SOME EFFECTS OF PASTURES SPECIES AND STOCKING RATE ON SHEEP AND PASTURE PRODUCTION

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CONTENTS

Chapter		Page
I	INTRODUCTION	1
II	REVIEW OF LITERATURE	3
	A. ANIMAL PRODUCTION	4
	1) SEASONAL VARIATION IN WOOL GROWTH	4
	a) SEASONAL VARIATION IN WOOL GROWTH OF GRAZING ANIMALS	5
	b) TEMPERATURE, LIGHT AND THE ANNUAL RHYTHM	7
	c) MEDIATION OF THE SEASONAL RHYTHM	10
	2) BODY GROWTH	11
	3) NUTRITION AND BODY GROWTH	13
	4) NUTRITIONAL REQUIREMENT FOR WOOL GROWTH	15
	5) EFFECT OF PASTURES SPECIES ON SHEEP PRODUCTION	18
	6) EFFECT OF STOCKING RATES ON SHEEP PRODUCTION	23
	B. PASTURES	31
	1) EFFECT OF STOCKING RATE ON PASTURE PRODUCTION AND ITS COMPONENTS	31
	2) EFFECT OF THE GRAZING ANIMAL ON THE YIELD AND ITS COMPONENTS	34
	a) EFFECT OF DEFOLIATION ON PASTURE PRODUCTION	34
	i) CARBOHYDRATE RESERVES	36
	ii) ROOT GROWTH	36
	iii) LEAF GROWTH AND LIGHT INTERCEPTION	37
	b) EFFECT OF DEFOLIATION ON BOTANICAL COMPOSITION	40
	c) TREADING	41
	d) EFFECT OF DUNG AND URINE	42

		e)	SELECTION OF PLANT MATERIAL BY THE GRAZING ANIMAL	44
		f)	SUMMARY OF THE EFFECT OF GRAZING ON PASTURE	45
III	EXPERIMENTAL			48
	A.	INTRODUCTION		48
	B.	MATERIALS		49
		1)	LOCATION OF THE EXPERIMENT	49
		2)	FIELD PLOTS DESIGN	49
		3)	EXPERIMENTAL ANIMALS	50
	C.	METHODS		51
		1)	PASTURE MANAGEMENT	51
		2)	PASTURE SAMPLES	51
		3)	BOTANICAL ANALYSIS	52
		4)	ANIMAL LIVE WEIGHT	52
		5)	WOOL SAMPLING	52
		6)	STATISTICAL ANALYSIS	54
IV	RESULTS			56
		1)	PASTURE AVAILABILITY	56
		2)	PASTURE GROWTH	57
		3)	BOTANICAL COMPOSITION	59
		4)	ESTIMATION OF GROUND COVER	60
		5)	LIVE WEIGHT	60
		6)	WOOL GROWTH	62
		7)	WOOL LENGTH GROWTH RATE	64
		8)	WOOL CHARACTERISTICS	65
V	DISCUSSION			67

VI	SUMMARY	77
VII	REFERENCES	80

LIST OF TABLES

Table		Following page
1a	Meteorological data for Manawatu - temperature	49
1b	Meteorological data for Manawatu - rainfall	49
2	Analysis of variance of total pasture available	56
3	Means of total pasture available (dry matter lb/acre)	56
4	Analysis of variance of total pasture growth	57
5	Means of total pasture growth (dry matter lbs/acre)	58
6	Estimation of botanical composition in terms of percentage of species present in the total dry matter available	59
7	Estimation of percentage of ground cover determined by point analysis method	60
8a	Analysis of variance of live weight	61
8b	Analysis of variance of live weight adjusted for live weight at the previous weighing	61
9a	Estimates of effect of factors on unadjusted live weight	62
9b	Estimates of effects of factors on adjusted live weight	62
10a	Analysis of variance of weight of wool per sample and weight per unit area	63
10b	Analysis of covariance of weight of wool per sample and weight per unit area adjusted for weight at the first sample	63

11a	Estimate of effect of factors on unadjusted wool growth	63
11b	Estimate of effect of factors on adjusted wool growth	63
12	Analysis of covariance of fleece weight adjusted for initial weight per unit area	64
13	Estimates of effect of factors on adjusted fleece weight	64
14	Analysis of variance of wool characteristics	65
15	Estimates of effects of factors on wool characteristics	65

LIST OF FIGURES

Figure		Following page
1	Experimental area	49
2	Changes in total pasture availability under low stocking rate (mean dry matter lbs/acre)	56
3	Changes in total pasture availability under high stocking rate (mean dry matter lbs/acre)	56
4	Total pasture growth under low stocking rate (mean dry matter lbs/acre)	57
5	Total pasture growth under high stocking rate (mean dry matter lbs/acre)	57
6	Live weight changes of sheep grazing at low stocking rate	60
7	Live weight changes of sheep grazing at high stocking rate	60
8a) 8b)	Greasy woolgrowth per unit area during sampling periods	62
9	Monthly variation in wool length growth of animals grazing at low stocking rate	64
10	Monthly variation in wool length growth of animals grazing at high stocking rate	64

LIST OF PLATES

Plate		Following page
1 & 2	General view of the experimental area	49
3	Selective grazing. Cocksfoot/white clover pasture under low stocking rate	59
4	Close up of white clover pasture low stocking rate showing invasion of Mentha puligium	59
5	Low stocking rate white clover pasture	60
6	High stocking rate white clover pasture	60
7	Animals grazing cocksfoot pasture. Left, low stocking rate; right, high stocking rate	61
8	Sheep grazing white clover high stocking rate	61
9	View of two high stocking rate treatments. Left, white clover; right, cocksfoot	72
10	View of cocksfoot pastures. Left, low stocking rate; right, high stocking rate	72
11	3 month wool growth. Animal grazing cocksfoot high stocking rate	76
12	3 month wool growth. Animal grazing white clover high stocking rate	76

I. INTRODUCTION

Agriculture in New Zealand as in other temperate regions of the World is dependent on the utilisation of pastures by the grazing animal. Species such as perennial rye grass (*Lolum perenne L.*) cocksfoot (*Dactylis glomerata L.*) and white clover (*Trifolium repens L.*) together, represent a large proportion of the feed available to sheep on the more improved pasture land of New Zealand. Considerable research has been done on the selection, establishment, and the productivity of these species for livestock. But this research has been predominantly concerned with pastures or with livestock as separate entities. Only occasionally have these two entities been studied in association.

In general, pasture species have been extensively evaluated in terms of their dry matter yield and botanical characteristics under different systems of cutting but comparatively few pastures trials have been reported in which the evaluation has been made in terms of animal products.

Higher growth rates of young sheep grazing white clover dominant pastures or grasses plus clover pastures as compared with pure grasses pastures were reported in New Zealand (Rae, Brougham, Glenday and Butler, 1963; Rae, Brougham and Barton, 1964; McLean, Thomson, Jagusch and Lawson, 1965; Hight and Sinclair, 1965, 1967) and in Australia (Gallagher, Watkin and Grimes, 1966; Wilson, 1966). Also differences were found in the growth rates of sheep grazing different types of grasses (Rae *et al*, 1964, McLean *et al*, 1965; Gallagher *et al*, 1966).

Increasing levels of wool production were observed on a *Phalaris tuberosa*/subterranean clover pasture compared with an annual grass/subterranean clover pasture (Arnold and McManus, 1960) and on grass plus clover compared with grass pastures (Gallagher *et al*, 1966) when compared at the same stocking rate.

The effects of stocking rates under different management systems upon animal production have been also analysed in studies published in New Zealand, Australia and England. The results showed that as stocking rates increased, production of meat and wool per head declined, but the production of both per acre rose. However these experiments have predominantly been confined to one pasture type.

There are few comparisons of the effects of different pasture species and mixtures on animal production under high and low stocking rates.

The experiment described in this thesis is an attempt to obtain preliminary information upon:

1) The effect of two stocking rates (6 and 13½ sheep per acre) on pasture production and botanical composition of different types of pastures.

2) The effect of different types of pastures grazed at two stocking rates on sheep production.

II. REVIEW OF LITERATURE

For clarity of presentation it has been considered preferable to review previous studies of this and related topics in two main sections. Studies relating to the principal environmental factors which influence wool and body growth will be outlined under the general heading of Animal Production.

Studies relating to the effects of stocking rates and the grazing animal on the yield and botanical composition of the sward will be reviewed under the general heading of Pasture Production.

A. ANIMAL PRODUCTION

1) Seasonal Variation in Wool Growth

Annual cyclic changes in the rate of wool growth have been observed by many workers in a variety of sheep breeds.

One of the first reports in which differences in growth during the year were mentioned, was that of Rohde (1857) in Germany. Other workers (e.g. Burns, 1931a; 1931b; Duerden and Mare, 1931) reported marked differences in wool growth between Summer and Winter, growth being greater in Summer. However, the interpretation of these experiments is difficult since the effects of season and nutrition were confounded.

Ferguson, Carter and Hardy (1949) using Camden Park Merino and Corriedale ewes, were the first to demonstrate that seasonal variation in wool growth may occur under constant nutrition. A seasonal rhythm of wool growth has since been found in many other breeds, when animals are fed on a constant ration or to constant body weight. (Coop, 1953; Wodzicka-Tomaszewska, 1960; Morris, 1961; Bennett, Hutchinson and Wodzicka-Tomaszewska, 1962; Hart, Bennett, Hutchinson and Wodzicka-Tomaszewska, 1963).

The amplitude of the wool growth cycle may vary between breeds. Ferguson *et al*. (1949) found that in Corriedale ewes the maximum Summer growth rate exceeded the Winter minimum by about 23% and in Camden Merino 44%. On the other hand, little variation in wool growth has been found in Peppin medium-wool Merino and Tasmanian fine-wool Merino ewes. (Hutchinson and Wodzicka, 1961; Williams, 1964).

Slee and Carter (1961) found a much greater seasonal difference with the Wiltshire Horn than the Merino, when both were kept in similar environments and on an adequate plane of nutrition.

These cyclic changes in wool growth rate have been observed to be affected by nutrition, climatic factors and physiological state (pregnancy, lactation, disease, etc.) The latter aspects will not be dealt with in this review since they have little relation to the present experiment.

a) Seasonal variation in wool growth of grazing animals.

In the grazing sheep the rhythm of wool growth appears to be greatly influenced by the amount and quality of feed available. It is well known that pasture growth rates vary considerably throughout the year as does the quality and herbage available to the grazing animal.

Marked seasonal fluctuation in grazing Romney sheep have been found by Story and Ross (1960). The average wool growth ratio for dry ewes was 3.6 to 1, being at minimum in July, August and maximum towards the end of January.

Coop (1953) kept Corriedale ewes on two different grazing regimes and found no basic difference in the seasonal pattern of wool growth between sheep on different regimes. The seasonal rhythm of wool growth was not prevented by provision of a submaintenance diet during Summer and a super-maintenance diet during Winter.

Higher wool production in Spring and a substantial fall during December and January were found in Australia by Hutchinson and Porter (1958), Arnold and McManus (1960), Stewart, Moir and Schinckel (1961), Sharkey, Davis and Kenney (1962), McFarlane (1965) in grazing sheep under different environment.

Willoughby (1959), Arnold and McManus (1960), McManus, Arnold and Paynter (1964) and McFarlane (1965) found two peaks of wool growth, one in the late Spring and one in the early Autumn with intervening troughs in Summer and in Winter. Both peaks in wool growth generally reached the same level, as did the two troughs.

Roe, Southcott and Turner (1959) on the other hand observed a low level of wool growth in August which reached a peak in January/February and showed a general decline thereafter. In all these experiments a close relationship between available green forage and wool growth has been found. From this Roe et al. (1959), Willoughby (1959) and McFarlane (1965) have suggested that changes in wool growth are more related to green forage rather than total forage available. McManus et al. (1964) observed that this change was associated with the digestibility of the pasture. Reduction in wool growth in Summer was associated with a low digestible organic matter intake.

Difference between breeds in wool growth response to annual nutrition cycle was reported by Doney (1966). He compared Cheviot, Merino x Cheviot cross sheep fed at similar levels. The ration was provided in three ways; simulation of the natural intake cycle, reversed intake cycle or as a constant daily ration. Seasonal differences in wool growth in the Merino group were largely due to variation in intake. In the Cheviot group intake, and wool growth were related in summer but not in winter. Reversal of the normal seasonal cycle of nutrition resulted in an almost complete elimination of the seasonal cycle of wool growth as a result of depression of the summer peak.

b) Temperature, light and the seasonal rhythm.

Ferguson *et al*. (1949) put forward the theory that atmospheric temperature was one of the factors which was responsible for seasonal wool growth. They obtained a good correlation between wool growth and mean environment temperature but temperature was confounded with day length. In a further experiment Ferguson (1949) showed that unilateral thoracic sympathectomy, which destroyed the heat regulating mechanism and caused unilateral vasodilation, produced a temporary increase in wool growth on that side for a period of ten weeks. The disappearance of the difference coincided with the advent of warm weather. However, Coop and Hart (1953) kept a group of sheep during the four winter months in a room maintained at 13°F above the outside temperature but wool growth was not increased.

Bennett *et al*. (1962) using equatorial day length and reversed temperature, found that lowest wool growth was achieved in the coldest experimental time of the year. Maximum growth was not in the warmest season, but immediately after the coldest experimental season.

On the other hand, covering midside patches to provide thermal insulation had little effect on seasonal growth. This result showed that annual rhythm of wool growth can, in certain circumstances, be modified by temperature. While the modified rhythm can occur in one part of the skin, an almost normal rhythm continues on other parts and can persist in the absence of the climatic stimuli.

Coop and Hart (1953) found that winter growth in Corriedale ewes was increased when they were subjected to constant short day length, that is, 8 hours light and 16 hours darkness or 4 hours light and 8 hours darkness. Summer growth was not altered but the amplitude of the rhythm was decreased, giving greater total annual production.

This finding suggested that photoperiodicity had some influence in annual rhythm. However, animals subjected to constant day length as continuous light did not change the rhythm and a considerable amplitude of growth remained between seasons. Keeping the sheep in complete darkness by hooding, Hart (1955, 1961) found that annual rhythm was initially unchanged but diminished, eventually being abolished completely.

In Rhodesia Symington (1959), found that Persian

Blackhead sheep kept in pens roofed with translucent plastic, which reduced the intensity of light entering in the pens, the rhythm of shedding was disrupted and the fleece was heavier and denser than those animals maintained under natural light intensity in tropical day length.

The annual rhythm may be reversed by reversing the photoperiodic rhythm. By reversing seasonal day length Morris (1961) reversed the seasonal wool growth, in Romney Marsh ewes. This reversal of wool growth rhythm occurred gradually and took two years to be complete. Similar experiments have been performed in Australia with Southdowns and medium-wool Merinos, and in New Zealand with Corriedales (Hart et al., 1963). As in Morris' experiment, the rhythm showed resistance to change and in this case the change was not gradual and resulted in a bimodal curve of production. In the Corriedales, small peaks of wool growth coincided with the experimental peak of day length and with the natural one. In the Southdowns and Merinos there were two peaks, one corresponding to the light treatment and the other before the normal peak. Differences in results in the later experiment have been explained as differences in the intensity of the artificial light employed. When incandescent lamps were added and changes of day length were more rapid (increasing photoperiodic stimuli) the entrainment of the rhythm was more successful (Hutchinson, 1965).

All these experiments showed the influence of temperature and light in the seasonal rhythm of wool growth but the fundamental causes remained obscure. It is possible that both factors interact in certain conditions and in certain breeds of sheep.

Hutchinson and Wodzicka (1961) have suggested that rhythm of wool growth is a modification of an archaic pattern of shedding regrowth and quiescence involving loss of the shedding phase.

c) Mediation of the seasonal rhythm.

It has been suggested that the increase of adreno-cortical activity may be responsible for seasonal variation in wool growth (Lindner and Ferguson, 1956). The administration of cortisone to normal sheep depresses wool growth and when wool growth resumes after a period of depression a break appears in the fleece (Lindner and Ferguson, 1956).

In view of these findings and those of Lindner (1959; 1964) and Reid (1962) that sheep subjected to physical or emotional stress increase the levels of cortisal in plasma, it was thought that environmental stresses such as low temperatures, caused greater adrenocortical activity producing some depression in wool growth in Winter. However, Ferguson, Wallace and Lindner (1965) found that seasonal periodicity remained in adrenolectomized animals, maintained on constant cortisone dosage.

Reduction in wool growth up to 60% and reduction in food intake in thyroidectomized sheep have been reported by Ferguson (1951). Daily injections of 0.5 mg. of thyroxine in normal sheep increase wool production but also food intake increased. Thus it was suggested that the increase in wool growth after thyroxine treatment might be due to an increase in appetite and by the decrease in the storage of protein in body tissue (Ferguson, 1958; Lambourne, 1964).

Hart (1955) suggested that the annual rhythm of wool growth might be due to an increase in thyrotrophic activity of the pituitary. Recently Ferguson et al. (1965) reviewed the effect of hormones in wool growth and showed that in sheep, hypophysectomy had a more profound effect than thyroidectomy. The administration of thyroxine partially restored wool growth in hypophysectomized sheep independent of dose rate, but the rhythm of wool growth remains, even when sheep are maintained at constant food intake, temperature, and cortisone dosage. Subfractions of crude thyrotrophic hormone were capable of stimulating wool growth. They concluded that pituitary gland exerts stimulating and inhibiting influences through the secretion of thyrotrophic and adrenocortical hormones respectively and that an unidentified pituitary factor in addition to thyrotrophic hormone can stimulate wool growth. Neither thyroid nor adrenocortical activity have been definitely implicated in the natural variation in wool growth.

2) Body Growth

Growth is a complex process which involves an increase in the structural tissues such as muscle, bones and organs and finally fat.

The changes of anatomical components during annual growth was studied in detail by Hammond (1932) and by McMeekan (1940) in pigs, Palsson and Verges (1952) and Joubert (1956) in sheep. They found that the various parts of the body develop at unequal rates. The skeleton increases as a percentage of the total body weight for a short period after birth and then decreases on this relative basis. The musculature increases as a percentage of body weight during growth. The various tissues also attained their maximum growth rates in a definite order of age. Thus nervous tissue is the earliest developing followed by bone then muscle and finally fat. Also the various internal organs show marked differential growth.

In his review Palsson (1955) concluded that the development of the different organs of the animal appears to be primarily functional. These tissues or organs which are required for the vital function of the animal life are the ones which have the earliest development, and as the animal ages, development follows a markedly functional path.

Also changes in chemical constituents of the body during growth and development occur. Spray and Widdowson (1951) and Reid, Wellington and Dunn (1955) reviewed the effects of growth on the chemical composition of mammals and showed that the greatest change during growth is due to an increase in fat.

A high negative correlation between fat per cent and water per cent has been found by Reid _et al_. (1955). Reid _et al_. (1955) and Kirton and Barton (1958a) suggested that as water and fat constitute the major part of the animal body, fattening appears mainly to be replacement of water by fat.

However, Moulton (1923) had pointed out that the water content of the fat-free empty body decreases and the ash and protein contents increase up to a point when the concentrations of those components become more or less stationary and after which no further appreciable changes take place. Moulton calls this stage chemical maturity.

Spray and Widdowson (1951) analysed different species at various stages of life. The results generally support Moulton's findings but there was considerable disparity in the ages at which all body constituents, except fat, reached a constant level.

However, Reid _et al_. (1955) and Kirton, Barton and Cresswell (1959b) reported that in the fat-free body the percentage of water decreases while protein and ash percentages increase with age and Kirton (1959a) has also shown that fatness can affect this constancy.

3) Nutrition and Body Growth

Growing animals require certain levels of nutrients to allow normal development of the different components of the body. The ratio of muscle to bone increases more rapidly at higher planes of nutrition. Thus to get optimal development "super maintenance " diets are necessary since maintenance as defined by Maynard and Loosli (1955) is "the amount of food required to hold adult animal at constant weight". This definition also implies constant body composition.

Hammond (1932) showed that the plane of nutrition had a profound effect on the amount of fat in the body composition. Verges (1939a, 1939b) in sheep McMeekan (1940) in pigs, Wallace (1948) and Palsson and Verges (1952) in sheep continued work in this field. Two groups of animals were submitted to high and low planes of nutrition and after a period of this treatment each group was divided into a high and low plane sub group. These workers showed that the relative growth of bone, muscle and fat under a high plane of nutrition is reversed under semi-starvation. The earlier maturing parts or tissues are least affected and the late maturing ones most affected.

Yeates (1964) and Butterfield (1965b) reported that the depletion of fat is more rapid and the degree of involvement of muscle and bones depends on the severity and length of time in semi-starvation. When an animal is kept on a sub-maintenance diet the different tissues and body regions are utilised for the maintenance of life in the reverse order of their maturity - i.e. fat is utilised first, followed by muscle and then bone. (Callow 1947).

On the other hand Wallace (1948) states that the pattern of development of a tissue is the same in a rapidly grown and in a stunted animal; a low plane of nutrition did not affect the latter developing loin muscle and it is not penalised any more than muscle in any other part of the body.

Child (1920) and Hammond (1944) noted that short periods of severely retarded growth in sheep produced marked compensatary growth and recovery of retarded tissues, provided that the undernourishment is not too long.

In cattle, evidence presented by Winchester and Howe (1955) showed that the three types of tissues in the carcass of animals subjected for a period of slow growth or maintenance diets had a strong recuperation capacity if sufficient time is allowed for recovery and if the check in growth is not so severe as to cause permanent stunting.

In sheep Robinson (1948) found that the various parts of the body increased and decreased along similar developmental curves.

4) <u>Nutritional Requirement for Wool Growth</u>

A considerable amount of work has been done on the influence of nutrition on wool production. In general it has been shown that feed intake affects wool growth (Weber, 1931; Fraser and Nichols, 1934; Marston, 1948; Ferguson, Carter and Hardy, 1949; Ferguson, 1959).

There have been a large number of observations and a variety of interpretations on the roles and significance of energy and protein for wool growth. Fraser and Nichols (1934, 1935) obtained a relatively large increase in wool growth on

Cheviot wethers, when the animals were fed by the addition of 200-500gr. maize starch to a mixed ration. Marston (1932) observed increased wool growth by grazing sheep fed a supplement of blood meal. Fraser and Roberts (1933), Bowstead and Larose (1938), and Slen and Whiting (1952) did not obtain responses in wool growth by increasing the daily intake of protein. Marston (1937), using isocaloric diet studied the effect of different levels of protein in the food. From a basal level of 60gr. protein per day in a maintenance ration, increases in protein intake by 100%; 200% and 400% obtained increases of wool growth of 50%, 95% and 145% respectively. Subsequently, Marston (1948) reported an experiment where Merino sheep received diets of constant composition at four levels of intake varying from below maintenance to twice the level of maintenance. With diet of energy equilibrium and a positive nitrogen balance obtained a production of 1.65gr. clean, dry wool per day. At a positive energy intake plus a positive nitrogen balance wool production was increased to a mean level of 6.95g. wool per day. However, the variations in protein and energy intake in this experiment were confounded.

