EFFECTS OF STOCKING RATE AND BOTANICAL COMPOSITION ON ANIMAL PRODUCTION FROM SOWN PASTURES IN A MEDITERRANEAN-TYPE ENVIRONMENT.

A thesis presented in partial fulfilment of the requirements for the Degree of Master of Agricultural Science, Faculty of Agricultural Science, University of Adelaide.

by

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PLATE 1

Aerial photograph taken in September 1972, of the Kangaroo Island Research Centre located on the plateau region of Kangaroo Island. The research centre building complex can be seen ringed by pine trees and the experimental site (15 elongate paddocks on either side of a central raceway) is clearly delineated in the foreground.

The natural vegetation, dry sclerophyll scrub some of which can still be seen along the road in the foreground, was cleared and sown to permanent pasture in 1950/51.

Areas of surface flooding would normally be evident during the winter months due to the poor drainage of the soil (lateritic podzol overlying an impervious clay at 20 to 60 cm).

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SUMMARY

A stocking rate experiment evaluating five pasture types was undertaken in a Mediterranean-type climate on the Kangaroo Island Research Centre, Parndana East, South Australia.

The hypothesis tested was that the renovation of an existing volunteer annual grass - Yarloop subterranean clover (*Trifolium subterraneum* L. cv. Yarloop) pasture by tillage, seedbed preparation and sowing of a mixture of the best available grass species and low oestrogenic subterranean clovers, would result in increased live weight and wool production from grazing wethers.

Merino wethers were continuously grazed for four years at six rates of stocking (10, 11, 13, 14, 15 and 17 sheep ha^{-1}) on each of the following five pasture treatments.

Treatment (A) - An unrenovated, volunteer annual grass-subterranean clover pasture dominated by Yarloop subterranean clover and barley grass (*Hordeum leporinum* Link.).

Treatments B, C, D and E - Tillage, seed bed preparation and sowing of grass, together with Mt. Barker and Woogenellup subterranean clovers. Treatment grasses sown were as follows: (B) Wimmera annual ryegrass (*Lolium rigidum* Gaud. cv. Wimmera), (C) Victorian perennial ryegrass (*Lolium perenne* L. cv. Victorian), (D) Medea perennial ryegrass (*Lolium perenne* L. cv. Medea) and (E) Hybrid phalaris (*Phalaris tuberosa* x *Phalaris arundinacea* cv. Siro 1146).

Large differences between pasture treatments in both pasture and animal productivity occurred in the first year and, to a lesser extent, in the second and third years of set stocking and these could be attributed to differences in botanical composition.

Dominant ryegrass stands in treatments B, C and D following pasture renovation and first year management procedures, proved less productive+ than the more subterranean clover - dominant pastures in treatments A and E. The data presented show clearly that the availability of the subterranean clover component was the dominant factor in the determination of animal production throughout the experiment.

Medea ryegrass consistently failed to demonstrate any degree of perenniality and Victorian ryegrass plants persisted over no more than three summers.

The influence of increased stocking rate in accelerating the between-year decline in density of Victorian ryegrass plants and the proportion of this species in the pasture, was clearly demonstrated. However, irrespective of stocking rate, the contribution of the three ryegrass species and sown subterranean clovers had declined to negligible proportions by the end of the experiment and this decline was associated with a concurrent increase in the pastures of Yarloop subterranean clover and other annual species, mainly of Mediterranean origin. In particular, the sowing of Mt. Barker and Woogenellup subterranean clovers proved unsuccessful in maintaining a low proportion of Yarloop in the overall legume component of the sward after a period of four to five years. This was highlighted by the level of hard seed reserves of subterranean clover measured in August 1973 in the renovated pasture treatments (mean of c. 210 kg ha^{-1}) of which c. 90 per cent was Yarloop.

The results demonstrated the excellent adaptation of Yarloop subterranean clover to the lateritic podzolic soils of Kangaroo Island: particularly its rapid growth during the winter and early spring and its ability to set copious supplies of seed, irrespective of stocking rate.

The large seed reserves ensure a potential for germination over a number of years. Hence the volunteer annual grass-subterranean clover pastures, typical of this

+In terms of plant and animal

environment, seemed to be assured a degree of quantitative and qualitative independence of stocking rate.

The results clearly demonstrated an interaction between stocking rate and botanical composition in the determination of animal production following the renovation and early management procedures used in this experiment. However, it was further demonstrated that this was only a short-term effect, because, as the experiment progressed, there was a trend towards like-botanical composition in all pasture treatments.

The efficiency of wool production, in relation to pasture production and rainfall, was dependent on stocking rate and the experiment highlighted the biological and economical inefficiency of low stocking rates.

Most importantly, the experiment showed that, with adequate subterranean clover, changes in botanical composition arising from differences from various stocking rates had not adversely affected animal production. None of the sown species and cultivars investigated performed as well as the original volunteer annual grass-subterranean clover (cv. Yarloop) pasture.

STATEMENT

The investigations reported herein were carried out as part of my duties as a staff member of the South Australian Department of Agriculture and Fisheries and as an external student in the Department of Agronomy, Waite Agricultural Research Institute, University of Adelaide.

This thesis contains no material which has been accepted for the award of any other degree or diploma in any University and, to the best of my knowledge and belief, it contains no material previously published or written by another person, except where due reference is made in the text of the thesis.

Peter R. Gibson

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INTRODUCTION

1. INTRODUCTION

Since European settlement, extensive changes have taken place in the botanical composition and productivity of pastures in southern Australia. The use of superphosphate for top-dressing native grass pastures (Cook 1939) led to a rapid invasion of exotic annual species (including many annual legumes) from the Mediterranean zone. The most notable legume, *Trifolium subterraneum L.* (subterranean clover), provided a substantial lift in soil fertility which further accelerated the invasion of many more of these free-seeding and fast-growing annual grasses and herbs. These invading species have been regarded as weedy and inferior to cultivars of imported temperate grasses (Tiver and Crocker 1951).

Any effort directed towards exploiting the naturalised volunteer pasture species has been, with few exceptions, confined to legumes of undoubted value such as subterranean clover. For example, by 1970, eleven naturally-occurring biotypes (commercial cultivars) of this species were in use in zones with distinct climatic and edaphic features. Some common examples are cv. Yarloop - regions subject to regular flooding: cv. Mt. Barker for long growing seasons: cv. Geraldton for greater speed of seed maturation, etc. (Donald 1970).

Only recently has the significance of the many attributes of some other common volunteer annuals been recognized (e.g. Carter 1968a and b, Smith 1968b). In particular, their persistence under intensive grazing, and their contribution to pasture and hence animal productivity under diverse management and seasonal influences is fast earning them the reputation of valuable pasture species in many areas of southern Australia.

There appear to have been no reported experiments carried out in the Mediterranean-type environment of southern Australia comparing animal production from pastures based on subterranean clover - volunteer annual grass and subterranean clover-sown temperate grass.+

This thesis describes an experiment comparing the liveweight response and wool production from wethers grazing at six different stocking rates on subterranean clover - volunteer annual grass pasture with and without the introduction of four temperate grass - subterranean clover mixtures. Particular emphasis has been placed on determining the extent of re-invasion of the renovated pastures by volunteer species, and the persistence of the introduced pasture species, as influenced by stocking rate. An attempt has been made to elucidate some of the inter-relationships of stocking rate and botanical composition as determinants of animal production in the Mediterranean-type environment.

The following review of literature covers factors affecting botanical composition and productivity of annual pastures with particular emphasis on the influence and productivity of grazing animals. Section 2.1 reviews the influence of the grazing animal on pasture, the main effects being treading, defoliation, seed dispersal and nutrient recycling. Section 2.2 briefly reviews the nutritive value of the commonly-occurring, volunteer annuals. Section 2.3 reviews the effect of botanical composition on animal performance and finally section 2.4 discusses the interaction of stocking rate and botanical composition in the determination of animal production.

+However, the earlier experiments of Neal Smith (1942) and Rossiter (1952) have some relevance here even though there were no direct comparisons of animal production between sown temperate grass plus subterranean clover and volunteer annual grass plus subterranean clover. In both experiments the lack of persistence of the sown grass component had little effect on plant or animal productivity.

Table 1

SCIENTIFIC NAMES OF ALL SPECIES GIVEN COMMON NAMES IN THE TEXT

Common Name	Scientific Name
Annual ryegrass	*Lolium rigidum* Gaud.
Annual veldt grass	*Ehrharta longiflora* Sm.
Barley grass	*Hordeum leporinum* Link.
Barrel medic	*Medicago truncatula* Gaertn.
Burr medic	*Medicago polymorpha* L.
Capeweed	*Arctotheca calendula* Druce
Cluster clover	*Trifolium glomeratum* L.
Cocksfoot	*Dactylis glomerata* L.
Fat hen	*Chenopodium album* L.
Geranium	*Erodium* spp.
Goosefoot	*Chenopodium* spp.
Lucerne	*Medicago sativa* L.
Meadow foxtail	*Alopecurus pratensis* L.
Musky crowfoot	*Erodium moschatum* L'Herit.
Perennial ryegrass	*Lolium perenne* L.
Phalaris	*Phalaris tuberosa* L.
Red clover	*Trifolium pratense* L.
Ripgut brome	*Bromus rigidus* Roth.
Rough-stalked meadow grass	*Poa trivialis* L.
Short rotation ryegrass	*Lolium perenne* L. x *Lolium multiflorum* Lam.
Silver grass	*Vulpia* spp.
Siro 1146 hybrid phalaris	*Phalaris tuberosa* L.x *Phalaris arundinacea* L.
Soft brome	*Bromus mollis* L.
Sorrel	*Rumex acetosella* L.
Subterranean clover	*Trifolium subterraneum* L.
Tall fescue	*Festuca arundinacea* Schreb.
Winter grass	*Poa annua* L.
Yorkshire fog	*Holcus lanatus* L.

LITERATURE REVIEW

2. LITERATURE REVIEW

2.1 The influence of the grazing animal on pasture

2.1.1 Treading

The effects of treading on vegetation were first highlighted by Bates (1935) and Davies (1938) in their studies of the vegetation of gateways, field tracks and grass verges. These workers attributed the ability of certain plant species to survive treading damage to structural adaptation. For example, Bates (1935) reported that the conduplicate stem and folded leaf section as found in *Poa pratensis* and *Lolium perenne* were significant characteristics possessed by these two species enabling them to withstand physical injury from treading.

Edmond (1964) ranked ten pasture species in order of their tolerance to treading and demonstrated a Treading x Species interaction which he attributed to morphological adaptation. Two examples of morphological adaptation are the rhizomatous growth of *Poa pratensis* and stoloniferous growth of *Poa trivialis*. The most important morphological attributes associated with treading tolerance are position of the growing point, growth habit and presence or absence of protective tissue.

However, physiological factors are also important in treading tolerance. Edmond (1964) reported that tolerance was related to the period of active growth in a number of species. For example, perennial ryegrass and short-rotation ryegrass were found to be more tolerant of treading in winter than in summer whereas white clover exhibited more tolerance in summer. Ellenberg (1952) reported that slow-growing pasture species with limited regenerative ability were found to be more susceptible to damage by treading and lack of vigour of the root system, during the period of slow growth, is one factor responsible for the slow recovery of such species.

The effect of treading may either encourage or destroy certain plant species and hence directly influence botanical composition (Edmond 1964). This may apply within one season (in a competitive situation) by reducing growth of one species *vis a vis* its competitors or, between two seasons, by differentially affecting seed yield and by compaction of the soil (Edmond 1958, Gradwell 1966, Brown 1968, Frame 1971). The destruction of many plant species and ingress by others in a heavily grazed pasture in New Zealand has been attributed to the effects of treading (Edmond 1966) and some species have shown a universal response. For e.g.Edmonds work, demonstrating high tolerance of perennial ryegrass to treading,agreed closely with the English (Bates 1935) and German (Ellenberg 1952) workers in other temperate climatic zones.

Annual pastures: Sivalingam (1973) and Carter and Sivalingam (1977) have reported what appears to be the only quantitative studies on treading on annual pasture in a Mediterranean-type environment. In one experiment, sheep treading on a mixed pasture of subterranean clover and annual ryegrass resulted in decreased plant density and tiller numbers, depressed pasture yield and poorer pasture regeneration in the following year. In a second experiment, perennial ryegrass demonstrated greater tolerance to treading than subterranean clover, and cluster clover was more tolerant than subterranean clover. In general, the grass species were more tolerant of treading than the legumes.

