs/ha}$$

TABLE 7.3 Market records for the breeding phase.

Date Marketed	Number of lambs	Market weight	Total weight 5,6/ha	Total weight/ha
28 September	80	41,0	3280	566
8 October	80	39,8	3184	549
12 October	5	37,2	186	32
19 October	5	38,7	194	33
24 October	4	40,0	160	28
20 November	6	35,0	210	36
TOTAL	180		7214	1244

stocking rate were 214 and 208 days to reach a mean market mass of 40 kg in 1982 and 1984 respectively, thus representing ADG's from birth to slaughter of 173 and 178 g. On average, therefore, Mr.Scott's lambs achieved a 41% higher ADG than that achieved in the Underberg trial, and this enabled them to be marketed 25 days earlier.

The ADG of the speculation phase lambs was 190 g, compared to the 170 g/day used in the model. Consequently, despite termination of grazing on November 20 in the farm trial (compared to December 15 in the model), the speculation phase on the farm produced 781 kg/ha while the model predicted a gain of only 500 kg/ha. This was primarily due to (a) the breeding phase being 25 days shorter on the farm, thus leaving 54 days for the speculation phase (compared to 40 days predicted by the model); (b) higher ADG in the speculation phase on the farm; and (c) a higher stocking rate in the speculation phase on the farm (76 lambs/ha compared to the 60 lambs/ha used in the model). The overall result was that the farm production system produced 2060 kg live weight/ha while the model predicted on average 1780 kg/ha.

7.3 Economics

7.3.1 Breeding phase

The pasture costs incurred in the farm evaluation were as follows :

	R/ha
Land preparation	61,39
Phosphate	292,64
Combination fertilizer (1:0:1)	134,28
Nitrogen @ R1,15/kg	364,55
30 kg ryegrass seed	48,00
3 kg Ladino clover seed	39,00
4 kg Kenland red clover seed	33,00
Irrigation and depreciation	30,86
TOTAL	1003,72

These figures reflect the actual costs incurred by Mr. Scott, and they therefore differ from those used in the economic model developed in the previous trial. In particular, higher levels of P and K were required to correct soil deficiencies in the farm evaluation compared to the grazing trial. Also, higher levels of N were applied in the farm evaluation. On the other hand, ryegrass seed costs were slightly lower as a result of the seed having been produced on the farm. Land preparation costs were also lower due to slightly different machinery being used, but the same dosing and labour costs were used. For the breeding phase only, this latter cost came to R138,68/ha. Mr. Scott sold his lambs directly to a local country town butcher in Kokstad who paid R1,90/kg live-weight and collected the lambs on the farm. No marketing costs were therefore involved.

Assuming a stocking rate of 32 lambs/ha which weighed on average 40,1 kg when sold, total income was 32 x 40,1 x 1,9 = R 2438/ha. Total expenditure/ha was R 1003,72 (pasture costs) plus R 138,86 for labour and dosing, amounting to R 1142. Profit for the breeding phase was therefore 2438 - 1142 = R 1296/ha, compared to an average predicted income/ha of R2560, expenditure/ha of R 1176 and profit/ha of R 1384. Despite pasture costs being R 281/ha higher on the farm than in the Underberg trial, the marketing costs of R 312/ha used in the model were not incurred by Mr. Scott. This resulted in total costs for the breeding phase on the farm being very similar to that predicted by the model. Income on the farm was slightly lower than that predicted by the model due to the slightly lower selling price/ha live weight on the farm (R 1,90 compared to the R 2,00/kg liveweight used in the model). The end result was that there was very little difference between the profit/ha achieved on the farm compared to that predicted by the model.

However, if Mr. Scott had marketed his lambs through the abattoir (which is the procedure most fat lamb producers in the Highland Sourveld would be expected to follow), he would have incurred the marketing costs. This would have raised his total costs/ha to R 1454 (R 1142 in animal and pasture costs/ha plus R 312 in marketing costs/ha) and his income would have been R 2566/ha, obtained by multiplying 32 lambs/ha by their live market weight (40,1 kg) and a price of R 2,00/kg. Consequently, expected profit would have been R 2566 - R 1454 = R 1112/ha. This represents a 20% lower profit than that predicted by the model using the average of the two years data from the Underberg trial, and can be ascribed primarily to the higher fertilizer costs incurred by Mr. Scott.