Slen and Whiting (1952) and Ferguson (1959) found that wool production did not increase when protein content of isocaloric diets was increased above 8-10%, but they found a large response in wool growth to total intake. In view of these results Ferguson (1959) suggested that energy rather than protein limited wool growth. However, Marston (1948, 1955) interprets the wool growth response to increased supply of amino acids, particularly cystine and methionine. Subsequently Reis and Schinckel (1961, 1963, 1964) obtained substantial increases in wool growth rates when casein was administered directly into abomasum as a supplement to a roughage diet containing approximately 12% crude protein. Similar results were obtained with cystine or methionine infused directly into the abomasum of sheep as supplement to a diet of chopped wheaten and lucerne hay (Reis, 1967).

After these results and in the absence of wool growth response to an increase in the percentage protein in the diet, it may be concluded from Reis and Schinckel's work, that wool growth is in general limited by the amount and composition of amino nitrogen absorbed from the intestine.

The apparent conflict between Ferguson's and Reis and Schinckel's conclusions have been clarified by Hogan and Weston (1967). Using diets differing in crude protein content they found little variation in nitrogen leaving the abomasum despite differences in nitrogen intake. That is, on diets of low protein content, nitrogen is gained during the passage of digesta through the stomach, while losses of nitrogen occur from the stomach with diets containing higher levels of protein.

The amount of protein reaching the gut will be dependent on the microbial activity in the rumen and the amount and kind of protein ingested. Rumen microorganism required a source of nitrogen for growth (Bryant and Robinson, 1959) which is normally obtained from protein in the ingested feed, but may also be obtained from non-protein nitrogen in the feed or from urea secreted in the saliva or reaching the rumen by direct passage through the rumen wall (McDonald, 1948). The ammonia resulting from the de-amination of the amino acids may be utilised as a source of nitrogen by other micro-organisms, but large quantities may be absorbed into the blood stream and subsequently excreted as urea (McDonald, 1948). This reaction is potentially an important avenue of loss of ingested protein nitrogen. The extent to which such wasteful de-amination occurs is related to dietary factors. In general soluble proteins are rapidly attacked while insoluble proteins are much more resistant (McDonald, 1952). This difference is of interest especially in regard to plant leaf proteins which are readily soluble, while the leaf is fresh and green, but become highly insoluble when the plant matures or dries as in hay making. The protein of fodder concentrates also varies considerably. Much of the protein of peanut meal is readily soluble and quickly degraded in the rumen while zein of maize is quite insoluble and consequently very slowly attacked in the rumen (McDonald, 1962). Differences in utilisation of different proteins may explain the variation in wool growth response to protein supplements used in different experiments.

5) Effect of Pastures Species on Sheep Production

One of the first studies in the live weight gain of sheep grazing different species, was reported by the Welsh Plant Breeding Station (Stapleton, 1933). Live weight gain of sheep grazing white clover and individual grasses grown with and without clover was compared. The results showed that animals on white clover had live weight gain (28%) higher than those animals grazing pure grasses. Animals grazing mixed pastures gained 19% and 16% more than on pure grass pastures of perennial rye grass and cocksfoot respectively.

Since then several reports have been presented in New Zealand, (Rae et al. 1963; 1964; McLean et al. 1965: Hight and Sinclair 1965; 1967) Australia (Gallagher et al., 1966; Wilson, 1966; Grimes, Watkin and Gallagher, 1967) and England (Milford and Minson 1966).

In general all the experiments carried out by these workers, compared live weight gain of young sheep and ewes grazing pure legumes stand and grasses with and without legumes in different seasons.

The results showed that sheep grazing pure legumes stand gained more weight than animals grazing pure grasses with or without clover throughout the year. (Hight and Sinclair, 1965; 1967; McLean et al. 1965; Gallagher et al., 1966; Wilson, 1966). Live weight gain of animals grazing grass plus clover were higher than those on pure grass (Rae et al., 1963; 1964; Hight and Sinclair 1965; 1967).

Rae et al. (1963; 1964) found significant differences in live weight gain in favour of the short rotation rye grass white clover, compared with perennial rye grass with white clover. Gallagher *et al*. (1966), reported one experiment in which perennial rye grass white clover mixed gave better live weight gains than animals grazing cocksfoot/white clover and tall fescue/white clover in this order, but these differences did not reach significance. In a comparison between grass strains, Rae *et al*. (1963; 1964) showed that animals made better live weight gain in short rotation rye grass than in perennial rye grass with Ariki rye grass intermediate. McLean *et al*. (1962; 1965) found that live weight gain on timothy in Summer and on short rotation rye grass in Autumn was higher when compared with live weight gain of sheep grazing perennial rye grass.

Growth of young sheep grazing cocksfoot, perennial rye grass and tall fescue were studied by Gallagher *et al*. (1966). Although final live weight differences were not clearly defined, animals on cocksfoot made better progress at the early part of the trial (December) and those on perennial rye grass at the end of the experiment (April). Over the whole experiment these two species were superior to tall fescue. Furthermore, Grimes *et al*. (1967) found that growth rate of animals grazing cocksfoot was lower than those grazing rye grass and tall fescue respectively.

Milford and Minson (1966) working with S37 cocksfoot, S23 rye grass and S24 rye grass reported that the final live weight gains on S23 and S24 rye grass were 17% higher than on S37 cocksfoot.

In a comparison between pure legumes stands, white clover was found to be superior to lucerne (McLean *et al.*, 1965) and both species gave better growth rate than sub clover.

Differences in wool growth of animals grazing different grasses with and without clover were found by Gallagher *et al.*, (1966). Although these differences were not significant in either sampling time between treatment, the analysis of pooled data from grass and grass plus clover treatment indicated significant differences in favour of the grass plus clover treatment.

In spite of the fact that variation in live weight gain and wool growth were noted on animals grazing different species and strains, the reasons for this were not fully examined in all cases.

In the experiments conducted by Rae *et al.*, (1963, 1964) herbage intake was not estimated but Johns, Ulyatt and Glenday (1963) in the absence of this data, attributed the observed differences in live weight gain, to differences in rumen fill and papillation as well as differences in the concentration and proportion of volatile fatty acids (VFAs) in the rumen. On the other hand, Bailey (1964) related chemical analysis of clipped herbage at monthly intervals to the live-weight gain. He suggested that the results were due to differences in the carbohydrate composition of the swards, especially cellulose, which may affect voluntary intake. This could be associated with changes in fermentation rates, and nitrogen and VFA utilisation.

high concentration of VFA and good development of the rumen papillae was found by McLean et al. (1965) in the animals with high growth rates, grazing white clover. Also the amount of food in the reticulum and rumen of these animals was low. The converse in all respects was associated with slow growth.

Milford and Minson (1966) reported differences in energy retention between two varieties of rye grass and cocksfoot. The retention on S23 rye grass and S24 was 18% and 17% higher than S37 cocksfoot respectively. This difference in energy retention showed a positive correlation with digestibility of herbage cut from the plants. Energy retention was found negatively correlated with the proportion of acetic acid in the rumen VFA fraction. The proportion of acetic acid was not correlated with the digestibility of the herbage. Intake in this experiment was not estimated and the analysis of herbage and rumen liquor were derived from a separate indoor feeding experiment.

A good association between live-weight gain and organic matter digestibility, and proportion of crude protein were found by Grimes, Watkin and Gallagher (1966). This also was associated with high food intake. Further, Grimes et al. (1967) found that live-weight gain was strongly correlated with the proportion of propionic and acetic acid in the rumen. The proportion of crude protein in the diet was negatively correlated with live-weight gain. The total VFA concentration was not significantly correlated with live weight gain and was negatively correlated with cellulose.

Joyce and Newth (1967) reported an experiment in which fresh white clover and perennial rye grass, both of similar levels of digestibility were fed either on *ad libitum* or restricted bases to penned wether hoggets over a 100 day period in Autumn. The result showed that sheep in *ad libitum* feeding of white clover ate 28% more organic matter and 34% more crude protein and gross energy than sheep fed with rye grass. Wool production and live weight gain were higher in white clover group. Animals of this group gained at a rate 91% faster than the rye grass group. The difference in live weight gained was only partly related to the level of digestible organic matter intake. Both energy and nitrogen retention were greater for sheep fed white clover at high levels of food intake than for perennial rye grass. At maintenance levels of feeding differences in energy retention disappeared. No measurement of VFA was made in this experiment.

6) Effect of Stocking Rates on Sheep Production

The Australasian literature dealing with the effect of stocking rate in animal production can be divided in two main groups. Those studies done in New Zealand in which production per acre was considered and those studies done in Australia on which more emphasis was put in the pasture grazing-animal eco-system.

Although similar results were obtained, in that production per animal decreased and total production per acre increased with increasing stocking rate, these results are difficult to compare due to the differences in environment, management and in the pastures and breeds utilised.

An early report was made by Walker (1955) from experiments carried out at Ruakura between 1950-55. This experiment was carried out on three different farms which were comparable in total area, soil type, paddock number and pastures. Different stocking rates were used for each farm: 4 sheep, plus ½ cattle beast (equivalent), 6 sheep plus ½ cattle and 8 sheep per acre respectively. Meat production (lamb per acre per year), wool production, lambing percentage and wool quality were recorded.

The results showed that lambing percentage at 6 ewes per acre was slightly higher than at 4 and 8 ewes per acre. However, meat production per acre was higher at the highest stocking rate. Ewe fleece weight at 4 sheep per acre was ½lb. heavier than at the intermediate stocking rate and just 1lb. heavier than at the highest stocking rate. Total wool production per acre, including lambs, were 43lb; 61lb; and 80lb. respectively which is roughly in the same ratio as the stocking rates.

With regard to wool quality, the percentage of breaks was quite high in every group. However, wool off the 4 per acre ewes showed the least amount of break, but the 6 per acre ewes were close to the 8 per acre ewes in this respect. The same trends occurred for cotted fleeces. Generally the 8 per acre ewes wool was inferior in both scores.

Even if the cattle numbers run are converted to ewe equivalents the results cannot be compared since the pastures did not receive similar grazing management due to the presence of the cattle.

This was shown by Suckling (1964a) who conducted an experiment on hill country in which he studied the effect of various stocking rates upon animal production. These trials were laid out as two blocks, with and without cattle. The number of sheep stocked in each block was 3; 4; 5; 6½; and 7, and in one of the blocks, cattle were added as required to control excess of pasture. Sheep of different ages were used and after 5 years all age groups were run in each treatment. The grazing management was predominantly set stocked. In this trial observations were made on ewe live weight trends, lamb growth rates, wool weights, tooth wear and general stock health as well as some observations in pasture effects.

The results showed the same trends as those of Walker's experiment. Live weight declined as stocking rate increased except that at 4 ewes per acre, without cattle, there was a slightly higher live weight gain than at 3 per acre. The highest lambing percentages were present at 3 ewes per acre, whilst the lowest were at the highest stocking rate. A small difference in favour of the 7 ewes per acre over the 6½ ewes per acre was found. Lamb losses were highest at 4, 5 and

6½ ewes per acre and the lowest at 7 ewes per acre which also had the lowest twinning rates. Lamb growth rates slow down as stocking rate increased but smaller differences were found between groups. Similar trends were reported by Lambourne (1956) working with lambs from lambing to weaning at three different stocking rates.

An interesting observation pointed out by Suckling (1964a) is that in all the above stocking trials, sheep run with cattle were slightly superior to those run alone, especially at the lowest stocking rate. Thus live weight, wool production, lambing percentage and also lamb growth at 2, 4 and 5 ewes per acre were higher where cattle were grazed. At the higher stocking rates both groups were not different. This might be due to the fact that a few cattle were used because of the very low amount of food available for cattle.

Wear in sheep's teeth was found to be directly proportional to stocking rate. Sheep grazed without cattle showed less wear than where cattle were present. Concerning foot rot the incidence was less as stocking rate increased.

Collin (1966) in hill country, compared the production from two systems of management - mob-stocking and set-stocking - at 6 ewes per acre and between 4½ ewes per acre set stocked. Comparison of results showed a little difference in production between mob-grazing and set stocking at the higher level. Between the two levels of stocking, individual animal performance was higher at the low stocking level, but overall per acre production was higher at the higher stocking level and marked differences occurred.

Further studies analysing seasonal pasture production and stocking rate were carried out in Australia with Merino sheep.

Roe et al. (1959) in New South Wales compared the effect of three stocking (0.8, 1 and 1.33 sheep per acre) rates upon animal production. The result showed no significant differences between grazing treatment on sheep live weight. Although seasonal variations in total pasture available were not marked, production of green forage increased in Spring and declined to a very low level during Winter. Sheep live weight followed the same trend, thus live weight increased during Spring and Summer and declined in Winter. These changes in live weight showed a significant correlation with the amount of green forage available. Wool fibre diameter showed almost similar seasonal fluctuations. Maximum diameter was attained earlier than maximum live weight.

Coincident with spring rise in the amount of green forage there was also an increase in the percentage of crude protein and phosphorus in the green components of the pastures.

However, mean body weight in the different treatment did not differ by more than 10% at any time of the year. This slight variation and also in wool production can be attributed to the small difference in rate of stocking between treatments, which might be not enough to stress the pasture, hence variation in nutrition may have not been sufficient to affect animal production.

Large variation in fleece weight at different stocking rates were reported by Sharkey et al. (1962). Variation in body weight of sheep grazed at stocking rates between 1 and 6 ewes per acre differed by as much as 50% in late Winter. In association with the lighter fleece weight, poorer wool style and character and decrease in fibre thickness were recorded. This experiment was carried out on a pasture composed of Wimmera rye grass and sub clover. Drake and Elliot (1960) found in general the same results. Wool production was reduced by 3lb. a head between two and six sheep to the acre in the second year of the experiment.

Arnold, McManus and Bush (1964) and McManus et al. (1964) reported an experiment carried out during 4 years in which long term cumulative effects on both pasture and animal production were studied.

The experiment was divided into 3 phases. In the first, annual and perennial pastures were stocked at the rates of 2, 4 and 6 Merino Wethers per acre.

In phases 2 and 3 the perennial pastures from the previous experiment were stocked at 2, 4, 6 and 9 sheep per acre (L; M; H; VH). The results showed that total greasy fleece weight did not differ significantly between treatment, but in the third year the highest mean fleece weight was recorded from sheep on the H treatment. In this particular year, sheep running at 9 per acre had also higher fleece weight than those at the lower stocking rate.

Wool growth in Summer was less than that in an equivalent period of Winter with the exception of very high, which actually changed the phase of wool production with respect to sheep at the lower stocking rate. These sheep produced more wool only in Spring than the other treatments but they produced less at all other times.

Two interesting features upon live weight were found. One was the large weight loss in Summer and the second the time when sheep ceased to gain weight at the different stocking rates.

Sheep at the two higher stocking rates gained weight for a month in Spring after those on the lower rates had started to lose weight. The time of maximum rate of gain differed by as much as four weeks between treatments. These findings were not observed by Willoughby (1959), perhaps due to differences in both pasture yield and quality.

The effects of stocking rates on fleece characteristics were negligible in all years. Seasonal patterns of staple length and fibre diameter follow those of wool production and weight change.

Differences in live weight gain between low and high stocking rate in Summer following the same treatment in Spring was reported by Eyles, Williams and Green (1956) in England.

Heavy stocking rates in Spring gave the greatest live weight increase per acre. No differences between treatment in the rate of gain of the individual animal were found at this time. However, sheep at the highest stocking rate gained weight more rapidly in Summer than those under the low stocking treatment. It was estimated that the low stocked animals had inferior quality of feed since the quantity of herbage on offer was estimated to be greater after lenient Spring stocking than after heavy Spring stocking.

B. PASTURES

1) Effect of Stocking Rate on Pasture Production and its Components

The effect of stocking rate has been found to govern the nature of swards (Davies, 1962; Sharkey, Davis and Kenney, 1964; Suckling, 1964; Arnold *et al.*, 1964; Kydd, 1966).

Davies (1962) found that the botanical composition of a sown pasture was altered considerably when it was stocked continuously with five lambing ewes to an acre. The original sown annual clovers and native grasses were largely replaced by capeweed and geranium (*Cryptostemma calendula*).

Sharkey *et al.* (1964) working with an established annual pasture of Wimmera rye grass (*Lolium rigidum*) and subterranean clover (*Trifolium subterraneum*) observed that both species virtually disappeared when grazed at 6 sheep per acre. It was attributed to the disappearance of seeds of these annual species from the soil. Also consumption of seedlings before they become well-established and limitation of leaf area of established plant by grazing might contribute to the change in botanical composition.

At the low rate of stocking, Wimmera grass became dominant despite the large seed reserves of subterranean clover in the soil. Slight changes in botanical composition from year to year in the areas grazed at three sheep were observed, but were not progressive.

Working on hill country where a mixture of rye grass and white clover was sown on the natural grassland, Suckling (1964b) observed changes in botanical composition with different levels of stocking. This experiment compared 3; 4; 5 and 6½ ewes per acre with and without cattle, set stocked over 4 years.

At three ewes per acre with no cattle, perennial rye grass and white clover were reduced and species such as browntop and chewing fescue increased, compared with paddocks which have been fully utilised. As stocking rates increased, so also did the rye grass and clover content, while all the other grasses remain at similar levels over the period. Increasing quantities of rye grass over the experimental period were shown when cattle and sheep were grazed to achieve complete utilisation of the pasture all year round at all stocking rates.

High levels of clover were recorded in these paddocks, particularly at three, four and five ewes per acre, plus cattle. At 6½ ewes per acre there was a marked reduction in clover content, due to the high grazing pressure.

At the lower stocking rates of three and four ewes per acre with no cattle, a very high proportion of the total herbage was made up of dead grass (52%). This proportion increased as the trial progressed.

As stocking rate increased, the proportion of dead grass decreased especially where cattle and ewes were grazed together. This proportion was of the order of 20 to 30% of the sample.

Effects on the growth form and botanical composition were observed by Kydd (1966) in a sward of perennial rye grass - white clover, stocked at two different levels. At 5 sheep to the hectare rye grass species assumed a prostrate growth habit in the first year. This condition was less prevalent at 3.3 ewes/hectare/year. The amount of rye grass slightly decreased in both, this effect being greater at the higher stocking level. White clover almost disappeared after 2 years in both treatments, and was replaced by Poa Spp. This resulted in a total ground cover of 42 and 57% in the grazed paddocks, at low and high stocking rate respectively, towards the end of the experiment.

These changes in structure and botanical composition of the sward were accompanied by an increase in the amount of dry matter production from year to year. However, there was no increase in the amount of dry matter grazed by the animals.

Arnold et al. (1964) subjected a Phalaris tuberosa - sub clover pasture to 4 levels of stocking. They found that after a period of 4 years grasses replaced clover as the dominant species in all treatment, except at the highest rate of stocking. Although botanical composition differed between treatments the same species were present in all pastures, and even at the highest stocking rate the phalaris did not disappear.

Using different intensities of grazing at different times of the year, Willoughby (1959), found that at any one stage, time and intensity of grazing had no great effect on botanical composition. It was suggested that in Winter, inadequacy of pasture restricted selective grazing, so that the components were consumed in proportion to their availability. In Spring where selective grazing was possible growth rate or abundance of all species were far in excess of consumption, and changes in botanical composition were then minimized.

2) Effect of the Grazing Animal on the Yield and its Components

Attempts have been made to explain the effect of the grazing animal on pasture production and its components under different grazing pressures. Since the influence of grazing animal upon the pasture is mainly through the defoliation, most of this work has been done without animals by adopting various methods of cutting at different intensities. The extrapolation of results of these experiments to grazing practices must be made with caution, since the animal also exerts its influence in the pasture through selective defoliation, trampling and addition of nutrients through dung and urine.

a) Effect of Defoliation on pasture production

The literature on the responses of pastures to variation in defoliation practice is somewhat confused. Humphreys (1966) states that this is due partly to "lacunae in the understanding of the basic processes involved and partly to conflicting management objectives resulting from polarities between imminent and long term responses and between animal and pastures requirements".

Conflicting results have been obtained from defoliation experiments in terms of the dry matter produced. For example, Kennedy (1950), Brougham (1959), Larger and Steinke (1965), Auda, Blaser and Brown (1966) found that increasing the severity of defoliation reduced dry matter yield.

In contrast, Hanson, Sprague and Meyers (1952), Reid (1959, 1966), Appadurai and Holmes (1964) obtained higher dry matter production from close compared with lax defoliation. On the other hand little effect on production from close defoliation was reported by Jackobs (1950) and Bernardon, Huss and McCully (1967).

The effect of different frequencies of defoliation also presents conflicting results. Burger, Jackobs and Hittle (1958) reported a reduction in production by increasing the frequency of defoliation while Tesar and Ahlgren (1950), Burger, Jackson and Hittle (1962) found that increasing frequency of defoliation resulted in increased production. Little effect on production from frequent defoliation has been reported by Brougham (1959), Lazenby and Rogers (1965).

Evidence of species and varietal differences in the response of the plant to defoliation was often found, and usually attributable to differences in plant morphology (Jones, 1933; Cooper and Seed (1949); Cooper (1960). Erect growing species showed a greater reduction in yield from close defoliation than did prostrate species.

Various attempts have been made to explain the response to defoliation in terms of developmental physiology and have generally revolved around three main theories (Alcock, 1964; Brown and Blaser, 1968) viz; carbohydrate reserves, root growth, and leaf growth and light interception.

i) Carbohydrate reserves

The importance of carbohydrate reserves in the root have been stressed by Weinmann (1952; 1961). He suggested that carbohydrates are depleted under frequent grazing and are the cause of the progressive reduction in root and herbage yield. Doubts about the validity of attributing the growth solely to these carbohydrate reserves were raised by May and Davidson (1958) and by the work of Marshall and Sagar (1965), using labelled radioactive $^{14}CO_2$. They showed that the decline in root carbohydrates of perennial grasses after defoliation is largely caused by lack of replacement from the leaves and not by their mobilization to initiate new leaf growth.

ii) Root growth

Defoliation has often been found to reduce the size and growth of roots.

Reduction in both shoot and root yield was found by Hunt (1952) under frequent defoliation.

Reduction in root respiration, root growth and absorptive capacity after defoliation due to depletion of available carbohydrates in the root was suggested by Davidson and Milthorpe (1966). The rate of growth of the plant may be limited by the rate of nutrient uptake during the recovery.

Poor growth after grazing has also been explained in terms of lowered ability of a defoliated plant to absorb water. It was indicated by Jantti and Kramer (1956) that defoliation of pasture plants reduces the diffusion pressure deficit in the roots from values between ten and twenty atmospheres, depending on the severity of defoliation. In dry soils where water is held at a tension greater than two atmospheres, the defoliated plant would be unable to absorb water.

iii) Leaf growth and light interception

Control of regrowth rate after defoliation has been attributed to residual leaf area remaining after defoliation by several investigators. (Watson, 1952; Brougham, 1956; Donald and Black, 1958; Langer, 1959).