Carter and Sivalingam found that treading influenced annual pastures similarly to the way it influenced perennial pastures, but more severely. For example, treading reduced the seed yield of Yarloop subterranean clover far more than that of cluster clover - a differential far greater than observed on plant survival in perennial pastures. It seems that treading has its greatest effect on the regeneration phase of annual pastures (possibly through soil compaction), a phase which is not seed-dependent in perennials.

2.1.2 Defoliation

Measurement of the effects of defoliation *per se* by the grazing animal in the field, without the confounding influence of treading, is extremely difficult, and no relevant studies have been reported. However, there are numerous publications on experiments using cutting techniques as a substitute for defoliation by the grazing animal. Most of these have attempted to assess pasture response to different frequencies and intensities of defoliation. Not only does the literature reveal differences between species in their response, but also the same species may respond differently in different experiments (Davidson 1969). I have made no attempt to review studies not involving the grazing animal although some cutting-only experiments are referred to where relevant.

Grazing management studies (comprising discontinuous stocking systems other than various intensities of set stocking) are considered relevant here as they pertain to the timing and intensity of defoliation of annual pasture by the grazing animal and the resulting effect on botanical composition.

Exclusion of grazing animals: Talbot and Biswell (1942) and Jones and Evans (1960) (cited by Rossiter (1966)) working in California have shown that in the absence of grazing, grass dominance quickly occurred in their annual pastures. Ripgut brome was the main dominant grass with an associated loss of clovers, burr medic and *Erodium* spp. A similar trend was observed by Rossiter and Pack (1956) in Western Australia over a seven-year period. An initial capeweed - subterranean clover pasture was dominated by ripgut brome grass after three to four years but eventually was replaced by annual veldtgrass.

However, results produced in the absence of the grazing animal, "have doubtful - if not frankly misleading - agronomic significance" (Rossiter 1966).

Rotational grazing: The early Californian workers placed much emphasis on rotational grazing to promote or inhibit certain annual pasture species. However, Heady (1961), in a review of grazing management systems on the Californian annual-type pasture, concluded that there were no obvious production benefits from rotational grazing systems on these pastures and that no obvious change in botanical composition could be related to management system. Rossiter (1966) states that he, and probably most agronomists in southern Australia, believed that set stocking was the best grazing system on annual-type pasture in southern Australia. However, no experiments have been reported comparing rotational grazing versus set-stocking management systems over an extended period of time on annual pastures in southern Australia and hence one cannot be certain that the results of management experiments performed in California can be extrapolated to southern Australia.

Autumn deferment: Smith, Biddiscombe and Stern (1973) studied the effect of a five week deferment in the autumn on the productivity of annual ryegrass and subterranean clover pastures in pure swards in Western Australia. Subterranean clover adopted a more prostrate growth habit under continuous grazing which resulted in a lower intrinsic availability of herbage for prehension by the sheep. The consequence of this morphological change may be important in determining changes in botanical composition in mixed swards. McIvor and Smith (1973a) reported that autumn deferment increased the survival of capeweed seedlings in consecutive years and of subterranean clover in one year but had little effect on the annual grasses. Despite the lower capeweed plant numbers under continuous grazing this species still remained a substantial component of the sward and by spring any changes in botanical composition due to deferment had disappeared.

Brown (1976a), in a comprehensive study of the effects of deferred grazing of sheep on annual pasture over a range of stocking rates at Kybybolite, South Australia, demonstrated an interaction of stocking rate and management system on botanical composition. Annual ryegrass was more persistent at the higher stocking rates under deferred grazing than under continuous grazing. However, winter grass invaded the higher stocked pastures irrespective of management system. *Hordeum* spp. increased at the lower stocking rates and the author noted more *H. hystrix* on the continuously grazed treatments and more *H. leporinum* on the deferred treatments.

In a study on the control of barley grass in irrigated pastures at Deniliquin, New South Wales, Myers and Squires (1970) were able to completely eliminate the barley grass by using a critical length of deferment in the autumn following irrigation. However, under dryland conditions, particularly in Mediterranean-type environments, identification of the critical length of the deferment period would be difficult and any heavy grazing following deferment may damage other pasture species components and reduce pasture production (Smith 1968b).

Spring grazing: A number of management studies have been designed to define practices that would reduce the proportion of some seemingly unwanted annual species (particularly barley grass and capeweed) in annual pastures in southern Australia. Smith (1968b) found that heavy grazing during the spring did not reduce the barley grass content of the pasture but increased the number of seed heads and often the number of seeds. McIvor and Smith (1973b) reported that close grazing during the spring increased the barley grass content, and if grazing continued throughout the spring, also the capeweed content. Associated with these increases was a decrease in the proportion of other grass species in the pasture, particularly if the grazing continued throughout the spring.

However, this is in contrast to the results reported by Carter (1969) and Brown (1976a) in which, after two or more years, *Hordeum* spp. increased only at the lower stocking rates of their factorial stocking rate experiments.

Certainly, the duration and degree of grazing pressure are likely to interact in determining changes in botanical composition in annual pastures and extrapolating results obtained within one season to the longer term would seem invalid.

Nevertheless, with the exception of the work by Myers and Squires (1970) on irrigated pastures, grazing management *per se* (comprising discontinuous stocking systems other than various intensities of stocking) does not seem to greatly influence the botanical composition of annual pastures, at least in the short term. This has particularly been the case where management practices have been used in an attempt to lower the barley grass and capeweed content of pastures. Smith (1968b) in summarizing his experiment on the control of barley grass, suggested that "Management practices designed to utilize the merits of barley grass may be more profitable than ones designed hopefully to control it". Carter (1968b) also suggested that it may be more profitable to exploit the useful features of aggressive annual species like barley grass and capeweed rather than try to exclude them from annual pastures in the Mediterranean-type environments of southern Australia.

Stocking rate: as distinct from the other forms of grazing management referred to above, can have a marked influence on the botanical composition of pasture under sustained continuous grazing in the Mediterranean-type environment of southern Australia.

Drake and Elliott (1963) reported dramatic changes in botanical composition after five years in a set-stocked, stocking rate experiment at Bengworden, Victoria. At the lowest stocking rate the pasture was grass dominant with a high component of Yorkshire fog. At the intermediate stocking rate grass and subterranean clover were present in equal proportions but fog grass was eliminated. At the highest stocking rate the capeweed component had increased from two to 17 per cent with a concurrent decrease in the grass component.

In Western Australia Davies (1965) and Rossiter (1966) demonstrated an increase in the volunteer capeweed and *Erodium* species and a decrease in volunteer annual grass components as stocking rate increased. In the latter study, partitioning of the annual grasses revealed a reduction in the ripgut brome component and an increase in the silver grass component at the higher stocking rate.

Mann *et al.* (1966), working near Mt. Barker in Western Australia, reported an interaction between superphosphate, stocking rate and botanical composition. After two years, subterranean clover was dominant at the highest stocking rate, irrespective of the rate of superphosphate application. At the lowest stocking rate, grass dominance increased with rate of superphosphate application.

In a set-stocked experiment at Kojonup, Western Australia, Greenwood, Davies and Watson (1967) recorded a marked invasion of a subterranean clover - soft brome pasture by *Vulpia* spp., *Erodium* spp., barley grass, ripgut brome and capeweed. At the end of the fourth year the subterranean clover component was higher at the higher stocking rate but this difference disappeared in the fifth year. After five years of set stocking, the pastures were dominated by *Vulpia* spp., ripgut brome and capeweed. The proportion of each volunteer species component was independent of stocking rate in each year, with the exception of the ripgut brome component, which was significantly greater at the lower stocking rate.

When three stocking rates were imposed on an annual ryegrass - subterranean clover pasture at Werribee, Victoria, Sharkey *et al.* (1964) found that both sown species disappeared from the pasture at the highest stocking rate with a concurrent invasion of *Vulpia* spp., *Crassula* spp., *Lythrum* spp. and winter grass. However, at the lowest stocking rate, an increase in annual ryegrass and a decrease in subterranean clover plants was recorded. This trend was reversed at the intermediate stocking rate.

Cameron and Cannon (1970) reported increased proportions of subterranean clover and annual volunteer grasses at intermediate stocking rates but a decreased proportion at the higher stocking rates, in an experiment in north eastern Victoria. However, winter grass, cluster clover, *Trifolium campestre* and *Trifolium dubium* all increased in proportion to increased stocking rate up to the highest rate. The broad-leaved component, consisting of capeweed, *Rumex acetosella, Erodium* spp. and *Cerastium viscosum,* showed no consistent change in magnitude.

Carter and Day (1970) reported a marked invasion of winter grass, cluster clover and, to a lesser extent, geranium at the highest stocking rate in a factorial stocking rate and superphosphate grazing experiment at Parndana, South Australia. The authors reported no consistent effect of stocking rate on the between-year changes in the proportion of subterranean clover in the pasture. The pastures were also invaded by silver grass, ripgut brome, soft brome, barley grass and capeweed, irrespective of treatment.

At the Waite Institute, South Australia, Carter (1969) reported a similar invasion of annual pasture by volunteer annual species, although a differential effect of stocking rate on the dominance of barley grass and capeweed was recorded in this experiment. At the highest stocking rate, cluster clover and winter grass were again the main invaders and barley grass and capeweed dominance occurred at the lower and intermediate stocking rates respectively.

Both Brown (1976a) at Kybybolite, South Australia, and Fitzgerald (1976) at Wagga Wagga, New South Wales, also reported a more marked invasion of annual pasture by barley grass at the lower stocking rates. The former author reported increased proportions of cluster clover, winter grass and *Juncus bufonius*, and the latter author, increased proportions of subterranean clover and silver grass at the highest stocking rates.

Although effective grazing pressures, soil type, climatic conditions, micro-environment and many other factors would have varied between experimental sites, the dominance of certain species at either high or low stocking rates is common to most of the experiments referred to above. In particular, the trend towards higher proportions of cluster clover and winter grass at the highest stocking rates is common to many of the experiments.

The reason for certain pasture species growing under different grazing regimes is unclear and many factors may be of importance. For example, tolerance to treading (see 2.1.1), preference for particular nutrient levels (although it is unclear if, and to what extent, stocking rate affects nutrient levels in the soil - see Section 2.1.4), seed production and dispersal (see Section 2.1.3).

Perhaps the most significant factor in the marked persistence of winter grass and cluster clover at high stocking rates is that a high proportion of the seeds of these two species pass through the alimentary tract of the grazing animal and remain viable (Carter 1969), thus maintaining a high level of seed reserves for propagation of the species. The differential digestibility of seed by the grazing animal is further discussed in Section 2.1.3.

Persistence of sown perennial species: Few experiments have reported any real degree of persistence by sown perennial grasses (with the possible exception of phalaris) in the pastures common to Mediterranean-type regions of southern Australia. The extent to which stocking rate influences the persistence of these sown perennial grasses is also uncertain. In the grazing experiment reported by Cameron and Cannon (1970), perennial ryegrass, although initially the major component, finally disappeared at all levels of stocking. However, in the short term (4 to 5 years), the decline in the perennial grass component was more rapid at the higher stocking rates.

Carter and Day (1970) reported a rapid between-year decline in the perennial ryegrass component in their experiment. In the first year the perennial component appeared to be depressed at the higher stocking rates, but by the end of the third season, its contribution was so small that no treatment influence was evident. The authors state that "the decline in the perennial ryegrass component was probably associated mainly with dry spring and summer conditions".

Comparisons of the persistence of different perennial grass species in a Mediterranean-type environment are almost totally lacking. Reed (1974) reported an interaction between the persistence of perennial species and stocking rate at Glenormiston, Victoria; phalaris proving slightly more persistent at the higher stocking rates than perennial ryegrass.

Differences in the persistence of perennial grasses under different grazing pressures have been recorded for other climatic regions of southern Australia. For example, Biddiscombe (1953), in a survey of grazed natural communities at Trangie, New South Wales, found that the perennial grass component declined and the annual component increased as the grazing pressure increased. Hutchinson (1970) reported an interaction between perennial grass species and stocking rate at Armidale, New South Wales, where phalaris showed marked persistence at high and low stocking rates, fescue persisted well at the lower stocking rates only, and both perennial ryegrass and cocksfoot plant numbers were severely reduced at both stocking rates.

2.1.3 Seed Dispersal

The attachment of seed, individually or in burrs and pods, to the hair or wool coat of the grazing animal is an important means of seed dispersal. However, it seems that no experiments have been reported assessing the importance of grazing management, particularly stocking rate, on external seed transfer and the resulting effect on botanical composition in annual pastures. It would seem logical that maximum movement of stock would enhance seed distribution by this means.