7.3.2 The breeding and speculation phases

Costs which could be specifically allocated to the speculation phase were labour and dosing (R 76,10/ha) and the additional application of N (R86,94/ha). Total expenditure therefore included these two values plus the R 1142/ha cost incurred for the breeding phase, which therefore amounted to R 1305/ha. This expenditure was clearly much lower than that used in the economic model because in this case additional lambs were already available on the farm, while for the purpose of the model it was assumed that they would have to be bought in.

Total gain/ha for the speculation phase was 781 kg which provided an income of R 1483,90 at R 1,90kg live weight. Income for both the breeding and speculation phases was therefore R 2438 + R 1484 = R 3922/ha, and profit was R 3922 - R 1305 = R 2617. This was 20% more than the profit predicted by the model. Here again, the main reason for the difference between Mr. Scott's profit and that predicted by the model is that Mr. Scott followed a different practice to that assumed in the model, and he also achieved a considerably higher stocking rate and higher gains in the speculation phase.

If Mr. Scott had bought in his lambs for the speculation phase they would have had to weigh 29,73 kg in order to reach 40 kg by November 20, and at R 1,50/kg, would have cost him R 3389/ha. In addition, his marketing costs would have been R 740/ha (76 lambs x R 9,74), if he had marketed to Cato Ridge Abattoir instead of the local Kokstad butcher. Consequently, his total expenditure for both phases would have been R 5434. His expected income from both phases would be R 8640/ha, and this would provide an expected profit/ha of R 3206. Thus, using Mr.Scott's production figures and the economic figures and marketing strategy assumed in the model, resultant profit/ha for both phases was 23% higher than that actually achieved by Mr. Scott when he sold his animals to the local butcher. This was primarily due to the advantage of a positive price margin which would apply if he bought lambs in at R 1,50/kg and sold them at R 2,00/kg liveweight. In fact, due to this price differential alone R14,87/lamb and R 1130/ha profit could be made on the purchase weight of lambs, and this clearly exceeds the marketing costs of lambs (R 740/ha).

7.4 Discussion

In the breeding phase, apart from the higher level of N, P and K fertilizer applied, pasture and animal management applied by Mr. Scott closely resembled that of the Underberg trial. However, Mr. Scott achieved higher rates of gain in both the breeding and speculation phase, and a higher stocking rate in the speculation phase. The end result was a profit of R 3206/ha compared to R 2188 predicted by the Underberg results; an increase of R 1072/ha, or 49%. When Mr. Scott's analysis was based on what he actually did (selling to the local butcher rather than to the abattoir as assumed for the model, and using lambs already on the farm instead of buying lambs in) he did not gain the economic benefit of buying lambs at R 1,50/kg and selling them at R 2,00/kg. However, he still made a profit of R 2617/ha.

8. GENERAL DISCUSSION AND CONCLUSIONS

Although not widely applied in grazing trials so far, the linear regression modeling procedure used in this study for analysing and interpreting grazing intensity data proved highly successful. The procedure clearly depends on existence of linear relationships between grazing variables, and prior to the trials this was the only reason for doubt about its appropriate use. However, despite the application of a wide range in stocking rates (16 to 40 sheep units/ha) and a large number of points for each regression (15, where data from all three nitrogen levels were considered together in chapter 5), there was no evidence that relationships were not linear. Consequently, this procedure is strongly recommended for use in future grazing research. What was apparent, though, was that three sheep per stocking rate treatment was too few, thus leading to poor correlation in some of the regressions presented in Chapter 4. At least five or six sheep per stocking rate are therefore recommended for future trials.

In view of the advantage of ryegrass + clovers over ryegrass alone, particularly under grazing by sheep, it is recommended that red and white clover be planted with ryegrass for the purpose of fat lamb production in the Highland Sourveld of Natal. No problems were experienced in this research program with bloat. This freedom from bloat may have been associated with a relatively low component of clover in the sward at the start of the grazing period, and a slow increase into spring and summer.