In general these workers have suggested that maximum growth rates after defoliation was dependent on the amount of light intercepted by the plant after defoliation. Differences in species and varietal response to defoliation were explained in terms of differences in optimum Leaf Area Index (L.A.I.). White clover was found to produce its maximum rate of growth under closer defoliation than grasses because of its lower optimum L.A.I. (3.5) than grasses such as perennial rye grass with an optimal L.A.I. of 7.7 (Brougham 1958). The optimal value will also depend on the light intensity above the crop. Hence it will vary during the year. Also the critical value will depend on the spatial arrangement, particularly the inclination of the laminae, being higher when foliage is erect than when it lies horizontally (Brougham, 1958; Donald, 1961).

Therefore, it could be possible to interpret the way in which different systems of defoliation affect yield by considering the degree by which they approach the ideal.

However, this theory does not explain those circumstances where close defoliation has in fact resulted in higher pasture production, than less severe defoliation. This is particularly so where such results have been obtained irrespective of the grazing frequency between close and lax defoliation treatments (Burger et al., 1962).

These different results have been explained as the effect of cutting on the transition from vegetative to reproductive growth and its effect on the pattern of development in grasses (Langer, 1959). Lax grazing often allows relatively uninterrupted development of the flowering shoot, resulting in an ultimate check to increase of leaf area in the sward. Flowering in general is accompanied by a decline in leafy vegetative tillers and with limited leaf development on the flowering shoot. Close defoliation during this stage inhibits the development of the flowering shoot and results in an increase in tillering and leaf development (Cooper and Seed, 1949) hence higher production.

On the other hand lax defoliation results in an accumulation of senescent and dead material (Campbell, 1964; Hunt and Brougham, 1967). This material is relatively or totally unresponsive photosynthetically to incident light energy and tillering may also be limited by low light intensities at the base of tillers (Mitchell and Coles, 1955).

Increased dead matter accumulation from about 840lb/acre in May to over 2000lb/acre in August in an undefoliated sward of Italian rye grass sward was reported by Hunt and Brougham (1967). Close defoliation on the other hand decreased the amount of dead matter (Campbell, 1964) and allowed tiller formation (Hunt, 1965; Hunt and Brougham, 1967).

On a pasture of rye grass leniently defoliated at weekly intervals over a period of 49 days Hunt and Brougham (1967) found that the rate of appearance of tillers decreased from 37 to 14 tillers per dm^2 per week and the total number of tillers present declined from 95 to 64 per dm^2. They concluded that the decrease in tiller numbers and the rate of appearance of tillers together with the build-up of sheath and dead material resulted in a sward of relatively low photosynthetic capacity.

Åslow (1965) reported that in Summer, herbage yields from cocksfoot and timothy pastures were correlated with the average tiller size.

The theories suggested to explain the response of pastures to defoliation have been briefly outlined. The fact that all experiments cited above have been carried out in diverse climatic and edaphic conditions, different height, different frequencies and methods of defoliations, and at different morphological and physiological stages, there will certainly be many and important exceptions to the generalisation made above.

b) Effect of defoliation on botanical composition

Defoliation has profound effects on the botanical composition of the sward.

There is a general agreement in the literature that in a grass-clover sward frequent and hard defoliation results in a clover dominant sward (Jones, 1933; Brougham, 1959; Reid, 1959). These changes were attributed mainly to the elimination of competition for light (Brougham, 1959; Donald, 1961), destruction of apical meristem and exhaustion of root reserves in the erect species (Weinmann, 1948, May, 1960).

On the other hand, under infrequent and lax grazing the sward tends to be grass dominant (Jones, 1933; Brougham, 1959; Reid, 1959; Stern and Donald, 1962a). Similar results were obtained in swards where grasses of different growth forms were differently treated, the more prostrate species being suppressed when the sward was leniently and infrequently grazed (Holliday and Hidman, 1965). Results obtained were explained in terms of light relationships in the sward. (Davies, 1954; Stein and Donald, 1962a).

In addition to the direct effects of defoliation on the pasture, defoliation may lead to marked changes in the microclimatic. Higher soil temperatures are likely to occur under frequent and severe grazing than under the lax and infrequent grazing.

Whilst these high soil temperatures are undesirable in Summer for temperate species, it is considered as an advantage to growth when frequent and severe grazings are adopted in Winter in New Zealand (Brougham, 1959). Lower levels of soil moisture have been recorded by Jantii and Kramer (1956) and Brougham (1959) to occur under frequent and severe grazing than under lax and infrequent grazings. Such differences in soil moisture and temperature could well lead to changes in the botanical composition of the sward due to the differences in species response to such conditions.

c) <u>Treading</u>

Evidence of pasture damage caused by treading is somewhat contradictory, but the experimental conditions and techniques employed to induce treading damage have also been divergent (Edmond, 1958a; 1958b; 1962, 1963, 1964; Scott, 1963; Campbell, 1966).

Reduction in aeration, water penetration and root growth have been recorded as result of soil compaction by trampling (Edmond, 1958b). Treading has been found to alter the form and shape of grasses from erect, round or tufted to prostrate and elliptical (Edmond, 1958a).

Heavy treading may reduce number of tillers and total production in dry or wet soils (Edmond, 1958a, 1958b, 1964). Also it has been shown (Edmond, 1964) that pasture species are affected differently by treading. Perennial rye grass and timothy appeared to be more tolerant than cocksfoot, red clover and yorkshire fog. Also active growth has been related to tolerance to treading. For instance, white clover appeared more tolerant to treading in Summer and short rotation rye grass more tolerant in Winter (Edmond, 1964). Brown (1968) reported different effects of treading on pastures of different heights. Treading pastures before the herbage was removed produced higher yields in Winter and Spring but not in Autumn and Summer, than pastures trodden after defoliation.

d) Effect of dung and urine

The animal has an important effect on the turnover of plant nutrients in the pasture eco-system.

Urine has been found to contain large amounts of nitrogen and potassium in available form, whilst dung contains almost all the phosphate and calcium together with slow-acting nitrogen and potassium (Sears, 1951). An estimation of the amount of fertiliser returned by the grazing animal was made by Levy (1945). Wethers grazing a pasture producing up to 15,000lbs. DM/acre/annum returned an equivalent of approximately 15 cwt. of sulphate of ammonia; 5.5 cwt. of superphosphate; 10 cwt. of 30% potash salts and calcium equivalent to that in 2.5 cwt. carbonate of lime. Similar manurial values of the dung and urine returned by mature wethers have been reported by Sears (1951).

The return of dung and urine by the animal may or may not influence the yield and botanical composition of the sward. It has been found to depend on the nutrient status of the soil (Wheeler, 1960; Davidson, 1964); the pasture and its ability to recover the nutrients from the soil (Davidson, 1964); the distribution of the excreta which will depend on the type of animal and its habit (Sears, 1951; Petersen, Woodhouse and Lucas, 1956; Hilder and Mottershead, 1963; Hilder, 1964-66); and climatic factors (Sears, 1951; Petersen *et al*., 1956).

Sears (1951) has shown considerable effects of dung and urine, on pasture productivity and botanical composition. He found that when both dung and urine were returned, the sward resulted in a balanced perennial rye grass/white clover pasture and produced the highest dry matter yield.

An increase of 120% of herbage production was found by Wheeler (1958) under full return of excreta in association with nitrogen fertiliser application. Similar trends were found by Watkin (1954). A decrease in the percentage of white clover, and a stimulus to grass growth was found with the return of urine alone (Sears, 1951). Wheeler (1958) obtained the same result but largely by a progressive increase in nitrogen application. Sears (1951) obtained a clover dominant sward when dung only was returned and attributed it to the low content of nitrogen in the dung which was not sufficient to maintain grass growth.

Petersen *et al*. (1956) found that the distribution of excreta has an important effect in the total production of the sward. He suggested that at a cow per acre the excretal return factor could be dismissed when considering overall fertility because of the high concentration of nutrients in patches, low total coverage and the speedy dissipation of these nutrients.

Hilder and Mottershead (1963) indicate that apart from losses from excretal patches there is also the problem of undue concentration in localised areas. Hilder (1966) showed that set-stocked Merino sheep tend to form sheep camps on small areas of the paddock where the excreta is accumulated. In this experiment thirty to forty-five per cent of the dung and urine was dropped on only six per cent of the paddock and where almost all the major nutrients reached higher concentration than the rest of the paddock.

e) Selection of plant material by the grazing animal

There is a general agreement in the literature that sheep and cattle select leaf in preference to stem, (Arnold, 1960; Reppert, 1960) and green or young material in preference to dry (Cowlishaw and Alder, 1960; Arnold, 1962; Grimes, Watkin and May, 1965). The nitrogen content of the selected material is usually higher than the nitrogen content of the ungrazed material. (Hardison, Reid, Martin and Woollock, 1954; Arnold, 1960; Gallagher *et al.*, 1966).

The intensity of selection by the grazing animal will depend on the plant material available to the animal (Arnold, 1962). This will affect not only the quantity and quality of plant material eaten, but also the utilisation of total material available. The presence of dry material and disliked species has an important effect on utilisation and on what is selected (Milton, 1953; Arnold, 1962). By selective grazing the animal will frequently reduce the area of pasture that it will graze, because uneaten areas become progressively less attractive (Arnold, 1962).

A pattern of patch-grazing was observed by Suckling (1964b) in three of the four stocking rates with ewes. At three ewes per acre, only a small proportion of the total area was under close grazing while the remainder was composed of patches of long rank herbage. The same trend but with smaller amount of roughage was observed in the four and five ewes per acre. At very high stocking rate this pattern of grazing almost disappeared.

Although the effect of selection is minimized at high stocking rates due to decrease in available forage, it still exists. Hodgson (1966) showed that tillers at high-stocking rate (30 sheep/acre) were defoliated on average, every 7-8 days and those in the medium-stocked sward every 11-17 days. The total green leaf length of tillers grazed by the sheep was generally greater than of tillers not grazed. On average, 27 and 40% of the green leaf length of tillers in the medium and heavily stocked swards respectively was removed at each grazing. Older leaves on the grazed tillers were defoliated much less frequently than were younger leaves.

f) Summary of the effect of grazing on pasture

Plant communities respond to rainfall and to temperature, resulting in distinct seasonal patterns of growth. This leads to excess feed at certain times of the year and periods of shortage at others.

The grazing pressure exerted by the animal population on the whole pasture or on particular components of the pastures tends to be greatest when either or both quantity of accessible available pasture and its quality are lowest. Under high pressure and especially in seasons of herbage shortage, the effect of close and frequent defoliation may affect botanical composition and hence final total production. Low grazing pressures, may affect plant community, through competition between existing components and invasion by species from outside. In addition, effects such as the growth and death of material (Campbell, 1964; and Hunt and Brougham, 1967), regeneration and reproduction of species including the survival and carry over of seed (Rossiter, 1961; Sharkey et al., 1964), nutrient cycling, particularly of the elements phosphorus and nitrogen, form an integral part of the biological system and has a strong influence on the above factors (Hilder, 1964; Kydd, 1966).

Soil moisture levels at different stages of growth may also have a great influence on pasture production and botanical composition. These effects will show up more frequently under high grazing pressure, because the lack of root depth will make the pasture more susceptible to climatic changes.

Nevertheless, a pasture under high grazing pressure is probably very dynamic and may respond more rapidly to environmental changes both good and bad, beneficial and harmful. It is likely that the nitrogen cycling through the animal-plant-soil system, is used more efficiently, because the plant is physiologically more responsive and less nutrients are lost to the system than in an under-stocked situation.

III. EXPERIMENTAL

A. INTRODUCTION

The object of this experiment was to compare the effect of permanent pastures of different species on the seasonal wool growth and live weight of Romney hoggets set stocked at two different levels of stocking; also to compare the effect of stocking rate on pasture growth, availability and composition.

The plot lay-out was designed by Professor B. R. Watkin and laid down before the writer's arrival at Massey University.

B. MATERIALS

1) Location of the Experiment

The experiment was set up at the "Tuapaka" research farm of the Massey University. This farm is situated 8 miles north-east from Palmerston North in the Manawatu district, at an altitude of 230 feet above sea level and on latitude 40^{o} 21S.

Temperature and rainfall records, presented in tables Ia and Ib have been taken from the D.S.I.R. weather station situated 8 miles away. However, these records are significant because of the lack of climatic variation in the area.

2) Field Plots Design

The experiment is a randomized block design of 32 plots representing 4 different pastures with 4 replicates. Each plot of 2/3 acre was sown in Autumn (16th-17th April) of 1966, with the following certified seed:

N.Z. "Grasslands" white clover (*Trifolium repens L.*)
N.Z. "Grasslands" cocksfoot (*Dactylis glomerata L.*)
N.Z. "Grasslands" perennial rye grass and white clover (*Lolium perenne L.* and *Trifolium repens*)
N.Z. "Grasslands" cocksfoot and white clover (*Dactylis glomerata L.* and *Trifolium repens*)
see fig. I.

General views of the experimental area are shown in Plates 1 and 2.

TABLE 1a

Meteorological Data for Manawatu

Recorded at DSIR-Grassland Division at 8 miles distant from the Experimental Area

Temperature °F 1967.

	Mean Maximum	Mean Minimum	Mean	Maximum Absolute	Minimum Absolute
Jan.	69.2	54.8	52.0	81.7	43.0
Feb.	70.4	53.8	62.0	80.0	41.4
Mar.	70.1	54.9	62.5	80.9	42.3
April	64.2	50.0	57.1	74.0	35.5
May	58.5	48.7	51.6	64.0	31.0
June	54.1	37.9	46.0	61.0	29.6
July	52.7	37.1	44.9	61.3	28.8
August	57.7	44.1	50.0	63.1	30.8
Sept.	57.3	42.1	49.7	66.1	29.2
Oct.	63.5	47.7	55.6	70.1	35.5
Nov.	65.6	50.0	57.8	81.8	35.2
Dec.	70.7	55.0	62.9	78.2	44.6

TABLE 1b

Monthly Rainfall for 1967 and average of 30 years

	Inches	No. of Days	30 year average
Jan.	3.11	13	3.39
Feb.	3.69	9	2.71
March	2.69	8	2.82
April	2.12	9	3.04
May	2.96	15	3.32
June	1.66	9	3.81
July	1.48	7	3.51
August	7.20	19	3.32
Sept.	1.22	15	2.75
Oct.	2.57	10	3.40
Nov.	3.70	13	3.20
Dec.	6.48	16	4.03
Total	38.88		39.30

Figure 1

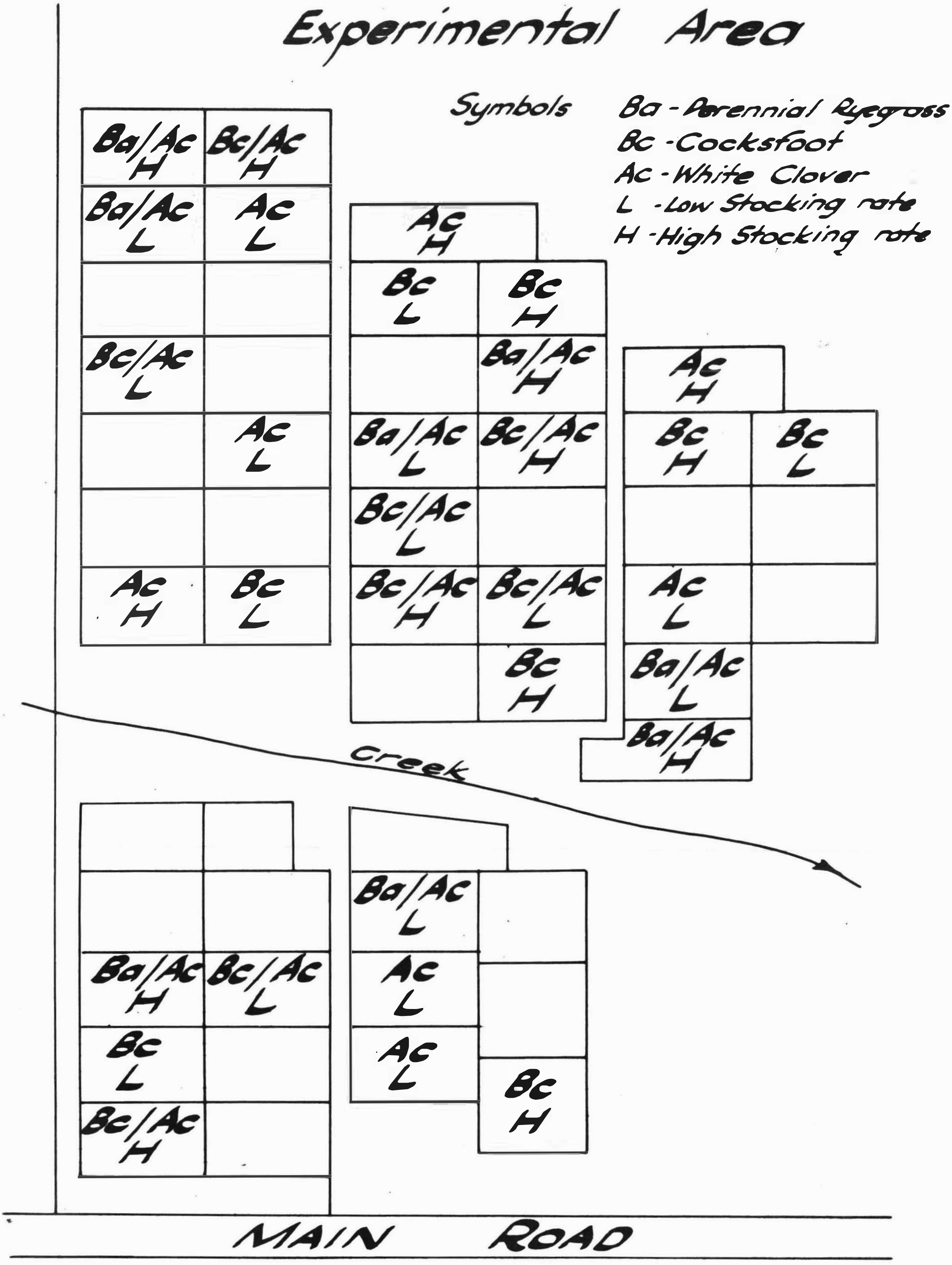

Experimental Area
Symbols
Ba - Perennial Ryegrass
Bc - Cocksfoot
Ac - White Clover
L - Low Stocking rate
H - High Stocking rate
Ba/Ac H
Bc/Ac H
Ba/Ac L
Ac L
Bc/Ac L
Ac L
Ac H
Bc L
Ac H
Bc L
Bc H
Ba/Ac H
Ba/Ac L
Bc/Ac H
Bc/Ac L
Bc/Ac H
Bc/Ac L
Bc H
Ac H
Bc H
Bc L
Ac L
Ba/Ac L
Ba/Ac H
Creek
Ba/Ac H
Bc/Ac L
Bc L
Bc/Ac H
Ba/Ac L
Ac L
Ac L
Bc H
MAIN ROAD

PLATE 1

PLATE 2

General view of the Experimental Area.

(August 1967)

3) Experimental Animals

On 26th May 1967, 208 Romney wethers from two different origins, 'Johnson's' (142) and 'Waikanae' (66) born in August-September, 1966, were weighed. Sheep were allotted to plots with randomization being restricted in order to give a similar live weight distribution and mean for all plots, at the rate of 4 and 9 in each plot. This represented a stocking of 6 and 13.5 wethers per acre.

The Waikanae group were not used at the low stocking rate but were used to make up the number in the high stocking rate. Data was obtained only from the Johnson group. The animals were set stocked for the period of the trial. Replacements were made in cases of death only to make up the numbers of animals per plot.

C. METHODS

1) Pasture Management

Following sowing and subsequently in Spring 1966 and Autumn and Spring 1967 3 cwt. of superphosphate plus 1 cwt. of muriate of potash per acre were applied to each plot. Pure grass was top dressed with 2 cwt. of urea in April, August and October 1967 to maintain the pure stand. Pastures were maintained in the pure state by the application of Dalapon, Tordon and M.C.P.A. according to the particular requirements. After establishment, the plots were periodically grazed with sheep until the experiment started, in order to control pasture growth.

2) Pasture Samples

Herbage samples representing the pasture available were collected at intervals of 13-16 days taking two subsamples of 3 square feet in representative areas of the grazed plots. At the same time 2 subsamples of the same plot or paddock were taken from under cages, previously placed, to measure pasture growth. Pastures were cut at ground level with Sunbeam electric sheep shears. After each cutting the cages were moved to a predefined "representative" area.

The pasture clippings were placed in a plastic bag and subsequently weighed in the laboratory and mixed for subsampling. Subsamples of 200gr. were taken and dried in a "Unitherm" electric oven for 16 hours at 80 $^{\circ}$C for dry matter determinations.

3) Botanical Analysis

Four botanical analyses were made approximately each two months by taking 40gr. subsample from the clipped sample mentioned above and hand separating it into grasses, clover, dead matter and other species. These samples were dried in the oven and weighed. The dry matter from each sample was referred as percentage of the total dry sample.

In order to estimate the amount of bare ground at the time of low pasture availability, point analysis methods were used. In each paddock 100 hits were recorded.

4) Animal Live weight

All animals were weighed every four weeks, to the nearest pound, using a sling suspended from a "Salter" spring balance supported by a tripod.

5) Wool Sampling

Midside samples were taken from each animal by clipping patches of approximately 100 sq. cm. every 12 weeks using "Oster" electric clippers (0000 blades). The patch dimensions were measured to the nearest millimetre using calipers with elongated points. The area was estimated from dimensions of the four sides assuming rectangular shape.

Midside samples of greasy wool were conditioned in a constant humidity room before weighing. Wool weights were made in a Mettler balance to the 0.001gr.

To assess monthly variation in wool length growth rate, the dye banding technique (Chapman and Wheeler, 1963) was used. Dye bands were applied four and eight weeks after clipping using a pipette to run a line of dye solution along the skin in one corner of the clipped patches. The dye used was an aqueous Durafur-Black R solution which was prepared immediately prior to use by dissolving 4g. of Durafur Black R flakes in 500 ml. cold distilled water. When the flakes were dissolved 4 ml. of concentrated hydrogen peroxide (100 vol.) were added.

Measurements on the clipped wool samples were made to the nearest millimetre using a ruler. The distances measured were from: the tip of the staple to the bottom of the first band, from the bottom of the first band to the bottom of the second band and from the last position to the bottom of the staple. In order to correct for the effect of the pile of wool left by the clippers, 2 animals were clipped on the midside and dye applied to the skin. The thickness of the dye band which appeared on the tip of the wool was measured. The mean of this measurement (2mm.) was discounted from the measurement done from the top to the first band and added to the measurement between the second band and the bottom of the staple.

Estimation of fibre growth length per day in millimetres was made by dividing the length obtained during each period by the appropriate number of days.

Fleeces were weighed at shearing on a Kendall fleece weighing table. Fleeces were graded according to the extent of discolouration and cotting within the fleece. A right midside wool sample was removed and later graded for soundness, colour, degree of cotting and other characteristics. Descriptions of the grading system used are given by Sumner (1969).

6) Statistical Analysis

Analysis of variance was performed on the dry matter available and pasture growth data collected at seven sampling times which coincided with animal weighings. The significance of differences between mean pasture types was evaluated by Duncan's multiple range test (Duncan 1955).