However, although higher stocking rates would probably ensure greater movement of livestock and therefore provide more potential carriers of seed, seed production may in fact be lower at the higher stocking rates with a resultant decrease in dispersal of seed by the grazing animal. In many situations, low stocking rates have encouraged grass dominance and, particularly if barley grass is present, resulted in increased seed fault in wool (Carter 1969).

The differential digestibility of seed in the alimentary tract of the grazing animal clearly is important in determining changes in botanical composition in annual pastures. Dore and Raymond (1942) estimated that 1100 viable seeds of red clover may be distributed through the alimentary tract of one cow in the grazing season. However, in this experiment no account was taken of 'hard' seeds which were still ungerminated at the time the counts were discontinued. Suckling (1952) estimated, that under a stocking rate where all the available pasture of white clover was grazed down in one day, four million viable seeds could be distributed in the combined faeces of the grazing sheep. This author, together with other workers (Bunton and Andrews 1948), advocated the practice of purposeful dissemination of seed by the movement of sheep from pasture which is plentiful in supply of certain seed to nearby depleted areas.

The proportion of whole seeds passed in the faeces appears to be related to seed size. Franklin and Powning (1942) recovered 57 per cent of uncrushed cluster clover seeds (weight of 1000 seeds = 0.4 g) compared to a three percent recovery of barrel medic seeds (weight of 1000 seeds = 3.7 g) reported by Vercoe and Pearce (1960).

Carter (1969), in a stocking rate experiment on annual pasture at the Waite Institute, South Australia, counted high numbers of viable seed of cluster clover, winter grass and capeweed in the faeces of sheep but recorded very low seed counts of subterranean clover, annual rye-grass and barley grass. The differences appeared to be related to differential seed digestibility rather than differential intake of seed. Continuous grazing at a high stocking rate caused rapid changes in botanical composition in his experiment. After four years of continuous grazing, the quantity of cluster clover seed obtained at the highest stocking rate (22.2 sheep ha^{-1}) was 440 kg ha^{-1} compared to 16 kg ha^{-1}

at 17 sheep ha^{-1} and less than one kg ha^{-1} at 14.8, 12.4 and 7.4 sheep ha^{-1}. These marked differences in seed production were reflected in botanical composition.

2.1.4 Nutrient recycling

The effect of excreta from the grazing animal on the botanical composition of annual pasture is not clearly understood (Barrow 1969). Increased stocking rates will increase the turnover of nutrients and should lead to lower requirements, but the large-scale heterogenous distribution of faeces and urine by the grazing animal may result in the majority of pasture being depleted in nutrients at high stocking rates, even though the grazing pressure may be more uniform (Hilder 1964 and 1966). The distribution of faeces and urine may be particularly uneven when involving camp sites near shelter, water on adjacent animals of like kind. Campbell and Beale (1973) concluded from their results of an experiment with Merino wethers grazing natural pasture at Trangie, New South Wales, that differences in stocking rate did not result in any discernible difference in soil nitrogen status that might in turn have brought about the observed change in barley grass content in their pasture.

The changes in botanical composition that occur on animal camp sites in response to the increased source of available nutrients may be important in the invasion of larger areas of pasture. The classical invasion patterns of barley grass and capeweed frequently show a spread from initial foci within such areas of enhanced fertility. Avoidance by the grazing animal of these areas of concentrated excreta can further accelerate invasion by vigorous annuals. However, the confounding influence of altered seed populations caused by differential digestibility of seed by the grazing animal makes the direct attribution of changes in botanical composition to altered nutrient levels *per se*, in these camp sites, untenable (Carter 1969).

While further work is required to establish to what extent the grazing animal influences the availability of nutrients in the soil there is little doubt that soil fertility may have a major influence on the competitive growth of some annual pasture species. For example, Moore (1965) demonstrated that barley grass was significantly more competitive than annual ryegrass at high levels of soil nitrogen and calcium. Smith (1966 and 1968a) has produced evidence correlating frost resistance in barley grass with the nitrogen level of both herbage and soil. However, Smith (1968a) also suggests that competition between annual ryegrass and barley grass in the vegetative stage may not be important because the roots of the two species explore mainly separate soil layers. Cocks (1974) reasons, that although barley grass is a plant of fertile soils its presence is probably not due to its competitive ability at high nitrogen levels, at least when compared to Wimmera annual ryegrass. He demonstrated that at low nitrogen levels barley grass was the successful competitor but its competitive ability decreased with increased plant density. At high nitrogen levels annual ryegrass became the successful competitor but the competitive ability of barley grass increased with its density.

Examples of particular pasture species requiring either high or low fertility regimes are numerous and beyond the scope of this review in so much as particular fertility regimes cannot be adequately related to the influence of the grazing animal.

2.2 The nutritive value of annual pasture plants

2.2.1 Digestibility

Growing season: The digestibility of pasture is markedly influenced by its chemical composition and, in particular, by the amount of structural cell wall material it contains (Armstrong *et al.* 1964, Jones 1972). The digestibility is usually high for young herbage and declines as the plants mature (Minson *et al.* 1960, Radcliffe and Newbery 1968). For any one species, leaf blades usually have a higher digestibility than stems, with leaf sheaths intermediate (Raymond 1969).

Rossiter (1966) quotes two early studies on the digestibility of annual pasture in southern Australia. a) For a mixed pasture under grazing at Roseworthy College, South Australia, Hutchinson and Porter (1958) obtained a value of c. 75 per cent for D.M.D. (dry matter digestibility) during the spring. b) With a mixed pasture of annual ryegrass and subterranean clover under grazing, Pearce *et al.* (1962) at Werribee, Victoria, obtained a value of c. 80 per cent O.M.D.† (organic matter digestibility) during the spring.

Only slight differences in the O.M.D. of different annual pasture species, when measured at comparable stages of growth, were found by Fels *et al.* (1959) and Davies (1965).

However, McIvor and Smith (1973c) have recorded some differences in digestibility between component parts of some annual species. For example, the stems of annual ryegrass and barley grass were much lower in digestibility at maturity than ripgut brome grass, soft brome grass, capeweed and musky crowfoot. However, the seed heads of annual ryegrass and soft brome grass were of higher digestibility than those of barley grass and ripgut brome grass.

The digestibility of many volunteer annual species compares favourably with that of introduced temperate grass species. For example, Jones *et al.* (1971) at Canberra reported that the digestibility of whole plants of capeweed (grazed or ungrazed), rough-leaved goosefoot and sorrel

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† per cent O.M.D. is usually 1 to 3 units higher than per cent D.M.D.

(grazed) and fat hen (ungrazed) compared favourably with equivalently - managed sown species of cocksfoot, lucerne, ryegrass and phalaris.

A marked decline in digestibility following the onset of flowering has commonly been reported in most pasture species. Radcliffe and Newbery (1968) recorded a decline in digestible dry matter of between 0.7 to 0.9 percentage units per day over the last month of the growing season (November) in five, winter grazed, perennial grass - subterranean clover pastures in the Adelaide Hills of South Australia. This decline was higher than that recorded by other workers in other environments (i.e. Minson *et al.* 1960, Pritchard *et al.* 1963, Mowat *et al.* 1965). In a later experiment, Radcliffe and Cochrane (1970) recorded wide variability in the rate of decline of digestibility of pure swards of perennial and annual grasses at Northfield, South Australia. In the month following flowering, annual ryegrass lost digestibility at the rate of 0.9 units per day which was similar to the decline observed in mixed pastures dominated by perennial ryegrass (Radcliffe and Newbery (1968). Lower values (0.3 to 0.5 unit decline per day) were recorded for phalaris, brome grass, silver grass, barley grass, subterranean clover and barrel medic. Wilson and McCarrick (1966) also observed that the rate of decline in digestibility of mixed swards of perennial ryegrass, rough-stalked meadow grass and meadow foxtail was lower than for pure perennial ryegrass. The authors suggested that this was probably due to the differential rate of physiological development of the many species that comprised the pasture.

Summer period: During the summer period, Fels *et al.* (1959) reported a value of 57 per cent O.M.D. for grass and 43 per cent for subterranean clover. In a subsequent experiment, Fels (unpublished data as quoted by Rossiter 1966) obtained values of 48, 47 and 52 per cent for grass, capeweed and subterranean clover respectively. Values of 55 to 60 per cent for both capeweed and burr-free subterranean clover, collected at the beginning of summer at Perth, were found by Rossiter (1966). In South Australia, 45 per cent D.M.D. was the most common value for mature summer pasture residue reported by Hutchinson and Porter (1958). More recently, Allden (1969) and Pullman and Allden (1971) reported D.M.D. values of 45 to 49 per cent and 53 per cent respectively for dry summer herbage in South Australia.

A drop in digestibility of dry herbage following summer rain has been reported by several workers in California (Guilbert and Mead 1931, Hart *et al.* 1932) but surprisingly little information is available on the extent rainfall *per se* affects the digestibility of dry herbage in the Mediterranean-type environment of southern Australia.

2.2.2 Dry matter content

Herbage intake by the grazing animal can be significantly affected by the dry matter content of the herbage (Arnold 1962, Davies 1962b). The latter author recorded a constant intake of 'wet matter' by sheep when the dry matter content was below 16 per cent. McIvor and Smith (1973c) recorded values of 10 to 20 per cent dry matter for a number of annual plant species prior to flowering.+ One noticeable exception was capeweed which mostly varied in dry matter content from 6 to 7 per cent. Davies (1962b) suggests that the nutritive value of capeweed may be impaired during the growing season because of its low dry matter content. However the dry matter content of most herbage plants increases as the herbage matures (Parrott and Donald 1970) and at maturity the nutritive value of capeweed is comparable to other pasture species (McIvor and Smith 1973c).

+Dry matter determinations were made on the leaves and not the whole plant.

2.2.3 Dry matter loss

Following maturity, large losses of dry matter can occur over the summer period (Ratcliff and Heady 1962, Rossiter 1966, Cameron 1966, Brown 1977). Large differences between species in the rate of disintegration of annual pasture, excluded from grazing, have been recorded in the Californian summer (Ratcliff and Heady 1962). This applies to both grasses and legumes; for example, ripgut brome and burr medic lost c. 80 per cent and 70 per cent of their maximum annual yield respectively. Under grazing, the loss of dry matter over the summer period in Western Australia has been estimated by Rossiter (1966) to be c. 50 per cent of total annual production of which almost half the loss was due to trampling and summer rains. Brown (1977) measured the rate of disappearance of the dry residues of nine pasture species over a 139 day period during summer at Kybybolite, South Australia. Clovers and capeweed disappeared at about two to three times the rate of perennial grasses. High rates of disappearance were associated with initially low fibre and high nitrogen, sulphur, calcium and sodium concentrations.

2.2.4 Chemical composition

Chemical analyses of annual grasses in California showed a decline in nitrogen concentration from 3.5 per cent, in the early vegetative growth stage, to 0.8 per cent at maturity. The corresponding values for burr medic were approximately 4.5 and 2.4 per cent nitrogen (Rossiter 1966). Values for subterranean clover have been found to approximate those of burr medic (Beck 1952, Rossiter 1958).

More recently, McIvor and Smith (1973c) ranked the nitrogen concentration of subterranean clover > capeweed > annual ryegrass, based on several analyses of the leaves of the species sampled in the field.

In each case, the nitrogen concentration declined slightly during the season. Only slight differences in nitrogen concentration were found for plant fractions of annual ryegrass and capeweed at flowering but the developing subterranean clover burrs were higher in nitrogen (3.8 per cent) than the leaves (2.6 per cent).

Rossiter (1966) reported a decline in the nitrogen concentration of dry herbage and large differences between sites during the summer period. However, Brown (1977) found nitrogen concentration increased with time in a number of pasture species over summer and Barrett *et al.* (1973) reported no change in their experiment.

2.2.5 Herbage preference and intake

Little work has been reported on species preference by sheep or cattle grazing annual pastures and no clear ranking of species on the basis of preference is possible. Davis (1964) recorded no distinct preference by sheep for either annual ryegrass or subterranean clover during the growing season at Werribee, Victoria, but in early summer there was a clear preference for grass and in late summer the sheep preferred the dry clover tops. At the same location Hodge and Doyle (1967) later reported no distinct preference for annual grass or subterranean clover by grazing sheep. Rossiter (1966) quotes a number of studies in California where forage preferences have been demonstrated for annual-type pastures. Weir *et al.* (1959) concluded that grasses (mainly soft brome) and to a lesser extent *Erodium* spp. were selected during the winter but, at maturity, medic was preferred. Van Dyne and Heady (1965) reported preference by sheep for *Erodium* seed heads over the summer period.