The main advantages of the clover are (a) its high quality, (b) adaptation to continuous grazing by sheep as a result of its creeping growth habit, and (c) the role it played in extending the grazing season into summer. In fact, in 1984, and in recent experience on other farms, by January the pasture became so dominated by clover that it could virtually be regarded as a pure stand. The question then, is whether to plough it out and replant to ensure a good proportion of ryegrass, or whether to use it as a pure clover pasture. Another alternative is to oversow the clover with ryegrass in February, but so far this procedure has not been successful in introducing an adequate proportion of ryegrass into the sward.

Notwithstanding the above, Smith (1985) achieved a projected gain/ha of 3000 kg by grazing three consecutive sets of weaned lambs on ryegrass alone, as opposed to the gain/ha of approximately 2000 kg achieved in this study. The suggestion here is that grazing weaned lambs is more efficient than grazing ewes with lambs, and that ryegrass alone is at least as productive as ryegrass + clover. However, results in the 1981 ryegrass vs. ryegrass + clovers trial in this study, do not concur with the latter suggestion. In fact, the most likely reason for the very high gain/ha achieved by Smith is that he used the put-and-take method of stocking, and it seems likely that this biased his estimates upwards. On the other hand, Burns, et al. (1970) found no difference between fixed and variable stocking.

Other work done in South Africa on irrigated winter pastures is that of Bartholomew (1985) who grazed young beef steers and heifers on ryegrass alone, at a number of stocking rates. Results showed that maximum gain/ha for these beef animals was in the order of 1000 kg, and this was fairly consistent over a 4-year period. Since the length of the grazing period was similar to that achieved in this study (about 210 days), the reason for the large difference is not clear. However, it seems likely that it may be largely due to the more efficient harvesting of the pasture by sheep than by cattle. This in turn, may be due to less severe fouling as a result of the pelleted nature of sheep dung, and less severe trampling as a result of smaller hooves.

One of the major limitations to higher production and profit in the fat lamb production system evaluated in this study, was the marked periodic growth pattern of the pasture : in autumn yields were moderate, in winter they were very low, and in spring and early summer production was very high. In particular, if the winter gap could be filled it seems likely that this would lead to an increase in productivity and profitability. Consequently, this issue should be regarded as a high priority for future research. A possible solution would be to plant a certain area to Japanese Radish in January. This could be fed to ewes and/or lambs on the pasture, and particularly to lambs in mid-winter, thus raising the autumn-winter stocking rate so that it is more in line with that achieved in spring/early summer. An alternative to feeding the radish on the pasture, would be to plant it adjacent to the ryegrass. This would facilitate grazing ewes on the radish and allowing lambs to creep "laterally" into the ryegrass, thus ensuring that only lambs made use of the high quality pasture.

Another option which may assist in smoothing out the forage flow is the use of rotational grazing in winter. Smith (1985) compared continuous and rotational grazing on ryegrass alone, during the period of autumn right through to the mid-summer month of December. He demonstrated that continuous grazing provided higher ADG and gain/ha in autumn and spring-early summer (apparently by providing feed of higher quality than rotational grazing), but rotational grazing resulted in higher ADG and gain/ha in winter (apparently by providing a greater quantity of pasture than did continuous grazing). The suggestion here, is that the highest yield would be obtained by applying continuous grazing in autumn, but switching to rotational grazing in winter, and then back to continuous grazing in spring. However, this implication arose from applying continuous and rotational grazing separately for the whole season. The question is, therefore, whether switching from continuous grazing to rotational grazing and then back again will give this implied result. Consequently, this strategy should be tested at least against continuous grazing alone. Another unknown in this regard is whether rotational grazing in winter would adversely affect the proportion of clover in the sward, and this too, would be determined in such a trial.

The detection of no significant difference between 275, 375 and 475 kg of N/ha under grazing was in a way surprising, and yet of great value to the producer. The obvious question which arises from this result is "How low can one go?" Although this is also another possible area for additional research, it should not be regarded as high in priority since yield of ryegrass in particular, is likely to drop off considerably when nitrogen is applied at rates of below 275 kg N/ha.