Differences in animal and wool characteristics were analysed by the least squares method for unequal sub-class numbers. Differences in body weight were tested by the co-variance analysis using the previous weight as the independent variable.

Wool growth differences of midside samples in grammes and weight per unit area gm/cm^2 were tested by covariance analysis using weights of wool samples taken at the beginning of treatments as the independent variable. Differences in total fleece weight was tested by covariance analysis with weight per unit area of the beginning of the experiment.

The model used for these covariance analyses was

$$Y_{bps} = \mu + \alpha_t + \gamma_p + \rho_s + \gamma\rho_{ps} + \beta(X_{bps} - \bar{x}) + \epsilon_{bps}$$

where:

Y_{bps} = an observation on one characteristic

μ = overall mean for that characteristic

α_b = effect of Blocks

γ_p = effect of pastures

ρ_s = effect of stocking rate.

All analyses were calculated using Massey University I.B.M. 1620 computer.

IV. RESULTS

1) Pasture Availability

Changes in dry matter available for pastures grazed at high and low stocking rate are shown in figures 2 and 3. The total forage available showed the same seasonal trend for all pastures under high and low stocking rate, with a minimum availability toward the end of Winter and maximum at the end of Spring. Within monthly observations, the significance of the difference in mean total dry matter available between pastures, blocks and stocking rates was tested by analysis of variance (Table 2) followed by Duncan's multiple range test. (Table 3). Total dry matter available was significantly greater ($P<0.01$) under low stocking rate. This effect was evident in all pastures treatment except white clover. In this case the difference between high and low stocking rate was not significant over the September to October period. Differences in availability between grasses (with and without clover) and pure white clover pasture under low stocking rate were significant ($P<0.05$) through the whole experiment, except for cocksfoot plus white clover at the end of November. This superiority of grasses over white clover was not so evident under high stocking rate. Differences were dependent on the ability of the individual grasses to respond to the grazing pressure. For example, cocksfoot with and without white clover was significantly superior to white clover from June to September, but thereafter

Figure 2

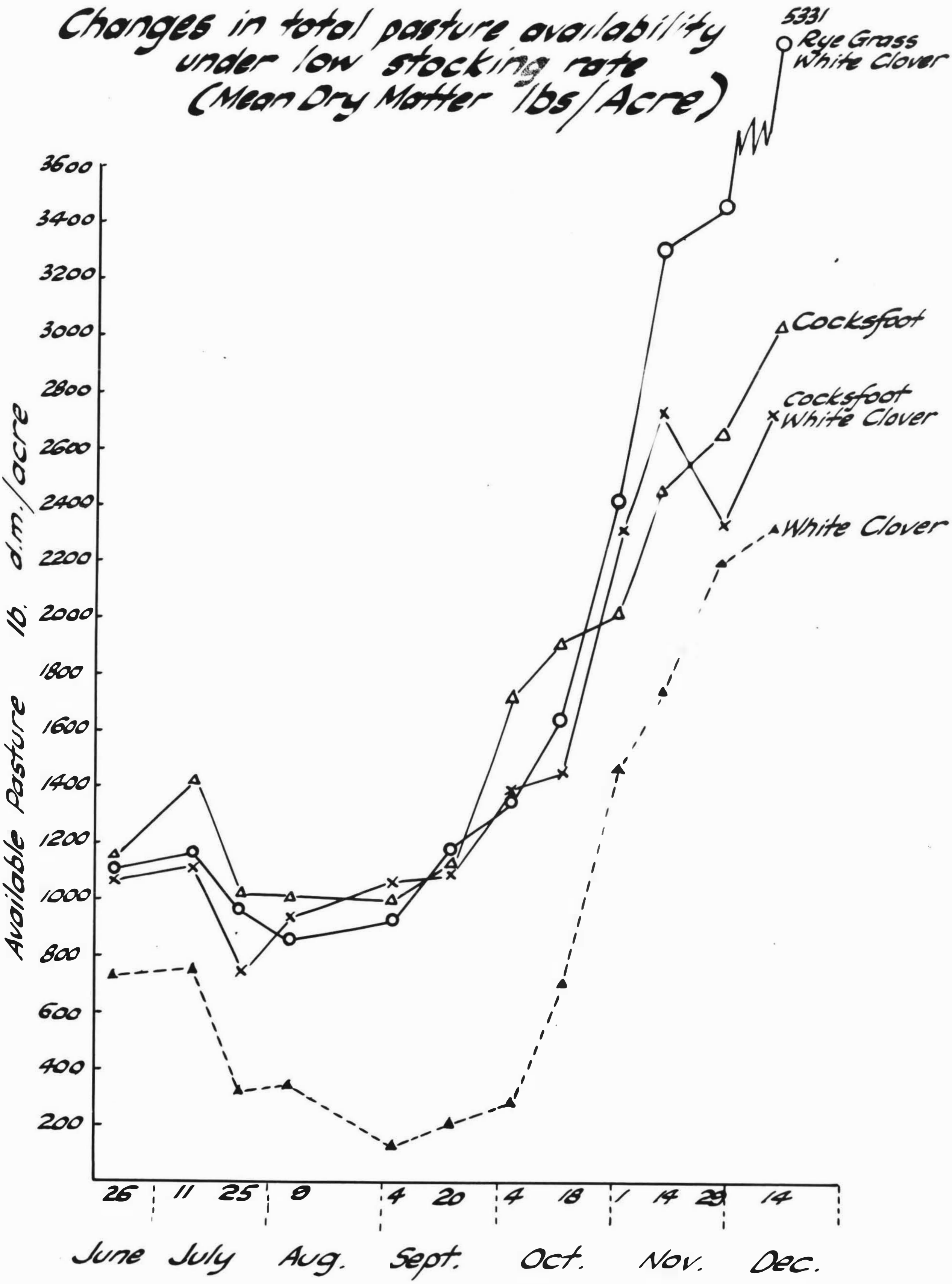
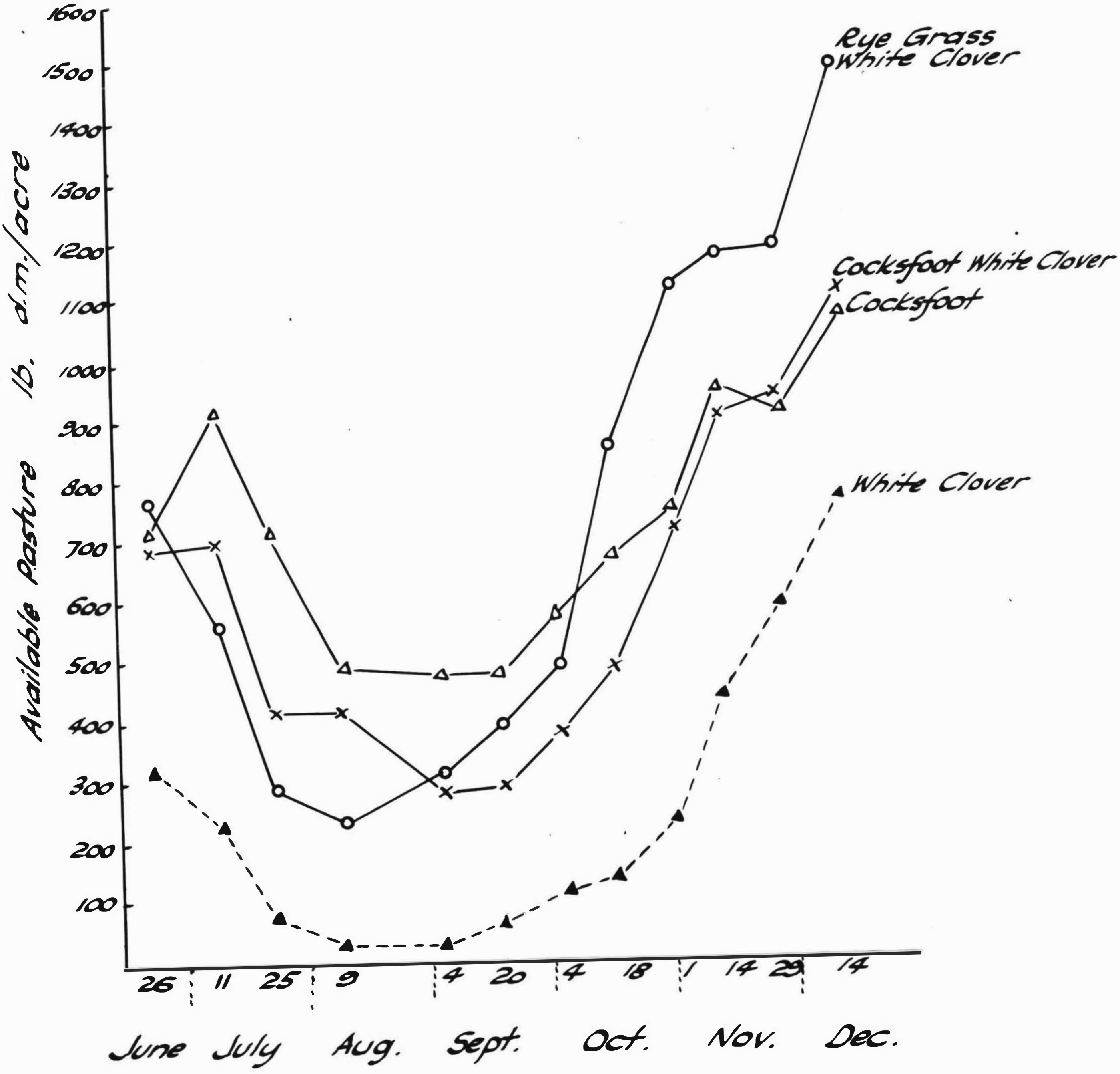

Changes in total pasture availability under low stocking rate (Mean Dry Matter lbs/Acre)
5331
Rye Grass White Clover
Cocksfoot
Cocksfoot White Clover
White Clover
Available Pasture lb. d.m./acre
3600
3400
3200
3000
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
26
11
25
8
4
20
4
18
1
14
29
14
June
July
Aug.
Sept.
Oct.
Nov.
Dec.

Figure 3

Changes in total pasture availability under high stocking rate (Mean Dry Matter lbs/Acre)



<u>TABLE 2</u>

<u>Analysis of variance of Total Pasture Available</u>

Source of Variation	Degrees of Freedom	M.S. 26/6	M.S. 11/7	M.S. 9/8	M.S. 4/9	M.S. 4/10	M.S. 1/11	M.S. 29/11
Pasture	3	310752.66**	620414.66**	480442.00**	739044.66**	1322778.6**	1211874.60**	1250330.00**
Blocks	3	20839.00	59565.00	1220.40	64964.56*	102043.66	685876.66*	499526.66**
Stocking rate	1	1192355.00**	2255316.00**	1949473.00**	2136968.00**	5442854.00**	16322041.00**	25412020.00**
Pasture/ Block	9	35476.11	62960.88	14140.00	21888.16	70549.22	138871.44	96341.11
Block/ Stocking rate	3	54755.66	16936.00	4464.40	4072.06	120878.33	101382.00	128573.33
Pasture/ Stocking rate	3	3408.33	12523.66	27781.73	155136.73**	415190.00**	63624.33	278290.00*
Error	9	30621.11	25856.88	21085.04	16614.93	62853.33	136130.33	52546.66
Total	31							

* = p 0.05

** = p 0.01

M.S. = Mean Square

TABLE 3

Means of total pasture available

(Dry Matter lb/acre)

Pasture	S.R.	26/6	11/7	25/7	9/8	4/9	20/9	4/10	18/10	1/11	14/11	29/11	14/12
Ba/Ac	L	1110a	1170b	976	862a	919a	1177	1372a	1631	2418a	3330	3478a	5331
	H	774bc	560d	289	238c	312bc	399	490b	863	1113bc	1179	1181d	1439
Bc/Ac	L	1071ab	1128b	764	927a	1078a	1111	1397a	1468	2318a	2731	2345bc	2727
	H	670c	704cd	429	424b	280bc	285	376b	486	722cd	911	920de	1118
Ac	L	733c	789c	334	364b	152cd	205	288b	721	1485b	1768	2212c	2343
	H	326d	228e	73	27c	16d	62	114b	132	235d	433	587e	764
Bc	L	1149a	1451a	1017	1004a	1014a	1143	1747a	1928	2192a	2495	2689b	3097
	H	719c	922bc	706	493b	488b	481	525b	674	722cd	955	908de	1093

S.R. = Stocking Rate

Symbols for pasture are the same as those in figure 1 and will be used in all tables.

Within observations means with the same letter do not differ significantly at the 5 per cent level (Duncan's Multiple range test).

its superiority failed to reach significance. By comparison rye grass/white clover reached lower level of availability during July and August and in fact was not significantly different from white clover in the latter month. However, from that point onwards rye grass/white clover showed a marked increase in dry matter availability, approximately a month earlier than the cocksfoot treatments, and continued to display this superiority throughout the remainder of the experimental period. It is interesting to note that the increase in the availability of the cocksfoot/white clover treatments appeared to be only slightly superior to and commenced about the same time as white clover.

The pure cocksfoot treatment was not depressed to the same extent as the grass/clover pastures. This might be due to the effect of the Nitrogen applied in August which sustained its response up to the end of November. However, the difference between dry matter available on the cocksfoot pastures and the white clover pastures did not reach significance at any time from October to the end of the experiment.

2) Pasture Growth

The means of the pasture and stocking rate treatments for total dry matter production per acre determined as outlined in section 1 are shown in Figures 4 and 5. Analysis of variance of the six sampling dates at which information was available on pasture availability are presented in Table 4. Where differences were significant Duncan's Multiple Range test was used, the re-

Figure 4

Total Pasture Growth under Low Stocking Rate (Mean Dry Matter lbs/Acre)

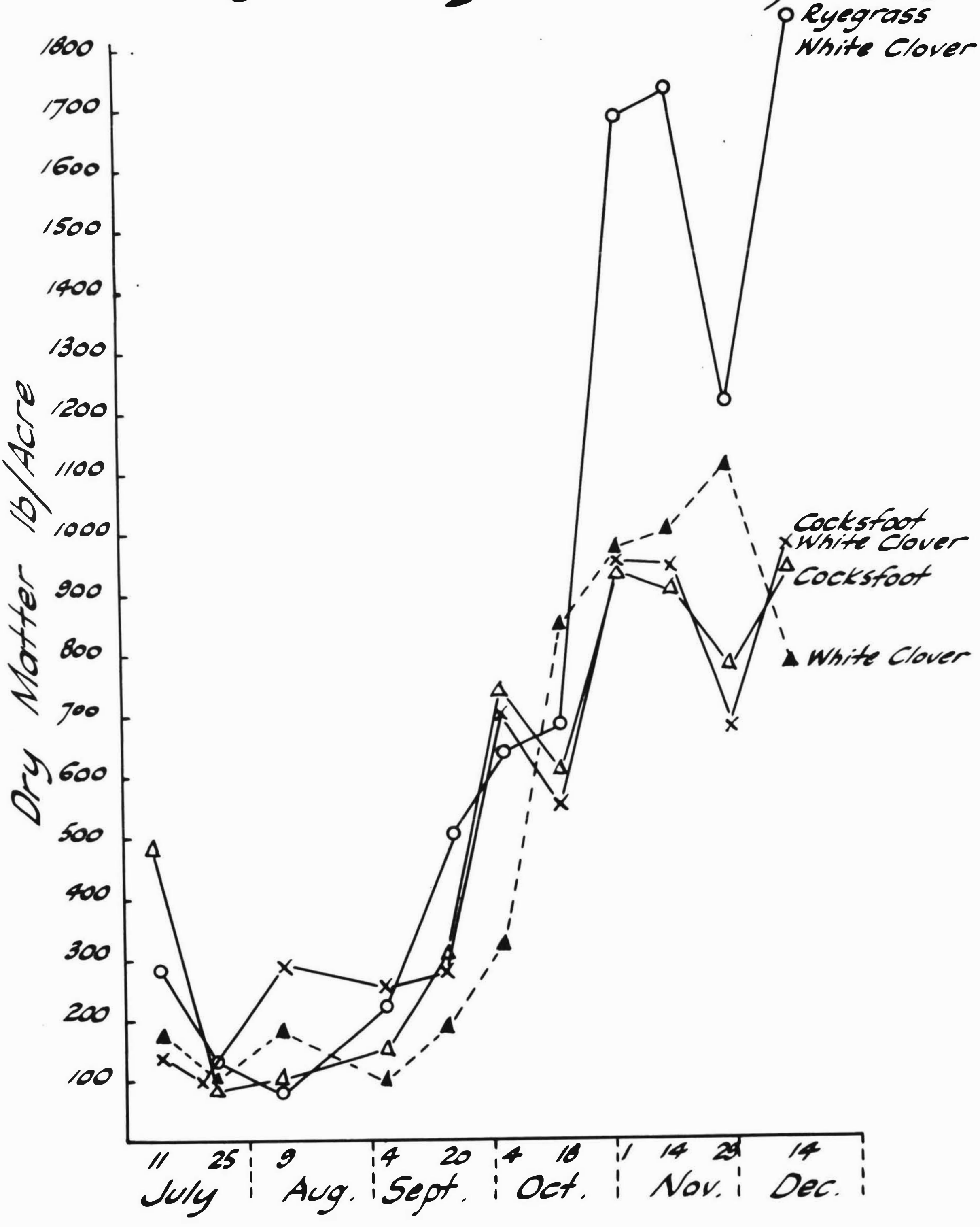


Figure 5

Total Pasture Growth under High Stocking Rate (Mean Dry Matter lbs/Acre)

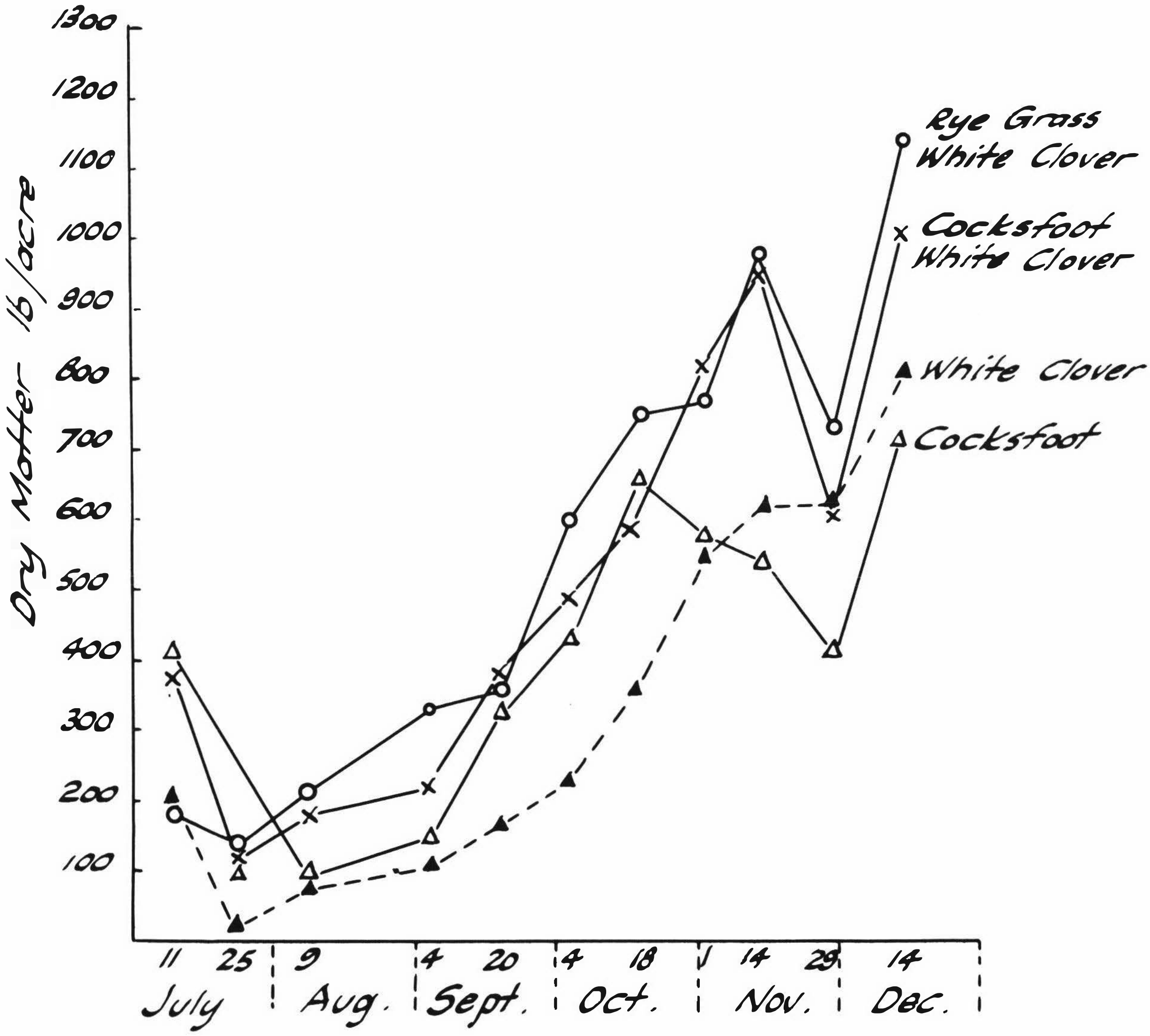


TABLE 4

Analysis of variance of Total Pasture Growth

Source of Variation	Degrees of Freedom	11/7 M.S.	9/8 M.S.	4/9 M.S.	4/10 M.S.	4/10 M.S.	29/11 M.S.
Pasture	3	107492.93	28086.40**	45911.63	226218.73**	371697.00	259225.00**
Blocks	3	100045.33	38352.94**	3787.00	8818.10	358113.00	151980.00*
Stocking Rate	1	1515.10	3296.73	3143.20	217717.4 *	1780620.00**	1040402.00**
Pasture/ Block	9	53303.78	7131.69	8907.73	43651.36	69609.11	68250.11
Block/ Stocking Rate	3	34104.36	5834.74	2206.66	128468.03*	2840.00	11741.33
Pasture/ Stocking Rate	3	37086.56	21574.53*	9355.26	29067.16	208231.33	78757.00
Error	9	49768.54	3999.67	12139.57	20856.13	109759.22	35813.33
Total	31						

sults being indicated in Table 5.

Growth of pastures, in general followed the same trend under both stocking rates up to the end of September. From then on, growth of the low stocking rate pastures was substantially greater than that of the high stocked pastures, especially for the rye grass/white clover sward. Differences reached significance in October ($p<0.05$) and November ($p<0.01$). The superiority of the grass the grass/clover pastures over pure clover was also evident during the early Spring, particularly at the high stocking rate. As the season progressed rye grass/white clover and pure white clover pastures reached higher levels of production than did the cocksfoot pastures.

Although the statistical analysis indicates that the growth of the two grass/clover pastures were superior to cocksfoot or white clover alone, in October, November and December, these effects were largely confined to the high stocking rate treatments and the low stocked rye grass/white clover treatment.