However in relation to animal production, the preference ranking of species under *ad lib* availability of pasture may not necessarily equate with a ranking based on intake when pasture availability limits intake (Arnold 1964). Accordingly, the effect of forage preference by the grazing animal on the botanical composition of pasture requires much more elucidation.

2.2.6 Animal performance

The limitations of annual grass-legume pasture as a productive feed for young sheep in the Mediterranean-type environment have been documented by Donald and Allden (1959). Although adequate liveweight gains can be made during the period of active pasture growth (autumn to early summer) the live weight usually reaches its zenith in early summer than declines over the summer-autumn period when the pasture is mature and dry.

The decline in live weight may continue until well after the autumn break of the following year (Cameron and Cannon 1970, Carter and Day 1970, Davis and Sharkey 1972, Brown 1976b).

The general pattern of wool growth of sheep grazing annual pastures is similar to the pattern of liveweight change except for an earlier and more marked decline in wool production at the end of the growing season. This decline in rate of wool growth is nearly always associated with the senescence and drying of the pasture and the live weight may not decline for some months later (Hutchinson and Porter 1958, Roe *et al.* 1959, Arnold and McManus 1960, Stewart *et al.* 1961). The dominant influence of nutrition in determining this seasonal pattern of wool growth is emphasized by the fact that potential wool production is highest in summer when the days are longer and the temperature higher (Morris 1961, Hutchinson and Wodzicka-Tomaszewska 1961).

Stocking rate can affect the pattern of liveweight change and wool production particularly during periods of low pasture availability, such as occurs during the autumn and winter in Mediterranean-type environments.

Brown (1976b) demonstrated a bi-modal change in the regression coefficient (rate of change in live weight or wool growth on stocking rate) in each of five years in which an annual pasture was set stocked at Kybybolite, South Australia.

2.3 Effect of botanical composition on animal performance

2.3.1 The importance of the legume

The greater nutritive value of legume pastures compared to grass pastures has now been well established over a range of environments and under differing experimental techniques. Examples are as follows: in set-stocked experiments (Gallagher *et al.* 1966, Spedding *et al.* 1966); experiments when herbage was non-limiting (McLean *et al.* 1962, Rae *et al.* 1963 and 1964, Hight and Sinclair 1965); in put-and-take experiments. (Heinemann and Van Keuren 1958) and in *ad lib.* pen-feeding experiments (Sinclair *et al.* 1956, Joyce and Newth 1967). For further references the reader is referred to a recent review on the subject by Reed (1972b).

In the Mediterranean-type environment of southern Australia, Davies and Greenwood (1972) demonstrated an effect of botanical composition on the relationship between liveweight gain and dry matter on offer during the pasture growing season. They showed that, despite the lower availability of grass-dominant pasture required for maintenance, there was greater liveweight gain and wool production from sheep grazing clover-dominant pastures due to the higher nutritive value of the legume component. Reed (1974) at Glenormiston, Victoria, also reported that most differences recorded in fleece weight of wethers grazing different pasture types in a grazing experiment were related to the proportion of subterranean clover in the pastures.

2.3.2 Differences between grasses

Neal Smith (1942) found no significant difference in live weight between ewes grazing annual ryegrass-subterranean clover pasture and those grazing phalaris-subterranean clover pasture over a five-year period at Kybybolite, South Australia.

Reed (1972a), at Glenormiston, Victoria, reported small, but not statistically significant, differences in the growth rate of lambs grazing pastures containing a range of perennial grasses and mixture combinations, all sown with a mixture of clovers. The author states that, "at Glenormiston, animal production could not be improved by the inclusion of a perennial grass in the pasture".

In other environments, few experiments have demonstrated large differences in animal production between grass species. For example, Hamilton *et al.* (1970) found lower liveweight gains by lambs grazing a pure sward of cocksfoot compared to either phalaris, Tall fescue and perennial ryegrass. But the difference was small compared to the large seasonal differences in growth of lambs grazing each species. In New Zealand some experiments have shown higher liveweight gain of sheep on short rotation ryegrass compared to perennial ryegrass (Rae *et al.* 1963, Barton and Ulyatt 1963, Johns 1966). However, in two experiments comparing the same two grass species, no difference in animal production was recorded (Ewer and Sinclair 1952, Barclay 1963).

No difference in fleece weight was recorded by Hutchings *et al.* (1963) at Canberra for sheep grazing phalaris and Tall fescue, although the fleece weights were higher than those from sheep grazing *Bromus coloratus* and *Bromus inermis*. However, Axelsen and Morley (1968), also at Canberra, recorded higher liveweights and fleece weights from ewes grazing phalaris-legume pasture compared to six other perennial (and one annual) grass-legume pastures. The results, however, demonstrated little or no advantage within, or to, the perennials apart from phalaris.

2.4 Interaction of stocking rate and botanical composition in the determination of animal production

Major between-year changes in botanical composition, associated with increased stocking rates, were recorded by Cameron and Cannon (1970) but there was no consistent change in the relationship between wool production and stocking rate. Brown (1976a) reported a depression in pasture production at high stocking rates which was associated with the dominance in the pasture of *Juncus bufonius* and winter grass. The author states that "a high proportion of these two species in pastures may be a useful indicator that the grazing pressure is too high, with an associated loss of production".

However, there appears to be no experiment reported where the effect of stocking rate on pasture production has been isolated from the effect of concomitant changes in botanical composition in annual pastures. In a number of experiments, higher stocking rates have resulted in higher animal production per head but, in most cases, the change in botanical composition, rather than an effect of stocking rate on increased quantity or quality of available feed, has been reputed to be the fundamental cause. For example, Mann *et al.* (1966) reported that sheep, grazed at the highest stocking rate in the second and third years of an experiment, maintained higher liveweight over the summer which the authors attributed to the greater subterranean clover component in the pasture at the higher stocking rate. Campbell *et al.* (1973) reported higher live weights of sheep grazing at the highest of three stocking rates which they attributed to less aggravation of the sheep in the presence of fewer barley grass plants and inflorescences at this stocking rate.

The discussion of stocking rate effects, independent of changes in botanical composition, is probably of academic importance only unless a stable pasture composition can be maintained over a number of years irrespective of stocking rate. This has been shown to be highly unlikely, even with perennial species, in the Mediterranean-type regions of southern Australia, and the interaction of stocking rate and botanical composition in determining the level of animal production is the prime consideration.

BACKGROUND, AIM, ENVIRONMENT AND SITE

OF EXPERIMENT

3. BACKGROUND TO EXPERIMENTAL PROGRAM

The few relevant experiments reported prior to 1970 showed the extreme lack of evidence for the popular belief that the introduction of perennial grass species into annual pastures in the Mediterranean-type regions of southern Australia, either stabilized pasture composition for an extended period, or resulted in increased animal production. However, the realization that volunteer annual species, in conjunction with an adequate legume component, may be useful pasture plants was not uncommon during the 1950's (Rossiter 1952).

In addition, little evidence was available on the effect of stocking rate on the rate of invasion of annual volunteer species into sown perennial based pastures or the concomitant decline in perennial grass component. The following experimental work reported in this thesis has attempted to provide evidence on some of these fundamental questions which are of immediate practical importance to the grazing industries.

A further impetus to the experimental program was the need to solve another important problem which was particularly relevant to Kangaroo Island, South Australia. In the period 1945 to 1970, 100,000 hectares of virgin scrub were cleared for development on Kangaroo Island. The soils are mainly lateritic podzols comprising sandy loams overlying impermeable clay at a depth of from 20 to 60 cm (Northcote and Tucker 1948). The region is typical of the more humid Mediterranean-type environments of southern Australia with precipitation exceeding evaporation during May to August and, due to poor drainage, the soil is generally waterlogged during most of this period. Early experiments carried out on the Kangaroo Island Research Centre, Parndana, demonstrated the outstanding herbage production of Yarloop subterranean clover during the winter (Day 1963) and the use of this cultivar in seed mixtures was widespread from 1957 to 1963. However, this has resulted in many newly-sown pastures being dominated by Yarloop subterranean clover, and by 1963, the occurrence of a general problem of clover-induced infertility in ewes (Bennetts *et al.* 1946) was recognized on Kangaroo Island, with Yarloop subterranean clover being implicated as the main causal species. The introduction of a successful perennial grass into these pastures could dilute the intake of oestrogenically-potent legume by the grazing animal and perhaps stabilize pasture composition.

4. AIM OF EXPERIMENT

The hypothesis tested in this experiment is specifically that the renovation of existing volunteer annual grass - Yarloop subterranean clover pasture by the tillage, seedbed preparation and sowing of a mixture of the best available grass species and low oestrogenic subterranean clovers results in increased live weight and wool production from grazing wethers. No attempt has been made to divorce the response due to tillage and/or seedbed preparation from that due to pasture species *per se* in the comparison of renovated and unrenovated treatments.

In essence, the aim of the experiment was to compare the productivity of two systems; one being an unrenovated established pasture comprising subterranean clover - volunteer annual grass (typifying the majority of existing pastures on Kangaroo Island and in many other areas of southern Australia) and the other, a renovated pasture involving tillage, clover seed and grass seed inputs - a new system as defined by the outcome of an established and recommended renovation practice. The experimental comparisons were specifically designed so that the results would be relevant to an established agricultural system; the importance of which had been stressed by Morley and Spedding (1968).

5. ENVIRONMENT

The experiment was located at the Kangaroo Island Research Centre (lat. 35° 48'S., long. 137°20'E., alt. 153 m.).

Climatic data for the Research Centre are presented in Table 2 and appendix Tables 1-5.

The vegetation of the experimental site was originally a dry sclerophyll scrub dominated by an *E. baxteri* - *E. cosmophylla* association. The main tall shrubs included *Casuarina stricta* (bulloak), *Banksia marginata* (honeysuckle), *Banksia ornata* (broad leaved honeysuckle), *Hakea rostrata* and *Xanthorrhoea tateana* (the endemic yacca). Undershrubs included *Daviesia genistifolia, D. brevifolia, Adenanthos terminalis, Lhotzkya glaberrima, Phyllota pleurandroides, Pultenaea viscidula, Logania ovats, Spyridium thymifolium, Petrophila multisecta, Isopogon ceratophyllus, Tetratheca halmaturina, T. ericifolia* and *Hibbertia stricta* (Northcote and Tucker 1948).

The first morphological description of the soil type was given by Northcote and Tucker (1948) as the Seddon gravelly sandy loam although listed under the incorrect heading of Seddon gravelly loamy sand (refer Carter 1970). The description is as follows:

0-5 cm†	A0	Scattered surface gravel; occasionally gravel pavement.
	A1	Greyish-yellow-brown to grey-brown sandy loam with some organic matter and slight‡ ironstone gravel.
5-25 cm	A2	Yellow-brown to yellowish-brown sandy loam with slight to medium amounts of ironstone gravel.
25-33 cm	B1	Light yellow-brown sandy clay loam sometimes with yellow

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† Depth originally described in inches but converted to centimetres in this text.

‡ 'Slight' corresponds to 12.5 - 25%, 'light' to 25 - 40% and 'heavy' to more than 70%.

	mottlings, with light to heavy amounts of ironstone gravel. (This horizon is frequently poorly developed).
33-56 cm B2	Light yellow-brown, brown, and sometimes yellow-grey mottled friable clay. Gravel is very slight.
56-102 cm B2	Mottled yellow-brown, brown, yellow-grey and light grey friable clay. Frequently with gravel bands giving medium amounts of ironstone gravel in this horizon.
102-152 cm B3	Variously mottled clay but light grey colour prominent, sometimes with ironstone gravel bands.
152-203 cm+C	Variously mottled clay but red and light grey prominent sometimes with ferruginized rock fragments.

TABLE 2

RAINFALL+ RECORDED AT THE KANGAROO ISLAND RESEARCH CENTRE, PARNDANA EAST

YEAR	Monthly Totals (mm)												
	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	TOTAL
1970	40	3	22	51	50	93	50	112	81	19	27	28	571
1971	6	11	34	138	96	66	62	143	66	37	81	62	792
1972	59	49	6	24	22	63	149	124	18	40	12	6	571
1973	6	8	71	42	62	108	90	140	72	56	18	43	699
1974	50	8	25	60	109	66	161	81	72	93	27	9	762
20 year Ave.	16	25	27	53	78	87	104	88	62	44	28	26	638

+Other climatic data are given in appendix tables 1 to 5.