Feed budgeting involves matching feed supply to feed demand. It can be achieved by manipulating feed supply and/or feed demand. Options considered so far apply to manipulating feed supply. However, there would also appear to be considerable scope for manipulating feed demand. In developing the model described in this study, it was assumed that lambs could be bought in spring for the speculatory phase. While this was actually done in 1984, the chances are that if fat lamb production off irrigated ryegrass + clover pastures were to become widely adopted, weaned lambs may become unavailable for the spring speculation phase. It is therefore best to attempt development of totally "closed" on farm production systems.

With the above in mind, the main option open to the producer is manipulation of lambing patterns. Perhaps the best strategy here would be to lamb one third to a half of the ewes down in mid-March, and the balance in June. As far as possible, ewes should be fed on Japanese Radish and only lambs allowed to creep into the ryegrass + clover pastures, and then later weaned onto them. It might be necessary to graze such pastures with the ewes early in the season, in order to prevent loss of the clover component. This would lead to the first group of lambs being marketed in September, and the balance in November and December. In particular, the advantage of such a system is that the producer would benefit from the high lamb prices commonly experienced in December. In this regard, he should probably aim at marketing the majority of his lambs (say, two thirds) at this time. However, without a supplement to ryegrass + clover pastures in mid-winter (such as Japanese Radish) this would not be possible without planting large areas of pastures.

An alternative is, of course, to plant sufficient area of pasture to enable all ewes to lamb down at the same time. If lambing is in March and April, lambs will be marketed around October. The benefit of the possible higher prices in December would therefore be lost; but the advantage of this strategy is that lambs can be weaned and ewes returned to the veld before the mid-winter period. Consequently, no Japanese Radish would be required. However, this approach would result in excessive pasture production after lambs were marketed. Some options here would be to (a) flush and breed ewes on these pastures, (b) graze beef long yearlings on the pasture, (c) calve beef cows down or (d) allow the ryegrass to grow out as a seed crop. The area of ryegrass/clover required to employ this strategy for 1000 ewes would be 30 - 35/ha.

In order to take advantage of high market prices in December, lambing would have to take place in June, which means that ewes would be suckling lambs in June, July and August. Consequently, a supplement such as

Japanese Radish would possibly be required, since one hectare of pasture would definitely not carry 30 ewes and their lambs through mid-winter, unless all autumn growth were accumulated for winter. This latter practice, however, is again likely to lead to substantial loss of clover from the sward, resulting in a higher demand for N fertilizer.

Another obvious option which comes to mind is lambing every eight months. A possibility would be to cultivate half the pasture area each year. This would result in just under a year of ryegrass + clover and a year of pure clover, (the two halves being staggered) thus ensuring high quality pasture throughout the year. However, it is unlikely that many producers would be able to achieve the very high level of management required for this extremely intensive system. In fact, even the less intensive system evaluated in this study would stretch the management capabilities of most producers to their limit. Finally, another breeding strategy which should be adopted in all the systems suggested above is selection for multiple births, a trait which is known to be highly heritable. This would consequently reduce the ewe : lamb ratio, and the economic advantages have been clearly demonstrated in this study.

The expected average gross margin from dairy herds in the Natal Midlands in which a mean lactation of 4000 litres/cow and profit of 4 c/litre (using figures from Broom, 1985), is achieved, would be R320 per hectare of pasture. Highland Sourveld farming experience has shown, that over a period of a year, 2 dairy cows can be carried on half a hectare of summer pasture plus half a hectare of winter pasture. Bartholomew (1985) on the other hand, showed an expected gross margin of approximately R750/ha from grazing young beef animals on irrigated ryegrass pastures. The fat lamb system evaluated in this study is therefore at least twice as profitable as the next best livestock option, and if well managed, gross margin/ha can exceed R 2000. Consequently, it can be concluded that the system evaluated in this study can be recommended with confidence to stock farmers in the Highland Sourveld of Natal.

This conclusion is supported not only by results from the grazing trials, and models reported on in this study, but also by the even better production and profit achieved by Mr. Scott under farming conditions. Further research, however, is warranted on evaluating modifications to the system that might increase its profitability.

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