Possibly the most interesting and significant aspects agronomically were; the delay in white clover response in the Spring under high stocking rate; the substantial growth response of the rye grass/white clover treatment in the Spring under low stocking rate; the relatively poor Spring growth of the cocksfoot treatments particularly at low stocking rate and the superiority of cocksfoot/white clover over cocksfoot at the high stocking rate in the late Spring.

Kg/ha = 1.12x
.0102
kg/ha/d14 = .08x
15 .0747
16

TABLE [illegible]

Means of total pasture growth

(Dry matter lb/acre)

Pastures	S.R.	11/7	25/7	9/8	20/8	4/9	20/9	4/10	18/10	1/11	14/11	29/11	14/12
Ba/Ac	L	280	138	93c	171	214	505	645ab	689	1696	1735	1218a	1852
	H	185	138	215ab	267	333	356	613ab	754	772	394	730bc	1143
Bc/Ac	L	175	107	297a	236	259	286	714a	570	982	974	685bc	990
	H	377	116	179bc	178	223	386	491abc	590	821	961	602bc	1016
Ac	L	184	117	170bc	90	112	193	324bcd	861	995	1005	1121a	799
	H	209	26	90c	86	105	158	217d	358	574	620	604bc	508
Bc	L	496	114	100c	123	157	302	733a	605	962	924	771b	941
	H	420	104	100c	125	155	338	432abc	670	582	544	414c	720

Within observations means with the same letter do not differ significantly at the 5 per cent level (Duncan's Multiple range test).

3) Botanical Composition

The estimation of botanical composition in terms of percentage of species present in the total dry matter available for pastures grazed at low and high stocking rate are shown in Table 6. The table shows that in some of the treatments there were considerable changes in botanical composition during the experimental period.

The proportion of grass and clovers in rye grass plus white clover and cocksfoot plus white clover pastures show similar trends. As the experiment progressed there was a slight increase in the proportion of grass. This accounts for the higher percentages of grasses in the total dry matter available in the high stocking rate treatment. While the proportion of dead matter on rye grass/white clover pastures did not differ greatly between stocking rates there were noticeable differences in this component between stocking rates on the cocksfoot/white clover pastures. For example, by the end of the experimental period dead matter represented as much as 20% of the available herbage under low stocking but only 8% on the high stocking rate. From observation there appeared to be a greater degree of "patchiness" on the cocksfoot pastures generally. As the Spring progressed increasing areas of tall ungrazed clumps of cocksfoot became more and more apparent and no doubt accounted for the high dead matter figures obtained. (Plate number 3).

Over the whole experiment high stocking rate clover pastures had a lower percentage of clover than low stocking rate.

TABLE 6

Estimation of Botanical Composition in terms of percentage of species present in the total dry matter available

		26/6				9/8				18/10				29/11			
Pasture	S.R.	Grass	Leg.	Dead Matter	O.S.	Grass	Leg.	Dead Matter	O.S.	Grass	Leg.	Dead Matter	O.S.	Grass	Leg.	Dead Matter	O.S.
Ba/Ac	L	76.8	7.5	12.7	3.0	90.2	3.3	3.7	2.6	79.8	11	6.1	2.8	78.8	8.9	10.5	2.5
	H	69.6	12.3	14.1	3.8	84.2	5.2	5.2	5.2	86	8.6	2.7	2.7	86.1	5.8	7.9	-
Bo/Ac	L	69	7.4	21.8	1.68	76.9	4.4	16.7	1.8	85.4	3.7	10.8	-	75.4	3.4	20.2	0.8
	H	63	17.5	16.4	2.7	78.7	7.5	10.3	3.4	63.67	13.8	11.2	11.2	86.1	5.6	8.2	-
Bc	L	74.5	1.6	23.7	-	75.4	-	24.2	-	83.8	-	16.2	-	73.7	-	26.2	-
	H	68.2	-	30.9	8.1	80.8	-	19.8	-	95.5	-	4.4	-	88.1	-	11.8	-
Ac	L	18.6	70.6	8.0	2.6	33.8	46.5	14.2	5.3	12.2	79.3	0.7	7.6	6.4	67.3	2.7	23.9
	H	31.9	53.1	10.6	4.2	17.2	71.4	3.2	7.7	3.26	63	-	4.3	37.6	49	9.2	4.1

Leg. = Legume　　O.S. = Other Species

The symbols used throughout these tables are the same as those used in Figure 1.

PLATE 3

Selective Grazing.
Cocksfoot/white clover pasture under low stocking rate.

(November 1967)

PLATE 4

Close up of white clover pasture low stocking rate showing invasion of *Mentha puligium*.

(November 1967)

Invasion of weed grasses such as Poa trivialis and Poa annua was greater under high stocking rate which accounts for the highest percentage of grasses in the total dry matter available. The substantial increase in other species recorded under low stocking rate white clover pastures were mainly due to the invasion of Mentha pulegium which in some paddocks reached 50% of the total dry matter available. (Plate number 4).

4) Estimation of Ground Cover

Point analysis was used in an attempt to measure the amount of bare ground at the time of lowest pasture availability. The results are shown in table 7.

Under high stocking rates the high proportion of bare ground was most evident, being about twice the area recorded under low stocking rate.

In grasses and grasses plus clover pastures the variation in the proportion of bare ground within stocking rates was small. However, white clover pastures at both stocking rates showed a substantially higher percentage of bare ground (Plates number 5 and 6) compared with the other pastures.

5) Live weight

Changes in live weight of animals grazing the different pastures at low and high stocking rates are shown in figures 6 and 7.

Animals grazing at the low stocking rate followed

TABLE 7

Estimation of Percentage of ground cover determined by point analysis method

Pastures	Stocking Rate	Bare Ground	Grass	Leg.	Clover Stolen	Weeds	Dead Matter
Ba/Ac	L	14	60	26	-	0.65	-
	H	32	46	17	1	1	-
Bc/Ac	L	14	65	19	-	0.5	0.5
	H	27	58	13	1	1	-
Bc	L	21	75	-	-	-	4
	H	38	61	1	-	-	-
Ac	L	36	12	37	11	4	-
	H	60	9	20	10	-	-

PLATE 5

Low stocking rate white clover pasture.

(August 1967)

PLATE 6

High stocking rate white clover pasture.

(August 1967)

Figure 6

Live Weight changes of Sheep Grazing at Low Stocking Rate

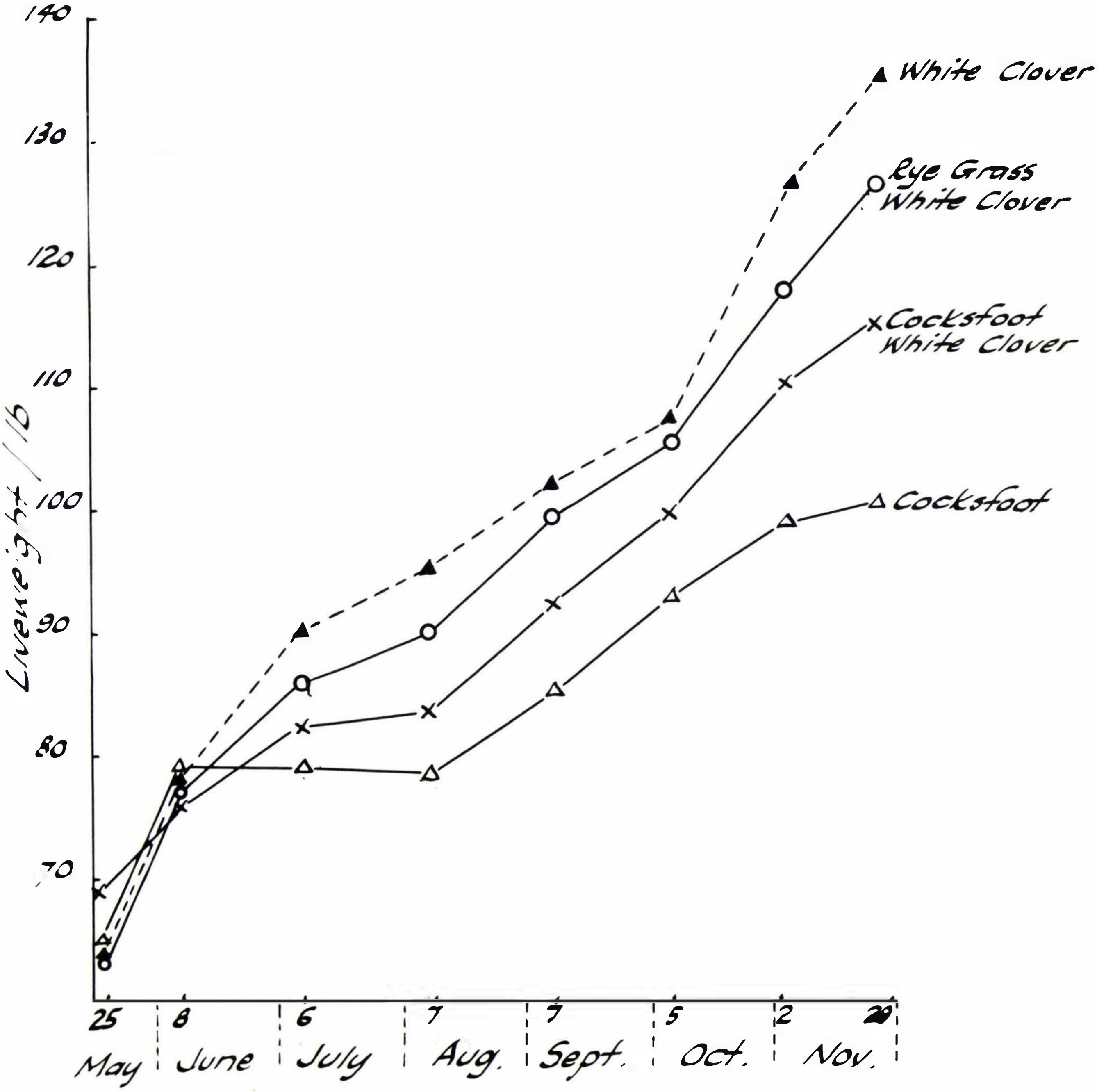
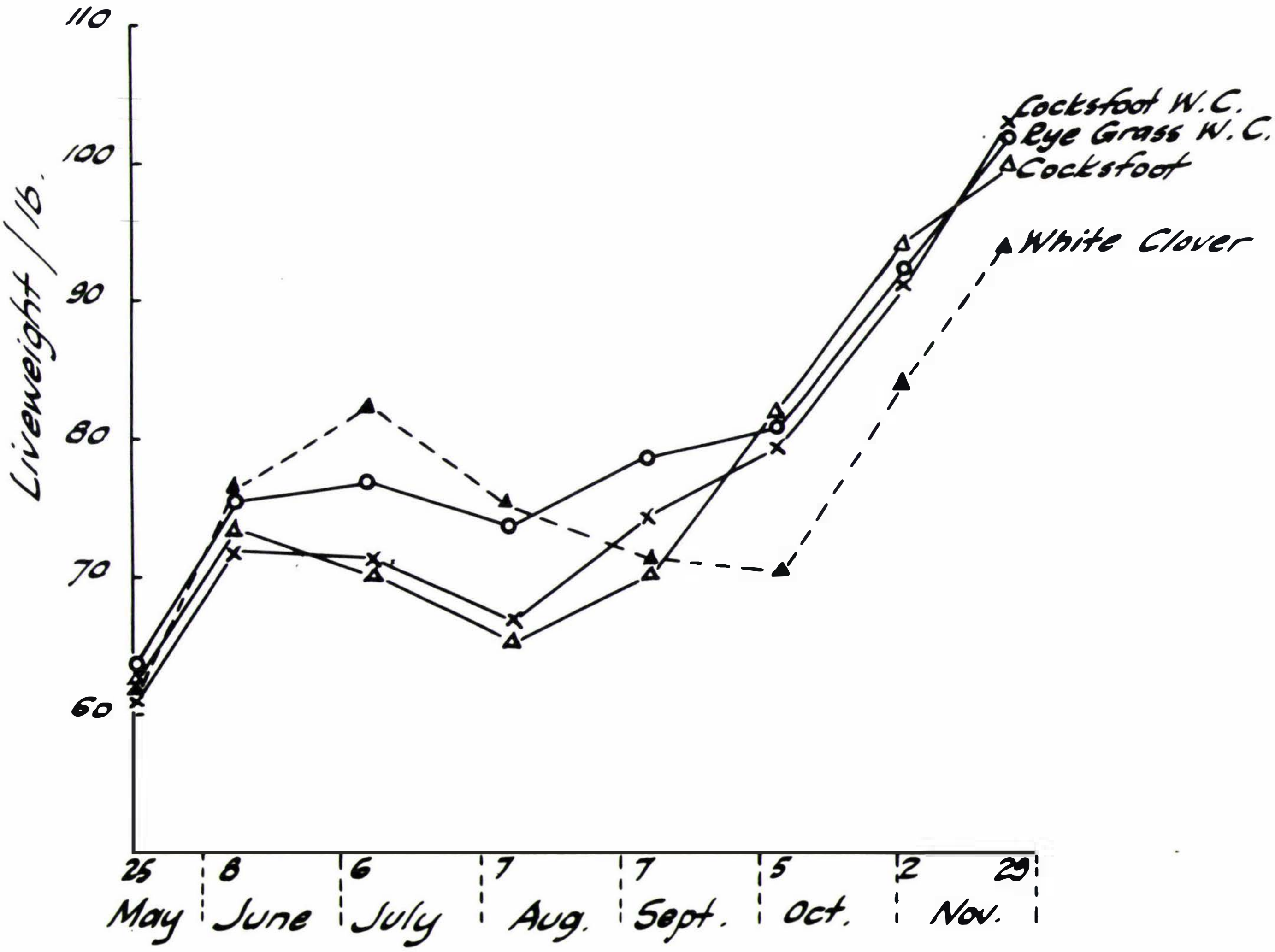


Figure 7

Live Weight changes of Sheep Grazing at High Stocking Rate



almost the same trend in live weight changes on all pastures. Throughout the whole experiment sheep grazing white clover, showed the fastest growth followed by rye grass/white clover, cocksfoot/white clover and cocksfoot.

At high stocking rate live weight changes were more variable. In this case live weight was related to some extent to changes in pasture availability especially in those animals grazing white clover, which lost weight from July to the end of September. (Plates 7 and 8).

Although animals grazing cocksfoot/white clover and cocksfoot pastures lost more weight than animals on rye grass/white clover in June and July, differences in final live weight between these pastures were small.

Differences in live weight, as indicated by eliminating the differences in body weight at the previous weighing by analysis of covariance (Table 8b) showed, that adjusted live weight of animals grazing at low stocking rate was significantly ($p<0.01$) better than at high stocking rate from June to the end of October. From the end of October to the end of the experiment the adjusted live weights of sheep grazing at the high stocking rate were significantly ($p<0.01$) better than on the low stocking rate. However, this superiority was not manifested in all pastures from September to the end of November as indicated by the presence of a significant interaction between Pasture treatment and stocking rate. For example: on pure cocksfoot, sheep grazing at high stocking rate were superior in

PLATE 7

Animals grazing cocksfoot pasture.
Left, low stocking rate; right, high stocking rate.

(August 1967)

PLATE 8

Sheep grazing white clover high stocking rate.

(August 1967)

TABLE 8a

Analysis of variance of live weight

Source of variation	Degrees of Freedom	25/5 M.S.	8/6 M.S.	6/7 M.S.	7/8 M.S.	7/9 M.S.	5/10 M.S.	2/11 M.S.	27/11 M.S.
Pasture	3	.78	20.45	737.91 **	1132.22 **	584.97 **	159.76	558.66 *	1688.501 **
Block	3	1.93	159.74 *	39.60	80.03	23.16	95.30	193.16	5.966
Stocking Rate	1	86.88	469.86 **	3166.68 **	9547.51 **	13639.09 **	17142.60 **	15614.00 **	11738.70 **
Stocking Rate x Pasture	3	1.08	21.89	20.69	149.98	363.50 **	787.56 **	1516.60 **	2037.43 **
Residual	123	33.73	42.85	51.88	68.49	75.08	95.11	121.94	154.22
Total	133								

TABLE 8b

Analysis of variance of liveweight adjusted for liveweight at the previous weighing

Source of variation	Degrees of Freedom	8/6 M.S.	6/7 M.S.	7/8 M.S.	7/9 M.S.	5/10 M.S.	2/11 M.S.	27/11 M.S.
Pasture	3	27.05	655.08	139.44 ***	200.49***	297.03***	327.50***	264.56***
Block	3	175.78***	77.53***	106.66 ***	117.14***	185.46***	225.16***	210.00***
Stocking Rate	1	186.16	1369.96***	1229.60 ***	485.40***	446.40***	346.60***	280.70***
Stocking Rate x Pasture	3	19.01***	31.17***	104.71 ***	68.74***	141.30***	101.50***	51.56
Residual	123	11.962	15.79	9.14	17.22	25.25	24.76	27.69
Total	133							

live weight to all low stocking rate pastures in the September-October period and superior to cocksfoot low stocking rate until the end of the experiment.

Cocksfoot/white clover high stocking rate had better live weight than the low stocking rate in November.

Animals grazing white clover and perennial rye grass/white clover at low stocking rate had better live weight during the whole experiment as compared with the same pastures at high stocking rate except in November. (Table 9b).

It is interesting to note that the final live weight of animals grazing pure cocksfoot under low stocking rate had the same live weight of animals on pure cocksfoot at high stocking rate.

6) Wool growth

Wool growth was assessed in terms of greasy wool weight from midside patches and weight per unit area over two sampling periods. The first, from the 7th of July (1967) to the 7th of September and the second from the 7th of September to the 26th of November. Wool growth per unit area (gr/cm^2) for both periods are shown in figure 8a.

Total wool growth for both periods as assessed by the total weight of wool removed from the patch and weight per unit area (adjusted for initial weight) was greater on animals grazing white clover and grasses/white clover as compared with pure cocksfoot pasture.

TABLE 9a

Estimates of effect of factors on unadjusted live weight

	25/5	8/6	6/7	7/8	7/9	5/10	2/11	27/11
General Mean	63.97	75.84	79.51	78.08	84.33	90.05	102.32	110.18
Ba/Ac	.10	.70	2.12	3.65	3.77	2.93	2.63	4.40
Bc/Ac	-.20	-1.40	-2.91	-3.07	-1.11	-.70	-.96	-1.10
Ac	-.04	.34	5.57	6.10	2.94	.18	3.83	6.55
Bc	.14	.36	-4.78	-6.68	-5.60	-2.41	-5.50	-9.85
High Stocking Rate	-.81	-1.88	-4.88	-8.47	-10.13	-11.35	-10.84	-9.39
Ba/Ac x Stocking Rate	.17	.97	.57	.28	.82	-.94	-2.16	-3.53
Bc/Ac x Stocking Rate	-.23	-.55	-.90	.06	.92	1.10	1.69	3.17
Ac x Stocking Rate	-.06	.38	-.41	-2.78	-4.72	-6.03	-7.94	-8.93
Bc x Stocking Rate	.12	-.80	.74	2.44	2.98	5.87	8.41	9.29

Stocking rate and pasture x stocking rate are shown as effects of high stocking only. Low effect is of the same magnitude but + or - signs reversed.

TABLE 9b

Estimates of effects of factors on adjusted live weight

	8/6	6/7	7/8	7/9	5/10	2/11	27/11
General Mean	75.22	78.64	77.81	83.80	88.24	101.18	108.26
Ba/Ac	.61	1.84	1.38	.41	-.71	-.37	1.72
Bc/Ac	-.89	-1.93	.06	1.71	.38	-.22	-.12
Ac	.38	5.26	.12	-2.66	-2.67	3.67	2.64
Bc	-.10	-4.81	-1.56	.54	3.00	-3.06	-4.24
High Stocking Rate	-1.11	-3.15	-3.25	-2.33	-1.57	.65	1.65
Ba/Ac x Stocking Rate	.80	-.32	-.33	.56	-1.74	-1.21	-1.32
Bc/Ac x Stocking Rate	-.40	-.41	1.03	.87	.22	.59	1.44
Ac x Stocking Rate	.44	-.75	-2.35	-2.16	-1.47	-1.84	-.84
Bc x Stocking Rate	-.92	1.48	1.65	.73	2.99	2.46	.72

Stocking rate and pasture x stocking rate are shown as effects of high stocking only. Low effect is of the same magnitude but + or - signs reversed.