6. SITE OF EXPERIMENT

The experimental site was cleared of native vegetation in 1950 by the South Australian Lands Development Executive and until 1962 had been used for experiments evaluating response to various rates and frequency of superphosphate and copper fertilizer applications. From 1963 to 1969 inclusive, the entire site was managed as a single paddock and received uniform applications of fertilizer. Experiments carried out on the Research Centre on the same soil type indicated that the possible optimum maintenance superphosphate requirement for pasture growth was between 250 and 375 kg ha^{-1} $year^{-1}$ (Carter 1970). The maximum and minimum mean rates of fertilizer applied to any portion of the site prior to 1970 were 243 and 154 kg ha^{-1} $year^{-1}$ respectively of superphosphate and 0.9 and 0.3 kg ha^{-1} $year^{-1}$ respectively of copper as copper sulphate. Hence the mean annual application of superphosphate was below the estimated optimum annual maintenance requirements for pasture production. Although the phosphate sorption capacity is reduced by application of phosphatic fertilizers (Kanwar 1956, Kurtz and Quirk 1965) this reduction is insignificant compared to the extremely large phosphate retention capacity of this soil i.e. 15,400 p.p.m. for virgin 0-10 cm soil and 11,250 p.p.m. for partially-developed 0-10 cm soil (Kanwar 1956). However, to minimize possible variation in pasture production due to previous variation in fertilizer application on the trial site, a blanket dressing of 348 kg ha^{-1} of superphosphate and 0.94 kg ha^{-1} of copper was applied in 1970, during the establishment of the experiment.

A pasture mixture of 4.5 kg ha^{-1} of Bacchus Marsh subterranean clover and a trace of Colac perennial ryegrass and GB 81 phalaris had been sown on the newly-cleared land in 1951 but these species were scarce on the site in 1970. In 1960 the site was worked up in the spring, stumps ripped and the soil levelled and in 1961 a mixture comprising perennial ryegrass and Yarloop and Mt. Barker subterranean clovers sown. By 1969 the pasture was dominated by Yarloop subterranean clover and barley grass.

Other cultivars or species present were Mt. Barker, Dwalganup (although never sowed on the site) and Bacchus Marsh subterranean clovers, silver grass, soft brome, ripgut brome, geranium and capeweed.

EXPERIMENTAL METHODS

7. EXPERIMENTAL METHODS

7.1 Site preparation

An area of 11.6 hectares of land was prepared in 1970, with the exception of certain areas allocated to an unrenovated pasture treatment (see 7.2.1), as follows:

Dried pasture residue remaining from the 1969 growing season was burnt in March, ploughed in early April, cultivated and harrowed in mid-April and finally rolled with a cultipacker in late April.

7.2 Treatments

7.2.1 Pasture treatments

Five pasture treatments were incorporated in the design as follows:

Treatment A: The unrenovated, volunteer annual grass - subterranean clover pasture that was present on the experimental site as described in 6. The paddocks comprising this treatment were untouched in any way during the renovation of the remaining four treatments and for the duration of the experiment (except for the topdresssing of fertilizer).

Treatments B, C, D and E: Tillage, seed bed preparation and sowing of respective treatment grasses together with Mt. Barker and Woogenellup subterranean clovers. Treatment grasses were as follows:

B: Wimmera annual ryegrass

C: Victorian perennial ryegrass

D: Medea perennial ryegrass

E: Siro 1146 hybrid phalaris

The pasture treatments will hereafter be referred to as A, B, C, D and E respectively.

Wimmera and Victorian ryegrasses have been and are the most commonly sown annual and perennial grasses respectively on Kangaroo Island (the latter was frequently recommended e.g. Carter 1958, Taylor 1961).

Cutting experiments carried out on the Kangaroo Island Research Centre had shown Victorian ryegrass to be the most productive perennial pasture species in this environment (Crawford 1956). Tall fescues and cocksfoots had generally produced only small quantities of dry matter compared to the ryegrasses (Crawford 1956) and great difficulty had been encountered in adequately establishing varieties of phalaris on the ironstone soils.

Medea ryegrass was a recently released cultivar developed at the Waite Institute (Silsbury 1961) by selection of plants collected near Medea in Algeria (Neal Smith 1955). This cultivar was reputed to be characterized by a high degree of summer dormancy and persistence (Barnard 1972) and would have potential for widespread use on Kangaroo Island if its reputation for persistence could be substantiated under grazing on this soil type. Trials in Victoria had also shown Medea to produce more dry matter in late autumn, winter and early spring than Victorian ryegrass but that it was less productive during the rest of the season (Cade 1969).

Siro 1146 hybrid phalaris was developed by the CSIRO by the hybridization of *Phalaris tuberosa* and the hexaploid race of *Phalaris arundinacea*. Details concerning the hybridization have been reported in several publications (McWilliam 1962, McWilliam and Neal Smith 1962, Anon 1962). The more recent results concerning the characteristics and performance of this hybrid have been described (McWilliam *et al.* 1965, Myers and Squires 1968). Prior to 1970 this pasture species had received little testing under grazing but in the few trials that were then in progress the hybrid had shown an ability to establish readily, to combine well with a variety of legumes and to persist under heavy stocking and through extended dry periods. Although it generally appeared that maximum benefit from the use of the hybrid would be obtained from regions where summer rainfall incidence was high or where irrigation was available, reports of superior ease of establishment and persistence under waterlogged conditions indicated that this species may have been useful in the Kangaroo Island environment.

7.2.2 Stocking rates[+]

Information derived from previous experiments carried out on the Kangaroo Island Research Centre (Day 1964, Carter 1965, Carter and Day 1970) indicated that large-framed, strong-wool type, South Australian Merino wethers could be continuously grazed without supplementary feeding at a stocking rate of 13 sheep ha^{-1} without undue stress on the sheep. This was based on the pasture containing a major component of subterranean clover and supplied with an annual maintenance dressing of superphosphate at c. 190 kg ha^{-1}.

Six stocking rates chosen for the experiment described in this thesis were 10, 11, 13, 14, 15 and 17 sheep ha^{-1}, giving a range, incorporating an average and maximum, slightly higher than the respective 13 and 16.5 ha^{-1} used in the grazing experiment of Carter and Day (1970).

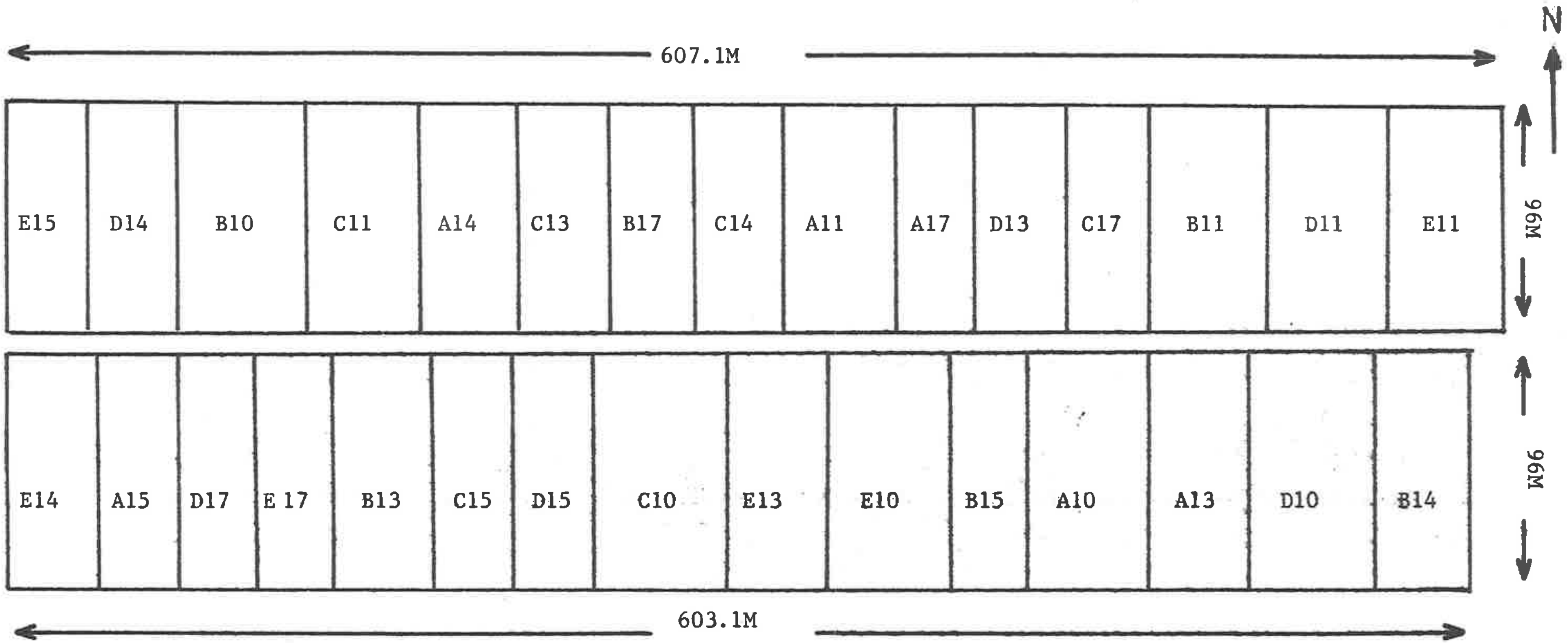
7.2.3 Layout and allocation of treatments

Pasture treatments and stocking rates were allocated at random to the experimental site which comprised fifteen elongate paddocks on each side of a single raceway. The length of each paddock was constant and the width varied to give the required areas for the allocated stocking rates. Seed bed preparation and sowing of pastures was completed prior to the erection of fences and watering facilities. Once set stocked, each paddock was continuously grazed by five sheep thus utilizing 150 experimental animals. There was no replication of treatments:

[+] In grazing trials, a number of stocking rates are necessary to detect treatment differences (Conniffe *et al.* 1970).

Plan of experimental paddocks

Pasture treatments and stocking rates were allocated at random to the experimental site. The length of each paddock was constant and the width varied to give the required areas for the allocated stocking rates. Each pasture treatment was unreplicated at comparative stocking rates.



<u>Treatments</u>

A - Unrenovated

B - Wimmera ARG

C - Victorian PRG

D - Medea PRG

E - Hybrid Phalaris

Postscripts for treatments indicate stocking rates in wethers hectare^{-1}

i.e. the 30 paddocks comprised Pastures (5) x Stocking Rates (6) = 30.

7.3 Pasture establishment

Pastures were sown on May 11, 12 and 13, 1970, as grass-subterranean clover mixtures through the seeds box of a 12 row, E series, Shearer combine. All seed, except Wimmera ryegrass, was certified with a potential germination of 90%†.

The experimental site had not previously been sown to Woogenellup subterranean clover: therefore, because of its specific rhizobial requirements, all Woogenellup seed was inoculated with commercial inoculant prior to sowing. Sowing rates used were approximately those currently recommended by the South Australian Department of Agriculture and adjusted to a 90% germination. Actual rates were:

- Wimmera ryegrass (Treat. B) 19.4 kg ha^{-1}.
- Victorian ryegrass (Treat. C) 10 kg ha^{-1}.
- Medea ryegrass (Treat. D) 9.7 kg ha^{-1}.
- Siro 1146 hybrid phalaris (Treat. E) 4.3 kg ha^{-1}.

Woogenellup and Mt. Barker subterranean clovers were sown in the ratio 3:2 at a combined sowing rate of 10.4 kg ha^{-1}.

7.4 Fertilizer application

All paddocks received 348 kg ha^{-1} of normal single superphosphate (9.6% P, 22% P_2O_5) during pasture establishment in May 1970, and applied as follows:

In treatments B, C, D and E 140 kg ha^{-1} was drilled in with the seed and in treatment A 140 kg ha^{-1} was topdressed onto the pasture. All treatments were topdressed again with 208 kg ha^{-1} of superphosphate

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† Tested by the South Australian Department of Agriculture and Fisheries' seed testing laboratory.

including 0.94 kg ha^{-1} of copper and 30 g ha^{-1} of molybdenum.