Figure 8a

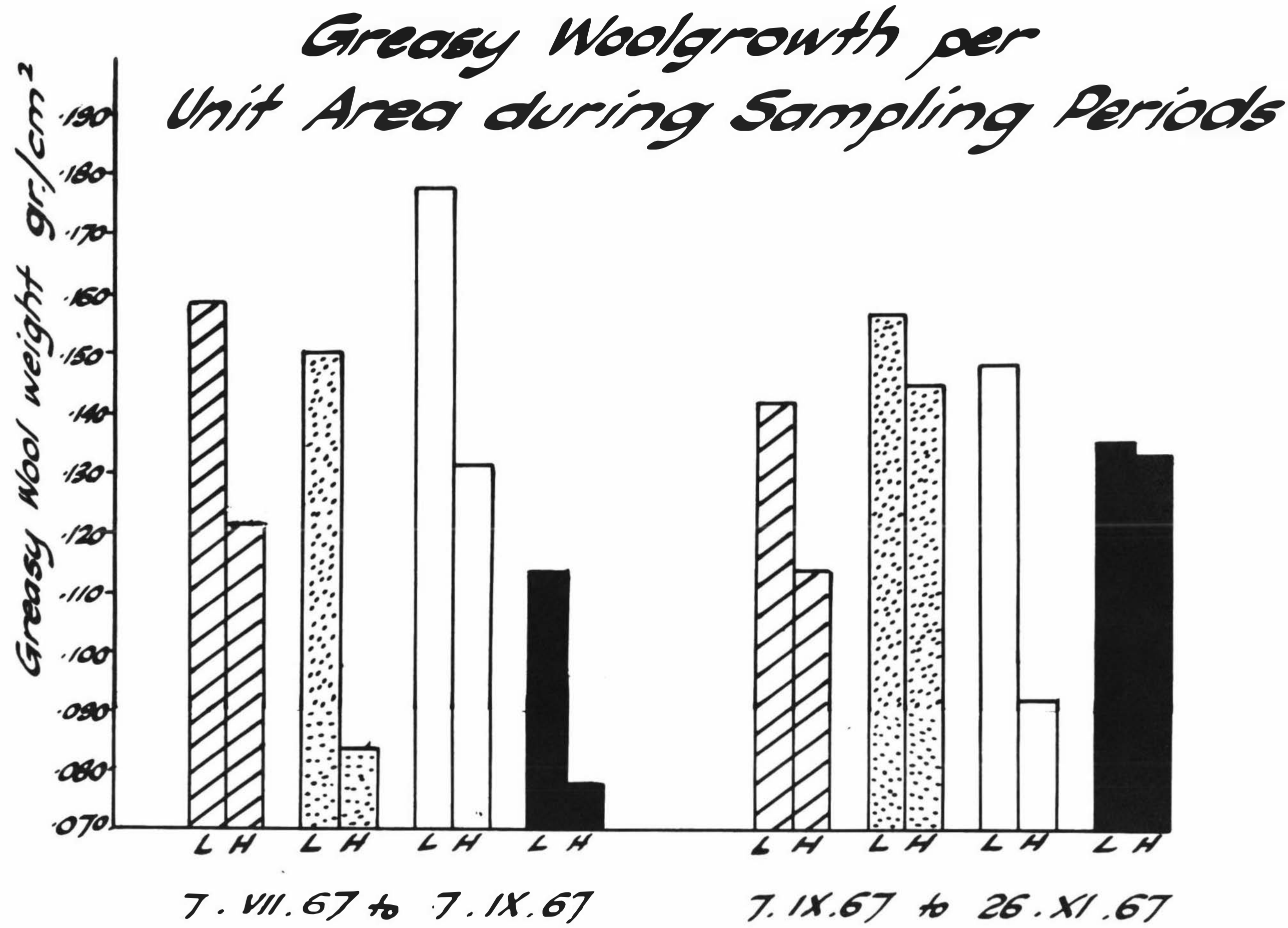
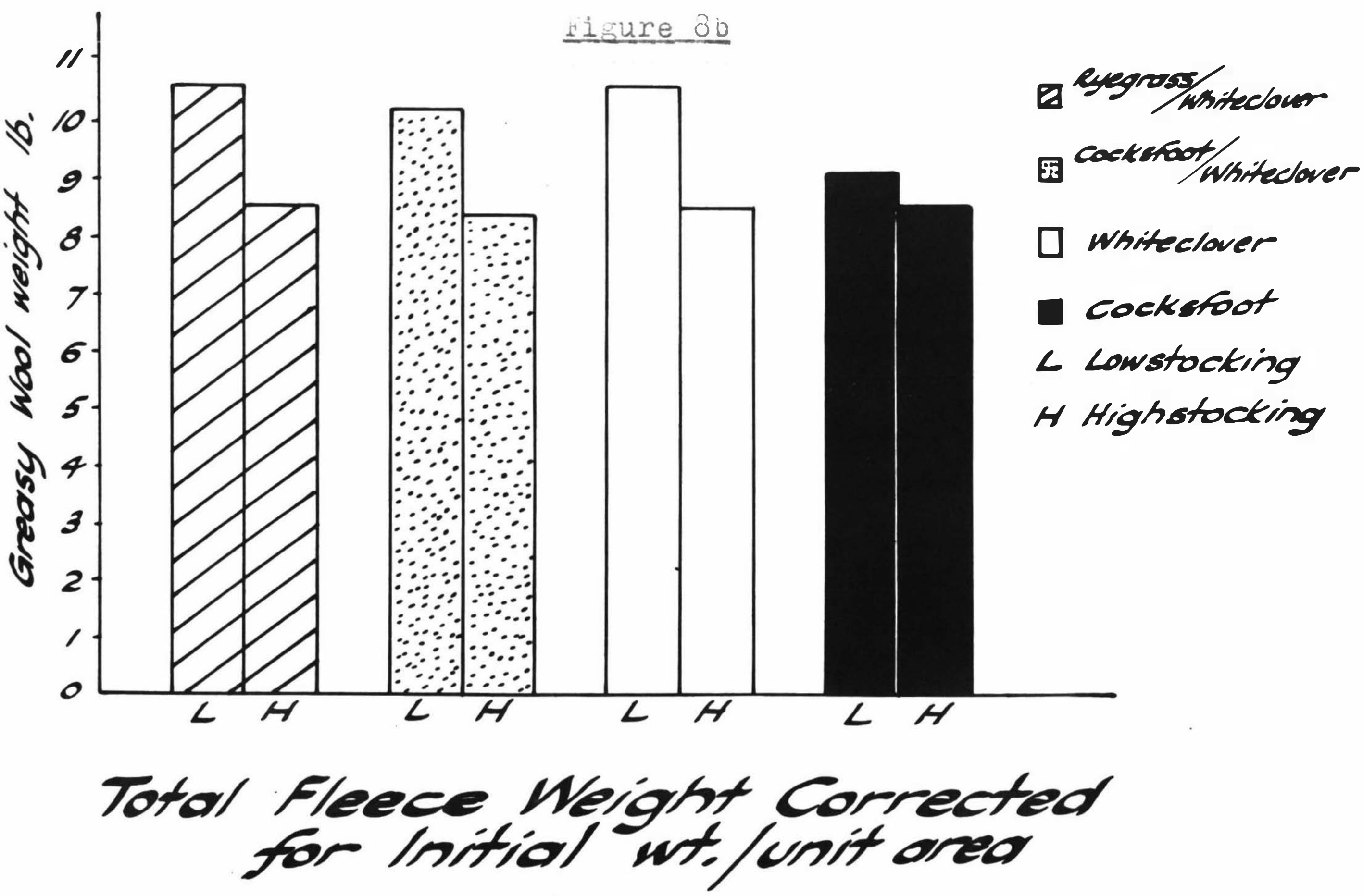


Figure 8b



Animals grazing cocksfoot pastures with and without clover had a lower wool growth rate during the first period under both stocking rates as compared with perennial rye grass/white clover and white clover pastures. During the second period both cocksfoot pastures under high stocking rate were superior to rye grass/white clover and white clover pastures.

Sheep at the low stocking rates grew significantly more ($p<0.01$) wool as compared with those grazing at the high stocking rate, in both periods, as is shown in the analysis of variance and covariance in Tables 10a and 10b. This effect was evident for all pastures treatments except for pure cocksfoot pasture in the second period, where differences were small as is shown in table of effect of factors (unadjusted and adjusted) on wool growth in Tables 11a and 11b.

Differences in greasy fleece weight tested by the analysis of covariance correcting for weight per unit area at the beginning of the experiment are presented in Table number 12 and figure 8b. The results showed that the fleece weight of animals grazing at low stocking rate were significantly superior ($p<0.01$) to those at high stocking rate, although differences between animals grazing cocksfoot pasture at low and high stocking rate were very small.

Differences in fleece weight between pasture type were small at high stocking rate. At low stocking rate the fleece weight of animals grazing perennial rye grass/white clover cocksfoot/white clover and white clover were consistently

TABLE 10a

Analysis of variance of

Weight of wool per sample and Weight per Unit area

Source of variance	Degrees of Freedom	Wool wt. per sample 8/6 M.S.	Wool wt. per sample 7/9 M.S.	Wool wt. per sample 26/11 M.S.	Wool wt. per unit area 8/6 M.S.	Wool wt. per unit area 7/9 M.S.	Wool wt. per unit area 26/11 M.S.
Pasture	3	37.45	308.47**	27.24	.0058	.0244**	0055**
Block	3	29.37	103.96**	1.41	.0019	.0051**	.0011
Stocking Rate	1	.02	1056.40**	369.18**	.0004	.0751**	.0166**
Pasture x Stocking Rate	3	5.35	41.49*	136.04**	.0014	.0022*	.0054**
Error	123	28.19	11.41	13.32	.0024	.0007	.0008
Total	133						

TABLE 10b

Analysis of covariance of weight of wool per sample and weight per unit area

adjusted for weight at the first sample

Source of variance	Degrees of Freedom	Wool wt. per sample 7/9 M.S.	Wool wt. per sample 26/11 M.S.	Wool wt. per unit area 7/9 M.S.	Wool wt. per unit area 26/11 M.S.
Pasture	3	256.20**	170.49**	.0104**	.0205**
Block	3	98.84**	131.80**	.0053**	0057**
Stocking Rate	1	1155.25**	789.49**	.0320**	0797**
Pasture x Stocking Rate	3	34.65**	131.06**	.0045**	0017*
Error	123	8.23	10.56	0007	0005
Total	133				

TABLE 11a

Estimate of effect of factors on unadjusted wool growth

	Wool weight per sample (gr)			Weight per unit area (gr/cm)		
	1st sample	2nd sample	3rd sample	1st sample	2nd sample	3rd sample
	8/6	7/9	26/11	8/6	7/9	26/11
General Mean	24.229	12.794	15.285	.261	.127	.134
Ba/Ac	.939	2.153	.555	.016	.017	.000
Bc/Ac	-.477	-1.361	957	.001	-.009	.017
Ac	.838	2.915	-.883	000	.027	-.014
Bc	-1.300	-3.707	-.629	-.017	-.035	-.003
Stocking rate	-.012	-2.819	-1.666	.002	-.024	-.011
Ba/Ac x Stocking Rate	.589	.988	.383	.002	006	.000
Bc/Ac x Stocking rate	-.190	-.661	.649	-.003	-.011	.004
Ac x Stocking rate	-.278	-1.226	-2.876	-.007	-001	-.017
Bc x Stocking rate	-.121	.899	1.844	.008	.006	.013

Stocking rate and pasture x stocking rate are shown as effects of high stocking rate only. Low effects are of the same magnitude but + or - signs reversed.

TABLE 11b

Estimates of effect of factors on adjusted wool growth

	Wool weight per sample (gr)		Weight per unit area (gr/cm)	
	7/9	26/11	7/9	26/11
General Mean	12.817	15.308	.127	.134
Ba/Ac	1.834	.257	.013	-.004
Bc/Ac	-1.200	1.108	-.009	.017
Ac	2.631	-1.149	.027	-.014
Bc	-3.265	-.217	-.031	.001
Stocking rate	-2.815	-1.663	-.024	-.012
Ba/Ac x Stocking rate	.788	.196	.006	-.001
Bc/Ac x Stocking rate	-.597	.708	-.010	.006
Ac x Stocking rate	-1.132	-2.787	.000	-.016
Bc x Stocking rate	.941	1.883	.004	.011

Stocking rate and pasture x stocking rate are shown as effects of high stocking only. Low effects are of the same magnitude but + or - signs reversed.

superior to pure cocksfoot pasture as is shown in Table 13 of estimates effects of factors on fleece weight.

7) Wool length Growth Rate

Estimation of monthly variation in wool length growth from measurement between dye bands of animals grazing at high and low stocking rate are shown in figures 9 and 10.

Wool length growth follows the classical seasonal curve of wool growth under both stocking rates. The minimum rate of growth occurred in July-August for all treatments except those high stocking rate animals grazing white clover pasture. For these animals the minimum was in September-October.

Wool length growth rate on animals grazing at the low stocking rate was superior to those grazing at high stocking rate during the June-early November period. During November differences were minimized and in the case of the pure stand of cocksfoot pasture better growth was attained at high stocking rate.

Low stocking rate animals grazing the white clover pasture and the grass/clover pastures showed better rate of wool growth throughout the whole experiment as compared with those animals on the pure cocksfoot stand. Under high stocking rate this pattern of wool growth occurs only in June and end of November. As the season progressed wool growth of animals grazing grasses with and without clover became superior to white clover, the differences being greater in October.

TABLE 12

Analysis of covariance of fleece weight adjusted for initial weight per unit area

Source of variation	Degrees of Freedom	Mean Squares
Pastures	3	9.89**
Blocks	3	7.03*
Stocking Rate	1	128.33**
Pasture x Stocking Rate	3	5.27
Error	124	2.44
Total	134	

TABLE 13

Estimates of effect of factors on adjusted fleece weight

General Mean	9.372
Ba/Ac	.339
Bc/Ac	-.011
Ac	.218
Bc	-.546
Stocking rate	-.338
Ba/Ac x Stocking rate	-.208
Bc/Ac x Stocking rate	-.144
Ac x Stocking rate	-.266
Bc x Stocking rate	.618

Stocking rate and pasture x stocking rate are shown as effects of high stocking only. Low effects are of the same magnitude but + or - signs reversed.

Figure 9

Monthly Variation in Wool Length Growth of Animals Grazing at Low Stocking Rate

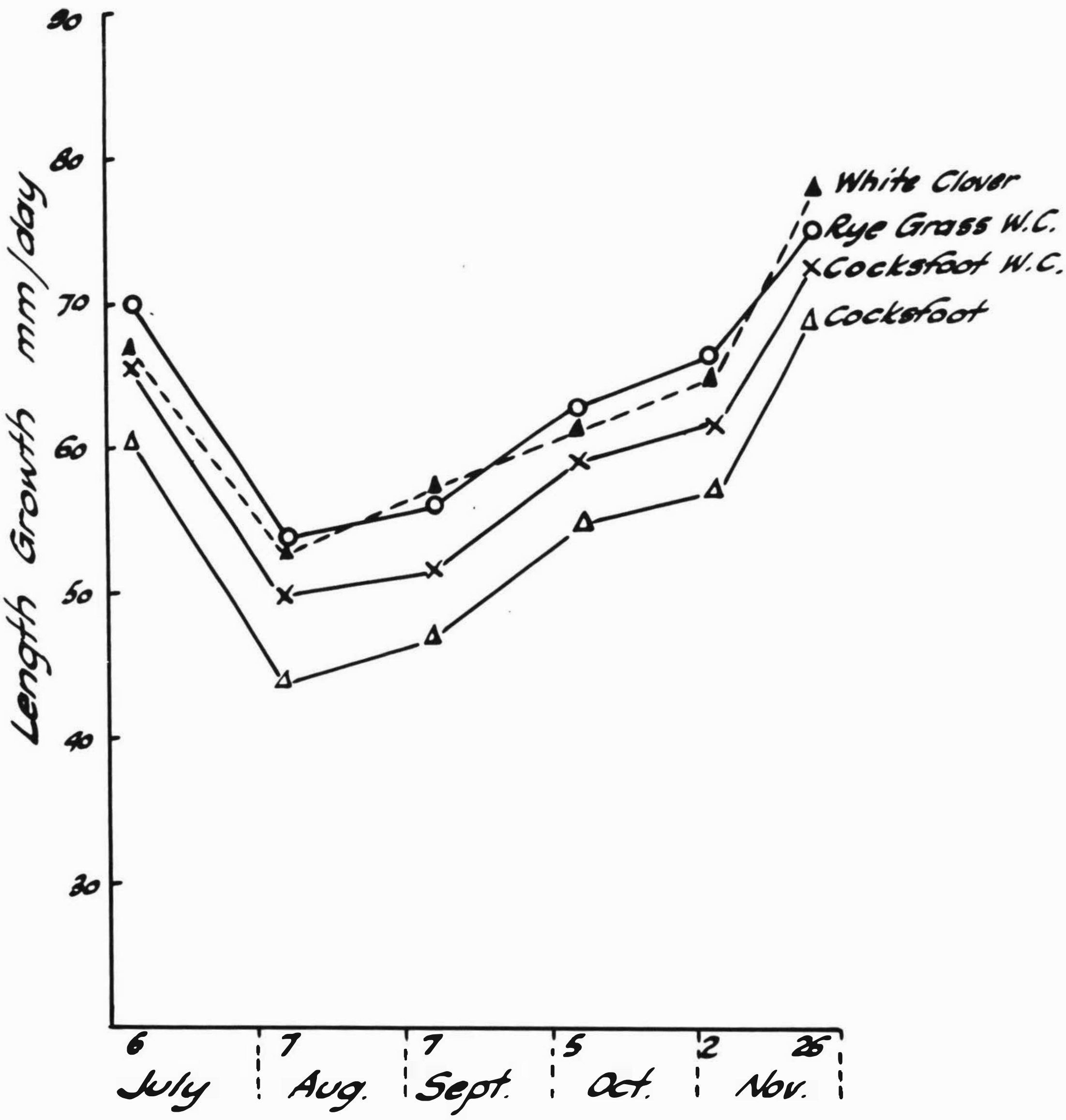
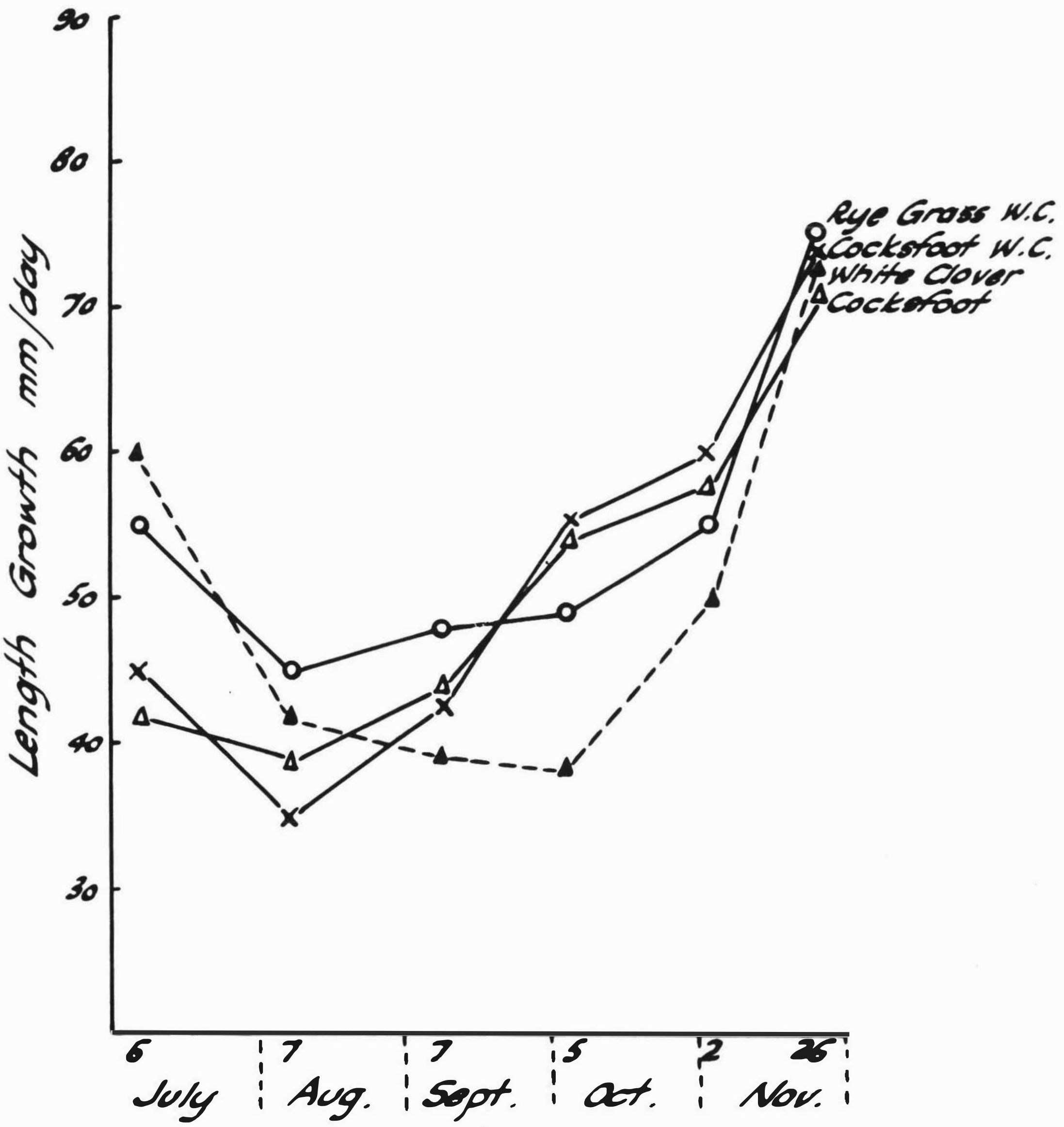


Figure 10

Monthly Variation in Wool Length Growth of Animals Grazing at High Stocking Rate



An interesting aspect is that the wool length growth rate of sheep grazing perennial rye grass/white clover pasture at the low stocking rate was always superior to that of the cocksfoot and clover and cocksfoot alone. However, at the high stocking rate the cocksfoot pastures were superior from late September to mid-November. This superiority of cocksfoot became minimal by the end of November.

8) Wool Characteristics

There was no significant difference in quality number, character, soundness, midside colour and midside cotting between pastures types. However, stocking rate had a marked effect upon all wool characteristics except for quality number, as is shown in analysis of variance in Table 14. Table of estimate of effect of factors on wool characteristics are presented in Table 15. For character, soundness and midside colour, differences reached a highly significant level ($P<0.01$) but for midside cotting differences were less significant ($P<0.05$).

Character, soundness and cotting were better on those animals grazing at the low stocking rate, while midside colour was better at the high stocking rate.

Stocking rate and pastures had significant ($P<0.01$) effects upon fleece colour. Discolouration of fleece was less on animals grazing at high stocking rate.

The area of fleece showing cotting was worse on animals

TABLE 14

Analysis of variance of wool characteristics

Source of variance	Degrees of Freedom	Midside Sample: Quality Number M.S.	Midside Sample: Character- M.S.	Midside Sample: Soundness M.S.	Midside Sample: Colour M.S.	Midside Sample: Cotting M.S.	Fleece: Colour M.S.	Fleece: Cotted area M.S.
Pasture	3	.57	.26	2.18	1.40	.20	2.74	.91
Block	3	4.92*	1.19	1.76	1.78	3.23*	1.40*	2.4
Stocking Rate	1	1.25	3.71**	65.10**	8.23**	3.53*	2.35*	.35
Pasture x Stocking rate	3	4.77*	.54	7.45	2.37	.63	1.26	6.31*
Error	124	1.32	.61	5.20	.95	.76	.75	1.77
Total	134							

TABLE 15

Estimates of effects of factors on wool characteristics

	Midside Sample					Fleece	
	Quality Number	Character	Soundness	Colour	Cotting	Colour	Cotted Area
General Mean	48.22	4.59	6.73	6.59	5.21	6.18	6.13
Ba/Ac	.13	.06	.09	.10	.10	.35	.23
Bc/Ac	-.04	-.02	-.17	-.25	.02	-.17	-.00
Ac	.08	.08	.32	.21	-.06	.12	-.11
Bc	-.17	-.12	-.24	-.06	-.06	-.30	-.12
Stocking rate	.09	-.26	-.69	.25	-.16	.14	-.05
Ba/Ac x Stocking rate	.56	.13	.61	-.11	.10	.27	.63
Bc/Ac x Stocking rate	-.23	-.17	-.42	.21	-.17	.00	-.42
Ac x Stocking rate	-.17	-.00	.12	-.32	-.05	-.08	-.12
Bc x Stocking rate	-.16	.05	-.31	.22	.12	-.19	-.19

Stocking rate and pasture x stocking rate are shown as effects of high stocking rate only. Low stocking effects are of the same magnitude but + or - signs reversed.

grazing white clover, cocksfoot/white clover and cocksfoot pasture at high stocking rate. This effect of stocking rate in cotted area was not shown in perennial rye grass/white clover where higher scores were obtained at the high stocking rate.

V. DISCUSSION

Total and seasonal production of dry matter from the different pastures followed the same trend for all pasture types at both stocking rates, with minimum production in Winter and maximum production towards the end of Spring. Under low stocking rate grasses with and without clover were superior to pure white clover throughout the whole experiment. These results are in agreement with those of Sears (1953) and Brougham (1955).