7.5 Selection and allocation of experimental animals

In October 1970, a line of 1000 wether hoggets (South Australian strong wool Merinos - Collinsville blood) from Pitlochry Cortina, Cantara, South Australia, were visually examined for any obvious foot, mouth, pizzle or wool defects and 370 culled from the main flock. The remaining 630 sheep were consecutively numbered and shorn. Total greasy fleece weight (weighed to 0.05 kg), including locks, skirtings and pieces but excluding belly wool and dags, was recorded for each sheep. The wethers were then weighed (to the nearest 0.5 kg) off-shears and 250 which conformed to the criteria, $40.9 \text{ kg} < \text{liveweight} < 52.2 \text{ kg}$ and $5.3 \text{ kg} < \text{greasy fleece weight} < 6.8 \text{ kg}$, were purchased.

Following transport to the Kangaroo Island Research Centre the wethers were given a cobalt bullet, drenched, tagged with large, easily-read cattle tags and grazed as a single flock until placed on their allocated paddocks on December 22, 1970. The allocation of sheep to paddocks was performed by graphically plotting the fleece weight against liveweight for each sheep (as determined in October, 1970) and stratifying the 250 wethers into groups. Allocation to both pasture treatments and stocking rates was made from these groupings at random. Each of the 30 paddocks comprising the experiment was allocated five sheep with similar mean liveweight and mean greasy fleece weight at the start of the experiment. The 100 wethers remaining were run as one flock of spares in laneways and spare paddocks around the experimental site. The wethers were two years old at the time of placement in their paddocks and thereafter they grazed their allotted paddocks continuously until the end of the experiment in January 1975.

7.6 Grazing management of pastures in 1970

Management of the pastures in the first year prior to set stocking with the experimental animals was designed to fulfil the following criteria.

a) Ensure that approximately equivalent amounts of pasture were available on all paddocks prior to the allocation of experimental animals to their paddocks in December 1970.

b) Ensure that the treatment grasses were dominant in 1971 (i.e. allow maximum seed set of treatment grasses in the spring of 1970) without undue suppression of the subterranean clover component.

c) Graze treatment A paddocks at least once in keeping with normal commercial practice.

Treatment A paddocks were uniformly grazed for six weeks (June 18 to July 29) by a large flock of wethers divided into equivalent numbers per unit area for each paddock. Treatment B paddocks were similarly grazed during the early spring (September 17 to October 7) as pasture production was far in excess of the other renovated treatments and severe suppression of the subterranean clover component was occurring. The allowance of an adequate growth period following the grazing of treatment B was considered essential to allow adequate seed set of the Wimmera ryegrass. Treatments C, D and E remained ungrazed until set stocked with the experimental animals in December 1970.

7.7 Routine management

7.7.1 Pastures

Fertilizer application: From 1971 to 1974 inclusive, all paddocks were topdressed with 200 kg ha^{-1} of single superphosphate prior to the opening rains in each year.

Insect control: All paddocks were misted with 350 g ha^{-1} (active ingredient) of 'Imidine' five weeks after the opening rains in each year to control red-legged-earth mite *(Halotydeus destructor)*. In some years a second misting was performed to control later hatchings.

7.7.2 Animals

Flystrike: The wethers were crutched once during the spring of each year and strategically jetted (common treatment to all sheep) with 'Diazinon' in the experimental paddocks as required.

Worms: All experimental animals were drenched in the autumn of each year with 'Thiobendazole' to control round worms. Additional drenching was carried out as required.

Lice: Dipping was carried out off-shears for control of lice *(Damalina ovis)* and ked *(Melophagus ovinus)* prior to selection of the experimental animals and again in January 1973.

Pizzle rot: During the experimental period a number of animals were lanced to release accumulated fluids.

Supplementary feeding: Wethers grazing in treatments B, C and D at the highest stocking rate (17 ha^{-1}) were fed 0.5 kg of oats $sheep^{-1}$ day^{-1} for one week only, commencing 2nd July 1972, to prevent death from undernutrition. No hand feeding or fodder conservation was carried out at any other time during the experiment.

Replacement of animals: Experimental animals that died in their paddocks were replaced within a few days (usually within 24 hours) from the reserve flock grazing near the experimental site. The replacement sheep were matched as closely as possible on the basis of live weight and wool cutting ability as determined in the original weighing and shearing (October 1970).

Live weights of replacement sheep were not used in the group data means for at least 12 weeks. Fleece weights and measurements of fleece characteristics of replacement animals were not used in the data analysis in the year of replacement.

Causes of death of experimental wethers other than undernutrition included pizzle rot, obesity[+] and flystrike and are listed in appendix Table 29.

7.8 Data collection procedures

7.8.1 Pasture data 1970

Established plants of the sown pasture species and Yarloop subterranean clover were counted in each of ten randomly-thrown, 0.04 m^2 quadrats on June 17, 1970. Pasture production in the sown treatments was measured over two periods i.e. May 11 to September 17 and September 17 to November 25 using the techniques described for 'open' cuts in 7.8.2. In treatment B both 'open and closed' cuts were taken because of the presence of grazing sheep as described in 7.6.

Available pasture was measured on all paddocks on November 11 to coincide with the end of the growing season.

7.8.2 Pasture data 1971-1974

The 'open and closed quadrat' method of McIntyre (1946) was used to estimate dry matter availability, seasonal and total dry matter production, and crude utilization (amount of pasture dry matter eaten or otherwise disappearing - refer Carter and Day 1970).

Samples were cut from six areas protected by 'Weldmesh' cages

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[+] several fat sheep died but the cause was listed as unknown in appendix Table 29.

(closed quadrats) c. 1.4 m square. Within each of these cages a 0.5 m^2 quadrat was cut at ground level with a mobile, motorized sheep-shearing hand piece with 'wide' combs and cutters. A corresponding sample was cut from without, but in close proximity to, each cage. Thus the number, size and shape of the 'closed' cuts from within the cages were the same as for the 'open' quadrats. Following cutting of the protected quadrat site, the cage was placed at random on a new un-cut site in the paddock. No pasture measurements were made during the characteristic 4-5 month period of summer drought and the protective cages were shifted to a new site just before the opening rains in each season. Three samplings were made during each growing season to approximately coincide with the end of the three calendar seasons, autumn, winter and spring. The one exception being in 1971 when an extra sampling was made in July. On most occasions, individual green weights were recorded for each of the six 'open' and six 'closed' samples. These samples were then bulked into 'open' and 'closed' lots and a representative subsample was taken from each lot. The size of the subsample was usually 10% of the total green herbage within each lot but varied depending on size and growth stage of the pasture plants. Strict mixing and subsampling procedures were followed to ensure representative subsamples.

Each subsample was hand-separated, while fresh, into botanical components which were then dried separately to constant weight in a forced air-drought oven at 85°C.

The components were as follows:

(1) Sown grass (2) Subterranean clover (3) Broad-leaved volunteers and (4) Narrow-leaved volunteers.

Plant density: Ten fixed sampling sites marked with yellow-painted jarrah pegs were selected at random in each paddock at the start of the experiment. In June of each year all perennial† plants and subterranean clover plants within a one m^{-2} quadrat, placed at each site, were counted.

7.8.3 Subterranean clover seed

Measurement of subterranean clover seed present in, or on, the soil was made on four occasions during the experiment, i.e. August 1973 and 1974 and January 1974 and 1975. The difference in quantity of seed recorded between the spring and following summer sampling was used as a crude estimation of seed produced during the season. No attempt was made to measure loss of seed due to trampling, eating, or any other cause, during the intervening period. The sampling during August also estimated the hard seed reserves present at that time.

At the August samplings 30 round cores of 10 cm diameter and 5 cm depth were taken at random within three transects across each paddock. The 10 cores from each paddock transect were bulked to give three lots per paddock which were then dried at 50°C, broken up and sieved through a 0.5 mm sieve to reduce the sample bulk by separation of fine soil particles. The sample was then thoroughly stirred in 'Genklene' solution (trichloroethane SG 1.314) to separate the coarse sand, gravel and stones from the floating sample mass (Carter, Challis and Ridgway 1977).

The sample was then air dried, threshed in a belt thrasher, hand-sorted into white seed (Yarloop) and black seed (non-Yarloop) and each lot weighed to 0.001 g.

At the January samplings, above and below-ground components were sampled separately. The above-ground sampling was performed by cutting six 0.5 m^2 quadrats at ground level in each paddock in a similar manner to that described for pasture availability during the growing season. The soil surface was then brushed with a fibre brush and all loose soil and dry herbage collected, dried at 50°C for 24 hours and hand-picked to

† plants that had survived at least one summer.

remove faeces, sticks and large stones. Following the removal of the above-ground material, the soil was carefully hoed to a depth of 5 cm, removed and bulked into three sample lots per paddock. Final treatment of the above and below-ground fractions was similar to that used for the August samples.

7.8.4 Sheep live weights

All sheep (experimental and spares) were weighed at approximately six-weekly intervals. Occasionally, additional weighings were made when animals were in stress periods. The sheep were weighed in the raceway, at the entrance to each paddock, using mobile scales. Liveweight data were recorded to the nearest 0.1 kg. Sheep were weighed throughout the day and no special measures were taken to ensure sheep were of similar gut-fill.

7.8.5 Annual wool production

All experimental sheep were removed from their paddocks on the day of, or one day prior to, shearing and were driven as a single flock to the shearing shed (c. 1 km). The sheep were transported back to their paddocks, the same day or early the next day following shearing, in their respective experimental groups. All sheep were combined into one flock in the shearing shed and randomly selected by the shearers. The same procedure was repeated in the spring of each year when the sheep were crutched and only on these two occasions, during any one year, were the experimental sheep removed from their paddocks.

Total greasy fleece weight in all data presented is the summation of the individual weights of dyeband sample (refer 7.8.7), midside sample (refer 7.8.6) locks, belly and skirted fleece of each sheep. Bellies, locks and fleece of each sheep were weighed separately in each year (with the exception of the January 1972[†] shearing when the total weight only was recorded).

7.8.6 Fleece characteristics

A sample of wool was taken from the midside of each fleece as each sheep was shorn. This sample was then weighed, placed in an air-tight plastic bag with an identification card, and sent to the Gordon Institute of Technology, Geelong, Victoria for analysis. The following fleece measurements were made on each midside sample: a) Yield at 16% regain b) mean staple length c) mean number of crimps per unit length of fibre (crimp frequency) and d) mean fibre diameter.

7.8.7 Seasonal wool production

On most occasions of liveweight measurement, a dyeband (10-15 cm long) was applied dorso-ventrally on each sheep in the approximate position of the last rib, according to the technique of Short and Chapman (1965).

Each year, one day prior to annual shearing, the dyeband staples were carefully removed by clipping the wool as close to the skin as possible using 'Oster' small animal clippers. Application of dyebands and removal of dyeband staples were performed in a sheep-holding cage. This unit contained a rotatable side to which the animal was strapped and held on its side at a convenient working height. The width of staple removed was from c. 2-3 cm of skin. Each harvested, dyebanded staple was weighed, had a length of tissue paper placed along its length, rolled and stored in a bag.

All dyeband staples for all years were measured as follows: The staples were opened so that an even spread of dyebands was obtained on both sides. Five measurements were made on each half of the sample

† shearing was in January each year (refer appendix Tables 17-20 for dates).

(taking care to measure staples of good length, i.e. away from the belly and back extremities). The staple was placed in a natural (unstretched) position and the measurements were made by zeroing a ruler on the base of the staple, and then reading off the lengths at the proximal end of each dyeband. The length between dyebands, used in conjunction with the total clean fleece weight, allowed estimates to be made of periodic clean wool growth during each year.

7.9 Data analysis

In all statistical analyses, the mean measurement for each paddock has been used as the basic experimental unit (e.g. mean live weight of the five sheep on each weighing occasion, or mean availability of pasture in each paddock on each sampling occasion). Regressions of each unit of measurement on stocking rate on each sampling occasion were performed and the relationship tested for linearity. On nearly all occasions, higher order polynomial relationships could not be justified statistically due to insufficient levels of the x variate (stocking rate), even though they may have been biologically possible or probable. Tests of homogeneity of regression coefficients (homogeneity of the slopes of the regression of each unit of measurement, for each pasture treatment, on stocking rate) were performed to indicate any significant interaction between pasture treatment and stocking rate. The mean regression coefficient for the five regression relationships (five pasture treatments on stocking rate) has also been calculated for each unit of measurement.

Where the heterogeneity of regression coefficients was not statistically significant ($P > 0.05$) a test of homogeneity of adjusted treatment means (adjusted to $x = \bar{\bar{x}}$ where $\bar{\bar{x}}$ = mean of all the x-values of K treatment samples+) was performed to indicate whether the pasture

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+ as the same stocking rates were used over each pasture treatment $\bar{\bar{x}} = \bar{x}$ (mean of stocking rates 10, 11, 13, 14, 15 and 17 ha^{-1}).

treatment means (averaged over stocking rates) were statistically different and the least significant difference (LSD) between these means calculated. Angular transformation of proportional data (percent) was performed as required.