Significant differences between grasses, with and without clover occurred in July and November. In July the pure cocksfoot pasture was superior to rye grass/white clover and cocksfoot/white clover. This might be due to the effect of the nitrogen applied to the pure cocksfoot pasture in May and the low nitrogen fixation on the mixed pastures at this time of the year (Gibson 1963). Rye grass/white clover were superior to cocksfoot pastures in November. This superiority displayed by the rye grass/white clover pastures, which started early in the season may be attributed to the differences in tiller number and growth of rye grass, as compared with cocksfoot (Mitchell 1956). Furthermore, as the season progressed, and pasture production increased, a marked pattern of patch-grazing was noticeable in all pastures. This characteristic was most evident on the cocksfoot pastures, where only 30% (approximately) of the plots was grazed. Visual assessment of the ungrazed patches, showed an accumulation of senescent and dead material to a greater extent in the cocksfoot pastures than in the rye grass/white clover pastures. This accumulation of senescent and dead material might have been responsible for the low growth of the cocksfoot pastures (Mitchell, 1954; Hunt and Brougham, 1967) towards the end of the experiment.

The nitrogen fertilizer applied to the pure cocksfoot pasture in August in order to maintain a pure stand, appeared to match the nitrogen contribution from the clover on the cocksfoot/white clover pasture and thereby resulted in a similar pattern of growth up to the beginning of November. Thereafter the proportion of clover in the cocksfoot/white clover pastures tended to decrease, due presumably to selective grazing and competition for light. As a result the nitrogen contribution from the legume probably declined and lead, as recorded, to a lower availability of pasture towards the end of the period compared with the pure cocksfoot stand receiving nitrogen. This poorer growth rate of the cocksfoot/white clover pasture and the higher growth rate of pure white clover pastures at the end of the trial probably explains the non significant difference recorded between these two pasture types.

Under high stocking rate, dry matter production of the different pastures was much more variable than under low stocking rate. This obviously reflected the differing ability of these pastures species to withstand the high grazing pressure. For example grasses with and without clover were significantly superior to white clover during Winter (June-September) except for rye grass/white clover in August. Apparently white clover alone was unable to withstand the total environmental impact and virtually "collapsed" as a viable pasture. Although rye grass/white clover pasture showed a better growth from June onwards, cocksfoot pastures appeared to be less depressed in terms of dry matter available up to the end of August. This may be attributed to the high percentage of dead matter present in the total dry matter on the cocksfoot pastures (Table 6). From September to the end of the experiment the rye grass/white clover treatment, under both stocking rates showed greater production than the cocksfoot pastures. On the other hand although cocksfoot pastures started to grow earlier than the white clover pasture, they did not maintain their superiority over the white clover to the same extent as in the winter period. This higher growth rate of white clover, in late Spring and early Summer, compared with the grasses, is probably due to the better temperature conditions for white clover growth at this time and better utilisation of light energy when compared with the poorly-grazed stand of cocksfoot containing excessive dead and senescent herbage.

Under high stocking rate the effect of artificial nitrogen on the cocksfoot treatment was not as evident as in low stocking rate, especially from October to the end of the experiment, when compared with the growth of the cocksfoot/white clover pasture. This might be due to the effect of the high grazing pressure, which in cocksfoot/white clover diminished the competition for light between cocksfoot and clover and hence allowed better growth of the clover with higher nitrogen fixation.

The effect of stocking rate on pasture production was observed in both pasture availability and pasture growth. The significant difference in total dry matter available in favour of low stocking rate is simply a reflection of differences in grazing pressure between the two groups. In the case of white clover, the non significant difference between stocking rate during the September October period is considered to be due to two possibilities. Either the productivity of white clover, shortly after the Winter stress, was hardly sufficient to meet the demands of the animals even at the low stocking rate (6 sheep/acre) or there was a temporary check to white clover growth caused by the application of weed killer in early August particularly at the low stocking rate, where clover was leafier than in high stocking rate. The effect of stocking rate on pasture growth was more noticeable during Spring, where low stocking rate pasture had better growth. This effect was most evident on rye grass/white clover and pure white clover pasture.

There was a marked variation in live weight response to the different pastures. This variation became greater as the trial progressed.

The analysis of variance showed that animals grazing white clover pastures reached a greater live weight than animals grazing the other pastures, followed by rye grass/white clover, cocksfoot/white clover and cocksfoot. This superiority of white clover pastures over grasses plus clover and pure grass has been demonstrated before (Rae *et al.*, 1963; Hight and Sinclair, 1965; Wilson, 1966; Gallagher *et al.*, 1966). These results were more evident in animals grazing at low stocking rate, where pasture availability was not a limiting factor at any time of the experimental period.

Possible mechanisms which may be involved in the higher live weight gain of sheep grazing dominant white clover or mixed grass-white clover than those grazing pure grasses were suggested by Johns *et al.* (1963), Bailey (1964), Ulyatt, (1964) and Joyce and Newth (1967). It has been suggested that the higher nutritive value of white clover in contrast to grasses could be explained by an effect on voluntary intake, associated with changes in fermentation rate, carbohydrate content, and the utilisation of nitrogen and volatile fatty acids. Higher food intakes on grass plus clover pastures than on grass only pastures was found by Grimes (1966) and Grimes *et al.* (1966) reported that this higher intake, which promotes higher live weight gain, was associated with higher crude protein and lower cellulose contents. Under high stocking rate, seasonal changes in live weight were greater due mainly to large losses during Winter when pasture availability was low. However, losses in live weight were not always closely related with total pasture availability.

A better relationship of live weight to green pasture available than to total pasture available was found by Willoughby

(1959). Although these relationships were not determined in this experiment it is likely that the amount of green pasture present was the cause of the losses in live weight by animals grazing cocksfoot pastures as compared with rye grass/white clover during July August period. Cocksfoot pastures during this period, had a greater percentage of dead matter in the total dry matter available as compared with rye grass/white clover pasture. This effect was more noticeable in the pure cocksfoot pasture which contained 30% of dead matter in the total dry matter available, in the early part of the experiment.

The fact that animals grazing white clover pastures under high stocking rate did not start to gain weight until October, meant that these animals showed lighter final live weight. In this case changes in live weight gain were more clearly related to pasture availability.

From June to November differences in live weight gain between stocking rate were in favour of sheep grazing at low stocking rate in all pastures except for pure cocksfoot. On cocksfoot the high stocking rate was superior from September onwards.

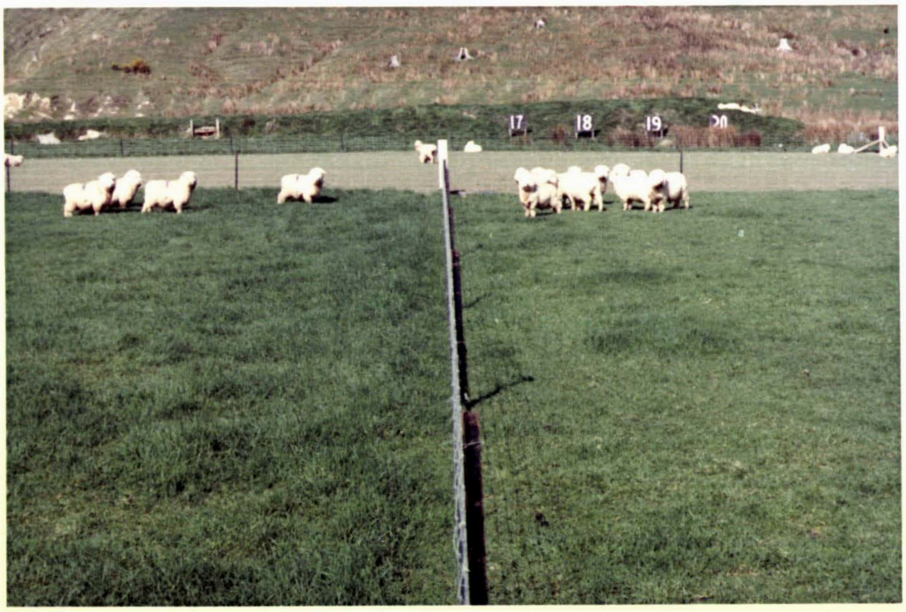
During this period great differences in pasture availability occur. (Plates 9 and 10). It has been suggested (Arnold, 1964) that as the amount of herbage on offer decreased, grazing time and energy expended on grazing probably increased so that although intake might be maintained or increased, the maintenance requirement of the animals increased. These

PLATE 9

View of two high stocking rate treatments.
Left, white clover; right, cocksfoot.

(August 1967)

PLATE 10



View of cocksfoot pastures.
Left, low stocking rate; right, high stocking rate.

(August 1967)

effects might be more evident in Winter and may be the causes of difference in live weight.

As the season progressed, an increase of senescent and dead material was noticeable on the low stocking rate paddocks especially in the cocksfoot pasture. Old and dead material has been associated with a decline in nutritive value (Waite, Johnston and Armstrong, 1964; Heanay, Pigden, Pritchard, 1966) and may limit voluntary intake (Arnold, 1962). On the other hand under high stocking rate the heavy grazing pressure over the pasture, maintained the pasture in green and leafy condition which has been associated with high nutritive value (Raymond, 1959; Reid, 1959) and increased voluntary intake. This might account for the superiority in live weight gain of the animals grazing cocksfoot from September onwards which meant that final live weights were almost the same as those at low stocking rate. The same trend occurred in cocksfoot/white clover pastures from the end of October and for rye grass/white clover pastures by the end of November but to a lesser extent than in pure cocksfoot pastures.

Total greasy wool growth ranked in the same order as final live weight under low stocking rate. Under high stocking rate differences in final live weight of animals grazing grasses and grass - clover pastures were small and the ranking of wool growth and live weight differed. This may be expected in view of the observations of Williams and Schinckel (1962) that live weight and wool growth do not respond at the same rate to change in the nutritional status.

Sheep grazing pure white clover, rye grass/white clover and cocksfoot/white clover pastures grew significantly (P 0.01) more wool than those animals grazing pure cocksfoot. These differences were not evident at high stocking rate. Similar results were also found by Gallagher et al. (1966) when pasture availability was not a limiting factor.

Wool production was significantly greater (P 0.01) at the low stocking rate. The differences might be attributed to differences in pasture availability. This effect was more evident in the white clover pasture.

Seasonal variation in wool growth as measured by greasy weight of the midside sample were less on animals grazing at low stocking rate. This agrees with results of Sumner (1969).

Seasonal variation in wool growth on animals grazing at low stocking rate vary between pasture types. Variation in seasonal wool growth may arise from variation in the amount of food eaten, the nutritive value of the food and digestive and absorptive efficiency (Schinckel, 1960). McFarlane (1965) found a relation between seasonal wool growth and available green feed. In the present experiment, it is considered unlikely that green pasture availability resulting in limited intake was a factor in causing differences in the seasonal variation in wool growth between pastures at low stocking rate. However it is possible that differences in digestibility between pastures might be present. Thus cocksfoot pastures have been found (Kingsbury, 1965) to have poorer digestibility than rye grass especially during Winter. This may account for a reduction in voluntary intake (Blaxter et al. 1961) of animals grazing these pastures. Joyce and Newth (1967) on the other hand found that sheep fed with white clover ate 34% more crude protein and gross energy than sheep fed with perennial rye grass. Wool production was greater in animals fed with white clover as compared with those fed with perennial rye grass.

Differences in seasonal wool growth between cocksfoot pastures, with and without clover, may be attributed to the presence of clover in the cocksfoot/white clover pasture.

At the high stocking rate seasonal fluctuation was greater where sheep were subjected to extremes of good and poor nutrition i.e. for sheep grazing white clover pastures.

Although the differences in length growth measured by the dye-banding technique were similar to results determined by weight of wool, the accuracy of this technique is limited.

The dye did not have the same effect in all types of wool. In general the coarser wools did not stain well which made them very difficult to measure. The differences in fibre growth rate within the staple, and differences in crimp between sheep meant that measurements were difficult to compare. For these reasons the results were not statistically analysed. However with finer wools, particularly when differences in quality number between animals are not great this technique could be useful as is shown in plates 11 and 12.

Stocking rate was the main effect on wool characteristics. The differences in soundness in favour of low stocking rate fleeces may be attributed to differences in nutrition in the Winter period which reduced fibre diameter (Coop, 1953; Arnold et al., 1964; Sumner, 1969).

The high stocking rate did not affect midside cotting to the same extent as it did the other characters. Differences in scores for the cotted area between high and low stocking rate fleeces did not reach significance. This lack of significance can be attributed to the better scores obtained on animals grazing rye grass/white clover at high stocking rate. This would also explain the significant pasture and stocking rate interaction.

The better scores for colour at the high stocking rate are probably attributable to the length of the pastures wetting the fleeces.

The highly significant depressing effect of the high stocking rate on character is surprising since this is usually considered to be a characteristic largely determined by "hereditary" factors.

The significant block effect on quality number defies explanation and is probably the result of an accident in randomisation.

PLATE 11

3 month wool growth.
Animal grazing cocksfoot high stocking rate.

(September 1967)

PLATE 12

3 month wool growth.
Animal grazing white clover high stocking rate.

(September 1967)

VI. SUMMARY

In a randomised block experiment with four blocks, rye grass/white clover, cocksfoot/white clover, cocksfoot and white clover pastures grazed at two stocking rates (low - 6 sheep/acre and high - 13.5 sheep/acre) were compared in terms of pasture availability, pasture growth and changes in botanical composition. The live weight gain and wool production of Romney hoggets grazing these pastures was also measured.

Pasture production, measured as pasture availability and growth, of grasses with and without clover was significantly ($p<0.05$) greater than pure white clover under the low stocking rate except for cocksfoot/white clover pasture at the end of Spring. Under high stocking rate differences over white clover were significant ($p<0.05$) during the Winter period and only rye grass/white clover was superior to white clover towards the end of Spring.

Cocksfoot pastures produced slightly more than rye grass/white clover during the Winter period and rye grass/white clover was superior to the cocksfoot pasture during Spring under both stocking rates.

Total pasture production was significantly ($p<0.01$) higher under low stocking rate for all pastures except for white clover pastures over the September-October period.

The grass component of the mixed pastures increased progressively through the experimental period. Dead matter

accumulation was considerable under low stocked cocksfoot/white clover and cocksfoot pastures while it remained at a lower level for other pasture types irrespective of stocking rate. Invasion by weeds was highest in clover pastures especially under high stocking rate.

Live weight gain and wool production of animals grazing at the low stocking rate were greater in those animals grazing white clover followed by rye grass/white clover, cocksfoot/white clover and cocksfoot. Under high stocking rate, pasture effects on animal production were closely related to pasture availability.

Live weight growth and wool production were significantly ($p<0.01$) greater in animals grazing at the low stocking rate, for all pasture treatment except for pure cocksfoot pastures where differences in final live weight and total wool production were small.

Animals grazing pure cocksfoot pastures under high stocking rate had better live weight gains from early Spring towards the end of the experiment, as compared with animals grazing cocksfoot at low stocking rate. Sheep grazing cocksfoot/white clover pastures under high stocking rates had better live weight gain from October to the end of the experiment.

Seasonal variations in wool growth were more marked on animals grazing at the high stocking rate. Seasonal variations in wool growth on animals grazing at low stocking rate, were less in the white clover and rye grass/white clover pastures as compared with cocksfoot/white clover and cocksfoot pastures.

The fleeces from sheep grazing at low stocking rate showed least tenderness and cotting than those from sheep at a high stocking rate. The colour however on the fleeces from sheep at high stocking rate was better than those from the low stocking rate. The effect of pasture treatments on these characteristics of the fleece was negligible.

VII. REFERENCES

ALCOCK, M. B. (1964). The physiological significance of defoliation on the subsequent regrowth of grass-clover mixtures and cereals. In "Grazing in Terrestrial and Marine environment". p. 25. Ed. D. J. Crisp. Oxford, Blackwell.

APPADURAI, R. R. and HOLMES, W. (1964). The influence of stage of growth closeness of defoliation and moisture on the growth and productivity of a rye grass/white clover sward. J. agric. Sci., Camb., 62, 327.

ARNOLD, G. W. (1960). Selective grazing by sheep of two forage species at different stages of growth. Aust. J. agric. Res., 11, 1026.

_____ (1962). Effects of pasture maturity on the diet of sheep. Aust. J. agric. Res., 13, 701.

_____ (1964). Factors within plant associations affecting the behaviour and performance of grazing animals. In "Grazing in Terrestrial and Marine environment". p. 133. Ed. D. J. Crisp. Oxford, Blackwell.

_____ and McMANUS, W. B. (1960). The effect of level of stocking on two pasture types upon wool production and quality. Proc. Aust. Soc. Anim. Prod., 3, 63.

_____, McMANUS, W. R. and BUSH, J. G. (1964). Studies in the wool production of grazing sheep. I - Seasonal variation in feed intake live weight and wool production. Aust. J. exp. Agric. Anim. Husb., 4, 392.

ASLOW, R. C. (1965). Grass growth in midsummer. J. Br. Grassld. Soc., 20, 19.

AUDA, H., BLASER, R. E. and BROWN, R. H. Tillering and carbohydrate contents of orchard grass as influenced by environmental factors. Crop. Sci. 1966, 6, 139.

BAILEY, R. W. (1964). Pasture quality and rumiant nutrition. I - Carbohydrate composition of rye grass varieties grown as sheep pastures. N. Z. Jl. agric. Res., 7, 496.

BENNETT, S. W., HUTCHINSON, J. D., and WODZICKA-TOMASZEWSKA, M., Annual rhythm of wool growth. Nature, Lond. (1962)., 194, p. 651.

BERNARDON, A. E., HUSS, D. L. and McGULLY, W. G. (1967). Effects of herbage removal on seedling development in cane Bluestem. J. Range Mgmt., 29, 69.

BOWSTEAD, G. E. and LAROSE, P. (1938). Wool growth and quality as affected by certain nutritional and climatic changes. Canad. J. Res., 16D, 361.

BROUGHAM, R. W. (1955). A study in rate of pasture growth. Aust. J. agric. Res., 6, 804.

_____ (1956). Effect of intensity of defoliation on regrowth of pasture. Aust. J. agric. Res., 7, 377.

_____ (1958). Interception of light by the foliage of pure and mixed stands of pasture plants. Aust. J. agric. Res., 9, 39.

_____ (1959). The effects of frequency and intensity of grazing on the productivity of a pasture of short-rotation rye grass and red and white clover. N. Z. Jl. agric. Res., 2, 1232.

BROWN, K. R. (1968). The influence of herbage height at treading and treading intensity on the yield and botanical composition of a perennial rye grass white clover pasture. N. Z. Jl. agric. Res., 11, 131.

BROWN, R. H. and BLASER, R. E. (1968). Regrowth following defoliation. Herb. Abstr., 38, 1.

BRYANT, M. P. and ROBINSON, I. M. (1959). Observations on the nutrition of bacteroides succinoges. a - ruminal cellulolytic bacterium. J. Dairy Sci., 42, 1831.

BURGER, A. W., JACKOBS, J. A. and HITTLE, C. N. (1958). The effect of height and frequency of cutting on the yield and botanical composition of tall fescue and smooth dromegrass mixtures. Agron. J., 50, 629.

_____ (1962). The effect of height and frequency of cutting on the yield and botanical composition of smooth dromegrass and orchard grass mixtures. Agron. J., 54, 23.

BURNS, R. H. (1931a). Monthly wool growth of Ramboullet ewes. J. Text Inst., 22, T 98.

_____ (1931b). Monthly wool growth studies. II(a) Hampshire Down ewes Corriedale ewes. J. Text Inst., 22, T 456.

BUTTERFIELD, R. M. (1966b). The effect of nutritional stress and recovery on the body composition of cattle. Res. vet. Sci., 7, 168.

CALLOW, E. H. (1947). Comparative studies of meat. I. The quimical composition of fatty and muscular tissue in relation to growth and fattening. J. agric. Sci., Camb., 37, 113.

CAMPBELL, A. G. (1964). Grazed pasture parameters dead herbage, net gain and utilisation of pasture. Proc. N. Z. Soc. anim. Prod., Vol. 24., p. 131.

_____ (1966). Effects of treading by dairy cows on pasture production and botanical structure on Te Kowhai soil. N. Z. Jl. agric. Res., 9, 1009.

CHAPMAN, R. E. and WHEELER, J. L. (1963). Dye-Banding: A technique for Fleece Growth Studies. Aust. J. Sci., Vol. 26, p. 53.

CHILD, C. M. (1920). Cited Hammond, 1944. Biol. Bull Wood's Hole, 39, 147.

COLLIN, R. H. (1966). Results from Tangoio and Waerenga-o-Kuri. Sheep fmg. A. 1966. p. 7.

COOP, I. E. (1953). Wool growth as affected by nutrition and by climatic factors. J. agric. Sci., Camb., 43, 456.

_____ and HART, D. S. (1953). Environmental factors affecting wool growth. Proc. N. Z. Soc. Anim. Prod., 13, 113.

COOPER, J. P. (1960). Selection for production characters in rye grass. Proc. 8th Int. Grassld. Congr., 41.

_____ and SEED, S. W. (1949). Studies on growth and development in lolium. I. Relation of the annual habit to head production under various systems of cutting. J. Ecol., 37, 233.

COWLISHAW, S. J. and ALDER, F. E. (1960). The grazing preferences of cattle and sheep. J. agric. Sci., Camb., 54, 257.

DAVIDSON, R. L. (1964). Theoretical aspects of nitrogen economy in grazing experiments. J. Br. Grassld. Soc., 19, 273.

DAVIES, H. L. (1962). Studies of time of Lambing in relation to stocking rate in South-western Australia. Proc. Aust. Soc. Anim. Prod., 4, 113.

DAVIES, J. J. (1954). A note on pasture management. In "Grazing Management". C.S.I.R.O., B11, 201, 97.

DAVISON, J. L. and MILTHORPE, F. L. (1966). Effect of Defoliation on the Carbon Balance in Dactylis glomerata. Ann. Bot., 30, 185.

DONALD, C. M. and BLACK, J. N. (1958). The significance of leaf area in pasture growth. Herb. Abstr., 28, 1.

DONALD, C. M. (1961). Competition for light in crops and pastures. XVth Symp. Soc. exp. Biol., 282.

DONEY, J. M. (1966). Breed differences in response of wool growth to annual nutritional and climatic cycles. J. agric. Sci., Camb., 67, 25.

DRAKE, F. R. and ELLIOTT, N. M. (1960). The production of wool per acre. J. Dep. Agric. Vict., 58, 645.

DUERDEN, J. E. and MARE, D. (1931). Rate of growth of Merino wool month by month. Fmg. S. Afr., 6, 103.

DUNCAN, D. B. (1955). Multiple Range and Multiple F tests. Biometrics, 11, 1.

EDMOND, D. B. (1958a). The influence of treading on pasture. A Preliminary Study. N. Z. Jl. agric. Res., 1, 319.

______ (1958b). Some effects of soil physical condition on rye grass growth. N. Z. Jl. agric. Res., 1, 652.

______ (1962). Effects of treading pasture in Summer under different soil moisture levels. N. Z. Jl. agric. Res., 5, 389.

______ (1963). Effect of treading perennial rye grass (Lolium perenne L.) and white clover (Trifolium repens L.) pastures in Winter and Summer at two soil moisture levels. N. Z. Jl. agric. Res., 6, 265.

______ (1964). Some effects of sheep treading on the regrowth of ten pasture species. N. Z. Jl. agric. Res., 7, 1.

EYLES, D. E., WILLIAMS, T. E. and GREEN, J. O. (1956). The influence of seasonal intensities of stocking on the live weight increase from a sward. Proc. Brit. Soc. Anim. Prod., 91.

FERGUSON, K. A. (1949). The effect of sympathectomy on wool growth. Aust. J. agric. Res., 2, 438.

FERGUSON, K. A. (1951). The effect of hypophysectomy on wool growth. J. Endocrin., 7, lxi.

_____ (1958). The influence of thyroxine on wool growth. Proc. N. Z. Soc. Anim. Prod., 18, 128.

_____ (1959). The influence of dietary protein percentage on growth of wool. Nature, Lond., 184, 907.

_____, CARTER, H. B. and HARDY, M. H. (1949). Studies of comparative fleece growth in sheep. I - The quantitative nature of inherent differences in wool-growth rate. Aust. J. Sci. Res., B2, 42.

_____, WALLACE, A. L. C. and LINDNER, H. R. (1965). Hormonal Regulation of Wool Growth. In the "Biology of the Skin and Hair Growth"., 655. Ed. A. G. Lyne and B. F. Short. Angus and Robertson, Sydney.

FRASER, A. H. H. and ROBERTS, J. A. F. (1933). Variation in the protein intake of sheep in relation to wool growth. J. agric. Sci., Camb., 23, 97.

_____ and NICHOLS, J. F. (1934). I - Wool growth in sheep as affected by the carbohydrate content of the diet. Emp. J. exp. Agric., 2, 9.

_____ (1935). II - Wool growth in sheep as affected by the carbohydrate content of the diet. Emp. J. exp. Agric., 3, 75.

GALLAGHER, J. R., WATKIN, B. R., and GRIMES, R. C. (1966). An Evaluation of pasture quality with young grazing sheep. I - Live weight growth and clean wool production. J. agric. Sci., Camb., 66, 107.

GIBSON, A. H. (1963). Physical environment and symbiotic nitrogen fixation. Aust. J. biol. Sci., 16, 28.

GRIMES, R. C. (1966). An estimate of the energy required for maintenance and live weight gain by young grazing sheep. J. Agr. Sci., Camb., 66, 211.

_____, WATKIN, B. R. and MAY, P. F. (1965). The botanical and chemical analysis of herbage samples obtained from sheep fitted with oesophageal fistulae. J. Bri. Grassld. Soc., 20, 168.

_____, WATKIN, B. R. and GALLAGHER, J. R. (1966). An Evaluation of pasture quality with young grazing sheep. II - Chemical composition, botanical composition and invitro digestibility in herbage selected by oesophageal fistulated sheep. J. agric. Sci., Camb. (1966)., 66, 113.

GRIMES, R. C., WATKIN, B. R. and GALLAGHER, J. R. (1967). The growth of lambs grazing on perennial rye grass, tall fescue and cocksfoot, with and without white clover, as related to the botanical and chemical composition of the pasture and pattern of fermentation in the rumen. J. agric. Sci., Camb., 1967., 68, 11.

HAMMOND, J. (1932). Growth and Development of Mutton Qualities in Sheep. Oliver and Boyd, Edinburgh.

_____ (1944). Physiological factors affecting Birth weight. Proc. Nutr. Soc., 2, 8.

HANSON, A. D., SPRAGUE, V. G. and MEYERS, W. M. (1952). Evaluation of Kentucky Bluegrass Strains grown in Association with White Clover. Agron. J. 1952., 44, 373.

HARDISON, W. A., REID, J. T., MARTIN, C. M. and WOOLFOCK. (1954). Degree of herbage selection by grazing cattle. J. Dairy Sci., 37, 89.

HART, D. S. (1955). The photoperiodic and hormones responses of wool growth in sheep. Proc. N.Z. Soc. Anim. Prod., 15, 57.

_____ (1961). The effect of light - dark sequences on wool growth. J. agric. Sci., Camb., 56, 235.

_____, BENNETT, J. W., HUTCHINSON, S. D. and WODZICKA-TOMASZEWSKA, M. (1963). Reversed photoperiodic seasons on wool growth. Nature, Lond., 198, 310.

HEANEY, D. P., PIGDEN, W. J. and PRITCHARD, G. I. (1966). Comparative energy availability for lambs of four timothy varieties at progressive growth stages. J. Anim. Sci., Camb., 25, 142.

HIGHT, G. K. and SINCLAIR, D. P. (1965). The Autumn Growth of Hoggets on different Pasture Types. N. Z. Jl. agric. Res., 8, 1079.

_____ (1967). Pasture length and species in relation to the Autumn growth of hoggets. N. Z. Jl. agric. Res., 10, 323.

HILDER, E. J. (1964). The distribution of plant nutrients by sheep at pasture. Proc. Aust. Soc. Anim. Prod., 5, 241.

_____ (1966). Rate of turnover of elements in soils. The effect of stocking rate. Wool Technol. Sheep Breed. XIII, 11.

HILDER, E. J. and MOTTERSHEAD, B. E. (1963). The redistribution of plant nutrients through free-grazing sheep. Aust. J. Sci., 26, 88.

HODGSON, J. (1966). The frequency of defoliation of Individual Tillers in a set-stocked Sward. J. Br. Grassld. Soc., 21, 258.

HOGAN, J. P. and WESTON, R. H. (1967). The digestion of two diets of differing protein content but with similar capacities to sustain wool growth. Aust. J. agric. Res., 18, 973.

HOLLIDAY, R. and WILDMAN, D. (1965). The effect of fertilizer nitrogen and frequency of defoliation on yield of grassland herbage. J. Br. Grassld. Soc., 20, 32.

HUMPHREYS, L. R. (1966). Pasture defoliation practices: A Review. J. Aust. Inst. agric. Sci., 32, 93.

HUNT, L. A. (1965). Some implications of death and decay in pasture production. J. Br. Grassld. Soc., 20, 27.

_____ and BROUGHAM, R. W. (1966). Some aspects of growth in an undefoliated stand of Italian rye grass. Jl. appl. Ecol. 1966., 3, 21.

_____ (1967). Some changes in the structure of a perennial rye grass sward frequently but leniently defoliated during Summer. N. Z. Jl. agric. Res., 10, 397.

HUNT, I. V. (1952). Resting Grassland for Greater Production. Scot. J. Agric., 32, 92.

HUTCHINSON, J. C. (1965). Photoperiodicity on wool growth. In the Biology of the Skin and Hair Growth., 565. Ed. A. G. Lyne and B. F. Short. Angus and Robertson, Sydney.

HUTCHINSON, J. D. and WODZICKA-TOMASZEWSKA, M. (1961). Climate physiology of Sheep. Anim. Breed. Abstr., 29, 1.

HUTCHINSON, K. T. and PORTER, R. B. (1958). Growth and wool production of Merino hoggets related to grazing intake in South Aust. Environments. Proc. Aust. Soc. Anim. Prod., 2, 33.

JACKOBS, J. A. (1950). The influence of Spring-clipping, Interval between cuttings and Date of last Cutting on Alfalfa Yields in the Yakima Valley. Agron. J., 42, 594.

J[illegible], A. and [illegible], I. J. (1956). Regrowth of pastures in relation to soil moisture and defoliation. Proc. 7th Int. Grassld. Congr., 33.

JONES, [illegible], [illegible] and [illegible], A. C. (1963). Pasture type in relation to live weight gain, carcass composition, iodine nutrition and some rumen characteristic of sheep. J. agric. Sci., Camb., 61, 201.

JONES, M. (1933). Grassland management and its influence on the sward. Pt. II The management of a clovery sward and its effects. Emp. J. exp. Agric. I, 122.

JOUBERT, D. M. (1956). Problems of Quality in Meat. Col. Plant and Animal Prod., 6, 79.

JOYCE, J. P. and NEWTH, R. P. (1967). Use of the comparative slaughter technique to estimate the nutritive value of pasture for hoggets. Proc. N. Z. Soc. Anim. Prod., Vol. 27., 166.

KENNEDY, W. K. (1950). Simulated grazing treatment. Effect on yield, botanical composition and chemical composition of a permanent pasture. Mem. Cornell Univ. agric. Exp. Stn., 295.

K[illegible]SBURY, L. R. (1965). Pasture quality in terms of soluble carbohydrates and volatile fatty acid production. Proc. N. Z. Soc. Animal. Prod., 25, 119.

KIRTON, A. H. and BARTON, R. A. (1958a). Live weight loss and its components in Romney ewes subjected to L-Thyroxine therapy and a low plane of nutrition. I - Effects on live weight, carcass weight and carcass composition. J. agric. Sci., Camb., 51, 265.

______ and C[illegible]SSWELL, E. (1959b). A note on a comparison between the carcass composition of Romney Marsh and Cheviot mature ewes. N. Z. Jl. agric. Res., 2, 252.

KYDD, D. D. (1966). The effect of intensive sheep stocking over a five-year period on the development and production of the sward. I - Sward structure and botanical composition. II - The Yield and quality of dry matter. III - Ecological discussion. J. Br. Grassld. Soc., 21, 284.

LAMBOURNE, J. L. (1956). A comparison between rotational grazing and set stocking for fat lamb production. N. Z. Jl. Sci. Technol., A37, 555.

LAMBOURNE, J. L. (1964). Stimulation of wool growth by thyroxine implantation. Aust. J. agric. Res., 15, 657.

LANGER, R. H. M. (1959). A study of growth in swards of timothy and meadow fescue. II - The effects of cotting treatment. J. agric. Sci., Camb., 52, 273.

_____ and STEINKE, T. D. (1965). Growth of lucerne in response to height and frequency of defoliation. J. agric. Sci., Camb., 64, 291.

LAZENBY, A. and ROGER, H. H. (1965). Selection criteria in grass breeding. VI - Effect of defoliation on plant growing in small plots in field and controlled environmental conditions. J. agric. Sci., Camb., 65, 397.

LEVY, E. Bruce. (1945). In "The establishment and early management of sown pastures". CA.B. Bull., 34, 97.

LINDNER, H. R. (1959). Blood cortisol in the sheep: normal concentration and changes in ketosis of pregnancy. Nature, Lond., 184, 1645.

_____ (1964). Comparative aspects of cortisol transport. Lack of firm binding to plasma proteins in domestic ruminants. J. Endocrin., 28, 301.

_____ and FERGUSON, K. A. (1956). Influence of the adrenal cortex on wool growth and its relation to breaks and tenderness of the fleece. Nature, Lond., 177, 188.

MARSHALL, C. and SAGAR, G. R. (1965). The influence of defoliation on the distribution of assimilates in Lolium Multiflorum Lam. Ann. Bot., 29, 365.

MARSTON, H. R. (1932). Studies in the supplementary feeding of Merino sheep for wool production. Cited Schinckel (1963). Proc. World Conf. Anim. Prod., Vol I., 199.

_____ (1937). The nutritive value of pastures for wool production. Proc. 4th Int. Grassld. Congr., 26.

_____ (1948). Nutritional factors involved in wool production by Merino sheep. I - The influence of fodder intake on the rate of wool growth. Aust. J. Scient. Res., B1, 362.

_____ (1955). In "Progress in the physiology of farm animals". Vol. 2, 543. Ed. J. Hammond. Butterworth Scientific Publications, London.

MAY, L. H. (1960). The utilisation of carbohydrate reserves in pastures plants after defoliation. Herb. Abstr., 30, 239.

MAY, L. H. and DAVIDSON, J. L. (1958). The role of carbohydrate reserves in regeneration of plants. I - Carbohydrate changes in subterranean clover following defoliation. Aust. J. agric. Res., 9, 767.

MAYNARD, L. A. and LOOSLI, I. (1955). Animal Nutrition. McGraw-Hill Book Co., New York.

McDONALD, I. W. (1948). The absorption of ammonia from the rumen of the sheep. Biochem. J., 42, 584.

_____ (1952). The role of ammonia in ruminal digestion of protein. Biochem. J., 51, 86.

_____ (1962). Nitrogen metabolism in the rumen. Proc. N. Z. Soc. Anim. Prod., 22, 79.

McFARLANE, J. D. (1965). The influence of seasonal pasture production and grazing management on seasonal wool growth. Aust. J. exp. Agric. Anim. Husb., 5, 252.

McLEAN, J. W., THOMSON, G. G., IVERSEN, C. E., JAGUSCH, K. T. and LOWSON, B. M. (1962). Sheep production and health on pure species pasture. Proc. N. Z. Grassld. Ass., 24, 57.

McLEAN, J. W., THOMSON, G. G., JAGUSCH, K. T. and LOWSON, B. M. (1965). Lamb growth and development in relation to pasture species. Proc. Ruakura Fmr's conf. week 1965.

McMANUS, W. R., ARNOLD, and PAYNTER, J. R. (1964). Studies in the wool production of grazing sheep. 2 - Variation in wool characteristics with season and stocking rate. Aust. J. exp. Agric. Anim. Husb., 4, 404.

McMEEKAN, C. P. (1940). Growth and development in the pig, with special reference to carcass quality characters. II - The influence of the plane of nutrition on growth and development., 387.

MILFORD, R. and MINSON, D. J. (1966). The energy retention of lambs grazing S37 cocksfoot, S23 rye grass and S24 rye grass at low grazing pressure. J. Br. Grassld. Soc., 21, 7.

MILTON, W. E. J. (1953). The palatability of herbage on undeveloped grasslands in West-central Wales. Emp. J. exp. Agric., 21, 116.

MITCHELL, K. J. (1955). Growth of pasture species. 2 - Perennial rye grass (Lolium perenne) cocksfoot (Dactylis glomerata) and paspalum (Paspalum dilatatum)., N. Z. Jl. Sci. Technol., A37, 3.

MITCHELL, K. J. and COLES, S. T. J. (1955). Effects of defoliation and shading on short rotation rye grass. N. Z. Jl. Sci. Technol., A36, 586.

MORRIS, L. R. (1961). Photoperiodicity of seasonal rhythm of wool growth in sheep. Nature, Lond., 190, 102.

MOULTON, C. R. (1923). Age and chemical development in mammals. J. biol. Chem., 57, 79.

PALSSON, H. (1955). In Progress in the physiology of farm animals. Vol. 2. London: Butterworths.

_____ and VERGES, J. B. (1952). Plane of nutrition on growth and development of carcass quality in lambs. P.I and II. J. agric. Sci., Camb., Vol. 42, 1.

PETERSEN, R. G., WOODHOUSE, W. W. and LUCAS, H. L. (1956). The distribution of excreta by freely grazing cattle and its effect on pasture fertility. Agron. J., 48, 444.

RAE, A. L., BROUGHAM, R. W., GLENDAY, A. C. and BUTLER, G. W. (1963). Pasture type in relation to live weight gain, carcass composition, iodine nutrition and some rumen characteristics of sheep. J. agric. Sci., Camb., 61.

RAE, A. L., BROUGHAM, R. W. and BARTON, R. A. (1964). A note on live weight gains of sheep grazing different rye grass pastures. N. Z. Jl. agric. Res., 7, 491.

REID, D. (1959). Studies on the cutting management of grass-clover swards. I - The effect of varying the closeness of cutting on the yields from an established grass clover sward. J. agric. Sci., Camb., 53, 299.

_____ (1966). Studies on the cutting management of grass-clover swards. IV - The effects of close and lax cutting on the yield of herbage from swards cut at different frequencies. J. agric. Sci., Camb., 66, 101.

REID, J. T., WELLINGTON, G. H. and DUNN, H. O. (1955). Some relationships among the major chemical components of the bovine body and their application to nutritional investigations. J. Dairy Sci., 38, 1344.

REID, R. L. (1962). Studies on the carbohydrate metabolism of sheep. XV - The adrenal response to the climatic stresses of cold wind and rain. Aust. J. agric. Res., 13, 296.

REIS, P. J. (1967). The growth and composition of wool. IV - The differential response of wool growth and sulphur content of wool to the level of sulphur containing amino acids given per abomasum. Aust. J. biol. Sci., 20, 809.

_____ and SCHINCKEL, P. G. (1961). Nitrogen utilisation and wool production by sheep. Aust. J. agric. Res., 12, 335.

_____ (1963). Some effects of sulphur-containing amino acids on the growth and composition of wool. Aust. J. biol. Sci., 16, 218.

_____ (1964). The growth and composition of wool. II - The effect of casein, gelatin and sulphur-containing amino acids given per abomasum. Aust. J. biol. Sci., 17, 532.

REPPERT, J. N. (1960). Forage preference and grazing habits of cattle at the Eastern Colorado Range Station. J. Range Mgmt., 13, 58.

ROBINSON, P. (1948). The effect of supermaintenance and sub-maintenance diet on mature Border Leister-Cheviot ewes. J. agric. Sci., Camb., 38, 345.

ROE, R., SOUTHCOTT, W. H. and TURNER, Helen N. (1959). Grazing management of native pastures in the New England region of New South Wales. I - Pasture and sheep production with special reference to systems of grazing and internal parasites. Aust. J. agric. Res., 10, 530.

ROHDE, O. (1857). Cited by Hutchinson, J. D., Wodzicka, 1961. Anim. Breed. Abstr., 29, 1.

ROSSITER, P. C. (1961). The influence of defoliation on the components of seed yield in swards of subterranean clover (*Trifolium subterraneum*). Aust. J. agric. Res., 12, 821.

SCHINCKEL, P. G. (1960). Variation in feed intake as a cause of variation in wool production of grazing sheep. Aust. J. agric. Res., 11, 585.

SCOTT, R. S. (1963). The effect of mole drainage and Winter pugging on grassland production. Proc. N. Z. Grassld. Ass., 25, 119.

SEARS, P. D. (1951). The technique of pasture measurement. N. Z. Jl. Sci. Technol., 33, 1.

_____ (1953). Pasture growth and soil fertility. I - The influence of red and white clover, superphosphate, lime and sheep grazing on pasture yields and botanical composition. N. Z. Jl. Sci. Technol., 35A, 1.

SHARKEY, M. J., DAVIS, I. F. and KENNEY, P. A. (1962). The effect of previous and current nutrition on wool production in Southern Victoria. Aust. J. exp. Agric. Anim. Husb., 2, 160.

_____ (1964). The effect of rate of stocking with sheep on the botanical composition of an annual pasture in Southern Victoria. Aust. J. exp. Agric. Anim. Husb., 4, 34.

SLEE, J. and CARTER, H. B. (1961). A comparative study of fleece growth in Tasmanian Fine Merino and Wiltshire Horn ewes. J. agric. Sci., Camb., 57, 11.

SLEN, S. B. and WHITING, F. (1952). Wool production as affected by the level of protein in the ration of the mature ewe. J. Anim. Sci., 11, 156.

SNEDECOR, G. W. (1966). "Statistical Methods". Iowa State University Press: Ames, Iowa.

SPRAY, C. M. and WIDDOWSON, E. M. (1951). The effect of growth and development on the composition of mammals. Brit. J. Nutr., 4, 332.

STAPLEDON, R. G. (1933). Welsh Plant Breeding Station. An account of the organisation and work of the station from its foundation in April 1919 to July 1933.

STERN, W. R. and DONALD, C. M. (1962a). Light relationships in grass-clover swards. Aust. J. agric. Res., 13, 599.

STEWART, A. M., MOIR, R. J. and SCHINCKEL, P. G. (1961). Seasonal fluctuation in wool growth in South-west Australia. Aust. J. exp. Agric. Anim. Husb., 1, 85.

STORY, L. F. and ROSS, D. D. (1960). Effect of shearing time on wool. VI - The rate of growth of wool and its relation to time of shearing. N. Z. Jl. agric. Res., 3, 113.

SUCKLING, F. E. T. (1964a). Stocking rate trials at Te Awa. Sheep fmg. A. 1964., 18.

_____ (1964b). Hill pasture behaviour under different stocking rates. Proc. N. Z. Grassld. Ass., 137.

SUMNER, R. (1969). M. Agr. Sci. thesis, Massey University.

SYMINGTON, R. B. (1959). Light regulation of coat shedding in a tropical breed of hair sheep. Nature, Lond., 184, 1076.

TESAR, M. B. and AHLGREN, H. L. (1950). Effect of height and frequency of cutting on the productivity and survival of ladino clover (Trifolium repens L.). Agron. J., 42, 230.

ULYATT, M. J. (1964). Studies on some factors influencing food intake in sheep. Proc. N. Z. Soc. Anim. Prod., 24, 43.

VERGES, J. (1939a). Cited Palsson (1955). Suffolk Sheep Society Year Book. Ipswich.

_____ (1939b). La Res., Buenos Aires No. 144.

WALKER, D. E. (1955). Meat production per acre. Proc. N. Z. Soc. Anim. Prod., 15, 51.

WALLACE, L. R. (1948). Growth of lambs before and after birth in relation to level of nutrition. Pt. I, 93. Pts. II and III, 243. Pt. IV, 367. J. agric. Sci., Camb., 38.

WATKIN, B. R. (1954). The animal factor on level of nitrogen. J. Br. Grassld. Soc., 9, 35.

WATSON, (1952). The physiological basis of variation in yield. Adv. Agron., 4, 101.

WEBER, A. D. (1931). The effect of the plan of nutrition on wool growth. Proc. 24th a. meet. Am. Soc. Anim. Prod., 228.

WEINMANN, H. (1948). Underground development and reserves of grasses. J. Br. Grassld. Soc., 3, 115.

_____ (1952). Carbohydrates reserves in grasses. Proc. 6th Int. Grassld. Congr. 1., 655.

_____ (1961). Total available carbohydrates in grasses and legumes. Herb. Abstr., 31, 255.

WHEELER, J. L. (1958). The effect of sheep excreta and nitrogenous fertilizer on the botanical composition and production of a ley. J. Br. Grassld. Soc., 13, 196.

_____ (1960). A response to phosphate on an all-grass sward. J. Br. Grassld. Soc., 15, 300.

WILLIAMS, A. J. (1964). The effect of daily photo period on the wool growth of Merino rams subjected to unrestricted and restricted feeding regimes. Aust. J. exp. Agric. Anim. Husb., 4, 124.

WILLIAMS, O. B. and SCHINCKEL, P. G. (1962). Seasonal variations in wool growth and live weight in several environments. Proc. Aust. Soc. Anim. Prod., 4, 38.

WILLOUGHBY, W. M. (1959). Limitation to animal production imposed by seasonal fluctuations in pasture and by management procedures. Aust. J. agric. Res., 10, 248.

WILSON, A. D. (1966). The growth rate of weaner sheep on irrigated pastures. Proc. Aust. Soc. Anim. Prod., 6, 179.

WINCHESTER, C. F. and HOWE, P. E. (1955). Relative effects of continuous and interrupted growth on beef steers. U.S.D.A. Tech. Bull, No.1108.

WODZICKA-TOMASZEWSKA, M. (1960). Seasonal variation in wool growth and heat tolerance of sheep. I - Wool growth, II - Heat tolerance. Aust. J. agric. Res., 11, 75, 85.

YEATES, N. T. M. (1964). Starvation changes and subsequent recovery of adult beef muscle. J. agric. Sci., Camb., 62, 267.