RESULTS

8. RESULTS

8.1 Pasture establishment

With the exception of the hybrid phalaris, the sown grasses and legumes established satisfactorily (Table 3), in particular, the density of perennial ryegrass plants (treatments C and D) were obviously higher than the density that could be maintained as perennial plants in the following years. The density of established hybrid phalaris plants was low, although superior to previously obtained densities of phalaris (cv. Australian) sown at similar rates on this soil type on Kangaroo Island. The density of hybrid plants was considered sufficient to allow this species to make a worthwhile contribution to pasture production in the later years of the experiment, provided that the individual plants expanded in diameter, as is characteristic of this species.

There was no significant ($P > 0.05$) difference between the density of established sown grass plants within each sown pasture treatment over the range of stocking rates, or in the case of subterranean clover plants, over all renovated paddocks. However, the mean density of Yarloop subterranean clover plants in treatment A was 580 plants m^{-2} compared to the combined 85 plants m^{-2} of Mt. Barker and Woogenellup and 25 plants m^{-2} of Yarloop subterranean clovers established in the renovated paddocks.

A visual inspection of the pastures during the spring showed that, within the narrow-leaved volunteer component, barley grass and ripgut brome were the dominant species in treatments A and E respectively.

8.2 Pasture production 1970

The superior pasture production in treatment B during the autumn and winter is shown in Table 4. There was less difference between pasture treatments in pasture production during the spring. A different seasonal growth pattern for the two perennial ryegrass species (treatments C and D) is also evident in Table 4.

Some variation in levels of available pasture was present at the end of the 1970 growing season (Table 4) because of the difficulty of achieving even grazing. Treatment A contained the lowest, and treatment D the highest, amounts of available pasture at the end of the 1970 growing season.

8.3 Botanical composition 1971-1974

8.3.1 Sown grasses

The renovation of the original pasture by the sowing of Wimmera ryegrass (treatment B), Victorian ryegrass (treatment C) and Medea ryegrass (treatment D), together with Mt. Barker and Woogenellup subterranean clovers resulted in ryegrass-dominant pastures in the autumn of 1971 (Table 5).

The majority of Victorian ryegrass plants died over the 1972/73 summer (Table 6) and although some self-sowing of this species occurred in the autumn of 1973, its contribution was negligible by the end of the 1973 season (Table 5). The Medea ryegrass plants died during each summer of the experiment except for a few plants which survived the 1973/74 summer at the lower stocking rates (Table 6).

In the first three years of set stocking there was a within-year decline in the ryegrass component in all three ryegrass treatments during the autumn and winter and in some years the decline continued during the spring.

An effect of stocking rate on the between-year decline in the proportion of Wimmera and Victorian ryegrasses was evident over the first two summers following set stocking (1971/72 and 1972/73) Figure 1.

Table 3

PURITY, VIABILITY AND ESTABLISHMENT OF SOWN PASTURE SEED 1970

Species	Purity %	Germ^n 14 days %	Viable Sowing Rate ($kg\ ha^{-1}$)	Potential Establish. ($plant\ m^{-2}$)	Actual[+] Establish. ($plant\ m^{-2}$)	Establish.[+] %
Wimmera A.R.G.	-		19.4	1000	290	29 .0
Victorian P.R.G.	99.8	90	10.0	600	190	31.6
Medea P.R.G.	99.5	90	10.0	600	200	33.3
Hybrid Phalaris	99.0	88	4.3	375	56	15
Mt. Barker	99.3	90	6.2	(110	(85	(77
Woogenellup	99.6	92	4.2	(	(	(

[+]established plants on June 17, 1970.

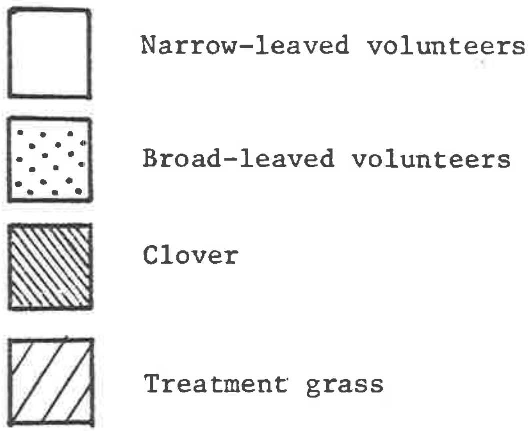
Table 4

PASTURE GROWTH FOR TWO PERIODS IN 1970 AND AVAILABLE PASTURE AT THE END OF THE 1970 GROWING SEASON ‡

Growth Period	Pasture treatment means A	B	C	D	E	LSD 5%
	Pasture growth ($kg\ ha^{-1} day^{-1}$)					
11/5-17/9	-	44	21	33	18	3.2
17/9-25/11	-	68	65	51	59	10.7
Date	Pasture availability ($kg\ ha^{-1}$)					
25/11	4575	6230	7210	7750	6360	570

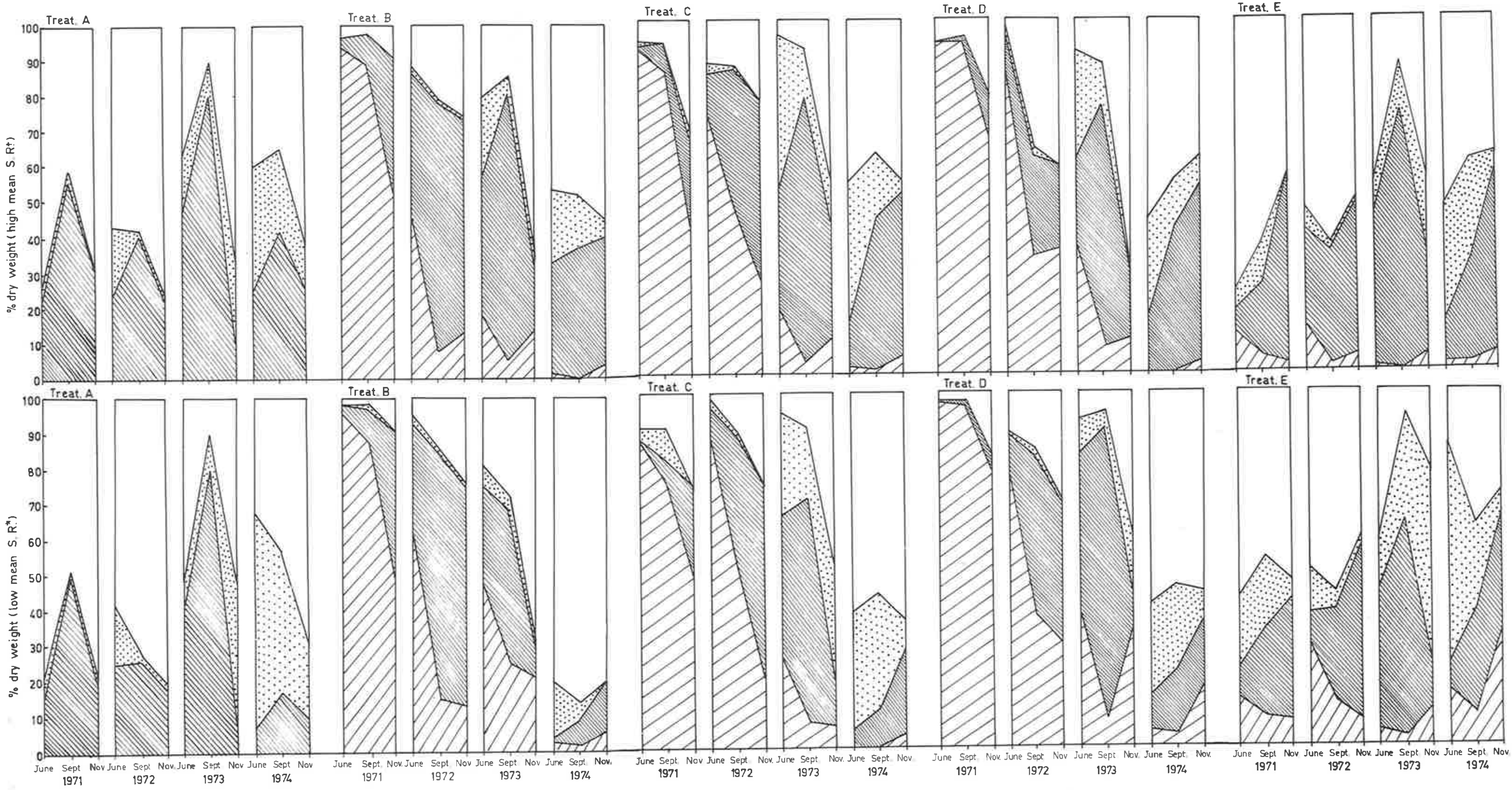
‡Pasture treatments A and B received 1600 and 3600 grazing days ha^{-1} respectively

Figure 1. Effect of stocking rate and duration of continuous grazing on the botanical composition measured in each treatment on three occasions in each year of the experiment.



$^{+}$ = mean of 14, 15 and 17 wethers ha^{-1}

* = mean of 10, 11 and 13 wethers ha^{-1}



Treat. A
Treat. B
Treat. C
Treat. D
Treat. E
% dry weight (high mean S. R†)
% dry weight (low mean S. R*)
0
10
20
30
40
50
60
70
80
90
100
June Sept Nov June Sept Nov June Sept Nov June Sept Nov
1971
1972
1973
1974

Table 5

PROPORTION OF SOWN GRASS IN THE PASTURE ON TWELVE OCCASIONS DURING THE EXPERIMENT

(% Dry Weight)

Date	Pasture Treatments B	C	D	E	Hetero. Adjt. Treat. Means	LSD 5%	Sig. Mean Reg. on SR.	Hetero Reg. Coeff.
2/6/71	97	91	97	15	***	5.6	NS	NS
8/9	90	83	97	8	***	9.9	NS	NS
24/11	*+ 51	45	73	6	***	14.5	NS	NS
27/6/72	56	** 82	83	22	***	18.4	*	NS
26/9	13	51	37	8	***	9.6	NS	NS
16/11	15	26	34	8	***	9.6	NS	NS
18/6/73	* 35	24	37	9	–	–	**	*
17/9	18	7	9	7	*	9.4	*	NS
26/11	19	9	* 23	12	–	–	*	*
10/6/74	4	3	4	12	NS	8.6	NS	NS
2/9	2	3	5	7	NS	3.8	*	NS
18/11	7	5	* 12	21	–	–	**	**

NS = P > 0.05 * = P < 0.05 ** = P < 0.01 *** = P < 0.001

+ = Significance of within-treatment regressions on stocking rate

Table 6

DENSITY OF PERENNIAL+ PLANTS PRESENT IN JUNE OF EACH YEAR

(Mean of 10 fixed locations per paddock)

(plants m^{-2})

Year	Stocking Rate						Sig.‡ Reg.
	10	11	13	14	15	17	
	Victorian perennial ryegrass						
1971	48	47	51	54	47	49	NS
1972	47	38	40	30	25	21	**
1973	5	2	1	0	0	0	*
1974	10	12	8	6	4	1	**
	Medea perennial ryegrass						
1971	0	0	0	0	0	0	-
1972	0	0	0	0	0	0	-
1973	0	0	0	0	0	0	-
1974	15	12	7	6	5	5	**
	Hybrid phalaris						
1971	25	29	28	28	34	30	NS
1972	18	23	20	19	26	20	NS
1973	17	22	20	18	25	19	NS
1974	17	21	19	18	26	18	NS

+ = Plants which have survived at least one summer

‡ = Significance of regression of plant number on stocking rate.

NS = $P > 0.05$, * = $P < 0.05$, ** = $P < 0.01$

PLATE 2

Victorian ryegrass plants in July 1971 grazed at 11 wethers ha^{-1}.

PLATE 3

The same location in April 1973 depicting the dead perennial ryegrass plants. The majority of the Victorian plants died over the 1972/73 summer.

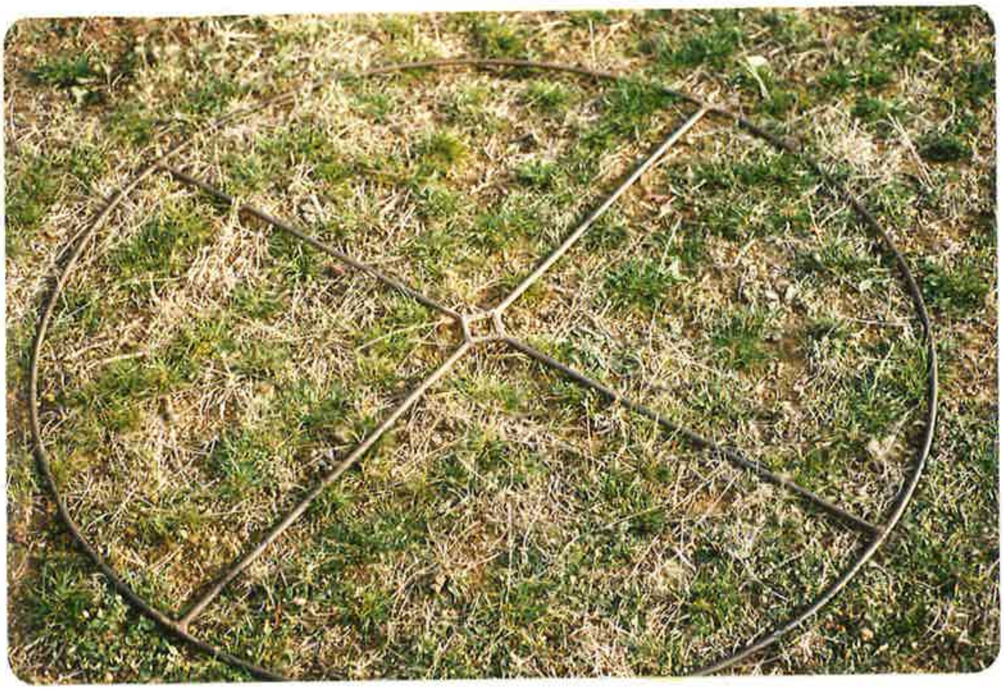


PLATE 4

Victorian ryegrass plants grazed at 10 wethers ha^{-1} and photographed in June 1972. The mean density of perennial plants in this paddock was $47m^{-2}$.

PLATE 5

Simultaneous photograph of Victorian ryegrass plants grazed at 17 wethers ha^{-1} depicting the severity of grazing pressure and the marked effect this has had on the density of perennial plants in this paddock (mean $21m^{-2}$).

In each case, higher stocking rates were associated with a lower sown grass component in the autumn of the following year.

In the Victorian ryegrass treatment the decline in proportion of ryegrass was usually associated with a between-year decline in the number of perennial plants that survived each summer and increased stocking rate enhanced this between-year decline in density of Victorian ryegrass plants (Table 6).

However, irrespective of stocking rate, the contribution of the ryegrass in treatments B, C and D had declined to almost negligible proportions by the 1974 season (Table 5).

In contrast to the three sown ryegrass treatments, the renovation of the original pasture by the sowing of the hybrid phalaris (treatment E) resulted in only a low proportion of this species component being present in the pasture in the autumn of 1971 (Table 5). The size of the hybrid phalaris component varied little over the experimental period and, although in most years there was a larger component at the lower stocking rates (Figure 1), on no occasion was the regression of the proportion of hybrid phalaris in the pasture, or density of perennial plants (Table 6) on stocking rate, significant ($P > 0.05$). Following an initial between-year decline from 1971 to 1972 the mean number of hybrid phalaris plants remained constant, although it was noticeable from visual observation that the crown circumference of the plants had increased over the experimental period, particularly at the lower stocking rates.

8.3.2 Subterranean clover

The proportion of subterranean clover in the pasture in 1971 was highest in treatment A and lowest in treatment D and reflected the management of the pastures in 1970. The vigorous growth of the sown ryegrasses in 1970 resulted in suppression of the clover growth (and probably seed production in the spring). The less vigorous growth of hybrid phalaris in treatment E did not result in the suppression of clover growth in 1970, and allowed adequate seed set of the introduced subterranean clover varieties (Mt. Barker and Woogenellup). Consequently, in 1971 the density of clover plants in treatment E, as also in treatment A, was significantly (P <0.001) higher than in the three ryegrass treatments (Table 7). However, all pasture treatments contained a substantial clover component by the spring of 1972 (Figure 1) associated with a rapid between-year increase in the density of clover plants in treatments B, C and D from 1971 to 1972 (Table 7).

The proportion of Yarloop in the total subterranean clover component averaged 27 per cent for the four renovated treatments (B, C, D and E) in June 1971 but the rapid invasion of Yarloop into these treatments (irrespective of stocking rate) resulted in this proportion being increased to 76 per cent by June 1974 (Table 8).

In treatment A the early physiological maturation of Yarloop resulted in a within-year decline in the clover component during the late spring following a peak contribution during the winter in all years (Figure 1). In contrast there was a general pattern of an increasing within-year subterranean clover component throughout the growing season in the renovated treatments, particularly in treatment E (Figure 1). In 1973 there was a marked decline in the clover component during the spring in all treatments (Figure 1) due to a severe attack of clover scorch caused by the fungus *Kabatiella caulivora* (Walker 1956, Beale 1972).

Only on one occasion (September 26, 1972) during the experiment was a significant (P <0.05) interaction between pasture treatment and stocking rate in the proportion of clover present in the pasture recorded (Tables 9 and 10). On this occasion a significant (P <0.05) increase in proportion of subterranean clover with increased stocking rate was recorded in treatment A but not in any of the other pasture treatments.

On November 24, 1971, November 26, 1973 and on all sampling occasions in 1974 the mean proportion of clover in the pasture increased significantly with increased stocking rate (Tables 9 and 10). The mean regression coefficient (mean proportion of clover over all pasture treatments on stocking rate) differed significantly from zero (Tables 9 and 10). However, with the exception of treatment D, no influence of stocking rate on the density of clover plants counted in June of each year was evident (Table 7). In treatment D, a decrease in the proportion of clover with increased stocking rate was evident on four sampling occasions from September 26, 1972 to September 17, 1973 inclusive although the regression was only significant ($P < 0.05$) on one occasion (June 18, 1973). This relationship was associated with a significant decline in density of clover plants with increased stocking rate in treatment D in 1972 and 1973 (Table 7). The data in Table 7 also emphasizes the lower mean density of clover plants in treatment D in 1971, 1972 and 1973 compared to the other pasture treatments.

8.3.3 Volunteer annual species

Treatment E was rapidly invaded by volunteer annual species (particularly ripgut brome) during 1970, the year of pasture establishment, due to the poor establishment and seedling vigour of the hybrid phalaris. In 1971, the broad-leaved component, comprising mainly capeweed and geranium, was greatest in this treatment, particularly at the lower stocking rates (Figure 1, Table 11). However, in both treatments A and E the narrow-leaved component, comprising mainly barley grass and ripgut brome respectively, was the dominant pasture component in 1971 (Table 13). The broad-leaved component increased from one year to the next in all treatments and by 1974 was making a significant contribution to the botanical composition (Figure 1, Tables 11 and 12). Particularly evident was the between-year increase in the broad-leaved component from 1972 to 1973 in treatment C (Figure 1, Tables 11 and 12) following the death of the Victorian ryegrass plants over the 1972/73 summer.

The mean (of treatments) broad-leaved component was significantly ($P < 0.01$) larger at the high stocking rates on the first sampling occasion in 1973 (June 18, 1973) but by the final sampling occasion in the spring of the same year (November 26, 1973) the relationship was reversed with a significantly ($P < 0.01$) smaller component at the high stocking rates (Figure 1, Table 12). However, no effect of stocking rate on the proportion of broad-leaved volunteers in the pasture was evident in 1974.

On three occasions in 1971 and 1972, significant interactions between stocking rate and pasture treatment in the size of the narrow-leaved volunteer component were recorded (Table 13). This interaction was mainly due to a decline in the narrow-leaved component in treatment A and increase in treatment E with increased stocking rate resulting in no record of any significant ($P > 0.05$) mean (over all treatments) influence of stocking rate on the size of the narrow-leaved component. In 1973 and 1974, instances of stocking rate affecting the size of the mean narrow-leaved component were recorded (Figure 1, Table 14); however the relationship was positive in 1973 and negative in 1974 (Table 14). In treatment E in 1974, as in 1971 and 1972, the size of the narrow-leaved component increased with increased stocking rate (this component tended to decrease with increased stocking rate in the other pasture treatments) resulting in a significant Pasture treatment x Stocking rate interaction being recorded on two occasions (Table 14).

Table 7

DENSITY OF SUBTERRANEAN CLOVER PLANTS PRESENT IN JUNE OF EACH YEAR

(plants m^{-2})

Year	Pasture treatments means					LSD 5%
	A	B	C	D	E	
1971	534	92	81	8	362	64
1972	438	411	288	172**+	318	87
1973	356	251	284	195*	373	51
1974	233	243	267	242	255	46

\+ = Significance of within-treatment regressions on stocking rate.

* = $P < 0.05$, ** = $P < 0.01$

Table 8

PROPORTION OF YARLOOP SUBTERRANEAN CLOVER IN THE TOTAL CLOVER COMPONENT PRESENT IN THE PASTURES IN 1971 AND 1974

(% dry weight)

Date	Pasture treatment means					LSD 5%
	A	B	C	D	E	
2/6/71	100	30	20	37	22	6.4
10/6/74	100	81	70	87	66	10.4

Table 9

PROPORTION OF SUBTERRANEAN CLOVER IN THE PASTURE ON SIX OCCASIONS IN 1971-1972
(% dry weight)

Date	Pasture treatment means A	B	C	D	E	Stocking rate means (sheep ha^{-1}) 10	11	13	14	15	17	Grand Mean	Hetero. Adjt. treat. mean	LSD 5% treat. mean	Sig. mean Reg. on SR.	Hetero. Reg. Coeff.
2/6/71	18	2	1	0	8	2	5	8	7	6	6	6	***	5.2	NS	NS
8/9	53	10	7	1	23	16	18	21	23	16	18	19	***	7.9	NS	NS
24/11	27	41	27	7	44	19	27	32	25	36	36	29	***	12.2	**	NS
27/6/72	24	35	9	10	18	10	21	16	20	22	26	19	**	13.6	NS	NS
26/9	33*+	70	38	37	29	38	38	46	40	44	42	41	-	-	NS	*
16/11	20	61	51	32	46	33	50	51	32	49	38	42	***	15.8	NS	NS

+ = Significance of within-treatment regressions on stocking rate.

NS = $P > 0.05$ * = $P < 0.05$ ** = $P < 0.01$ ***= $P < 0.001$

Table 10

PROPORTION OF SUBTERRANEAN CLOVER IN THE PASTURE ON SIX OCCASIONS IN 1973-1974

(% dry weight)

Date	Pasture treatment means					Stocking rate means (sheep ha^{-1})						Grand mean	Hetero. Adjt. Treat. means	LSD 5% treat. means	Sig. mean Reg. on SR.	Hetero. Reg. Coeff.
	A	B	C	D	E	10	11	13	14	15	17					
18/6/73	44	33	36	35 *‡	40	41	35	38	39	40	31	37	NS	11.7	NS	NS
17/9	81	59	69	75	67	70	60	67	78	76	71	70	NS	18.2	NS	NS
26/11	7	13	22 *+	14	20	10	9	11	23	15	22	15	NS	13.2	*	NS
10/6/74	16 *	17	10	13	10	4	2	12	16	25	19	13	NS	12.4	**	NS
2/9	29 **	22	27	29	30	14	7	28	38	35	42	27	NS	15.4	***	NS
18/11	18 *	25	36	34	42	21	14	26	35	48	42	31	*	13.9	***	NS

+ = Significance of within-treatment regressions on stocking rate.

NS = P > 0.05 * = P < 0.05 ** = P < 0.01 *** = P < 0.001

‡ = negative correlation

Table 11

PROPORTION OF BROAD-LEAVED VOLUNTEERS IN THE PASTURE ON SIX OCCASIONS IN 1971-1972

(% dry weight)

Date	Pasture treatment means					Stocking rate (sheep ha^{-1})						Grand mean	Hetero. Adjt. treat. means	LSD 5% treat. means	Sig. mean Reg. on SR	Hetero. Reg. Coeff.
	A	B	C	D	E	10	11	13	14	15	17					
2/6/71	4	0	2	0	12 **+	6	8	3	3	1	1	3.6	-	-	**	**
8/9	2	1	4	0	15	10	2	7	4	2	2	4.5	*	9.8	NS	NS
24/11	0	0	0	0	2	2	1	0	0	0	0	0.5	-	-	NS	**
27/6/72	19	2	3	2	10	7	6	10	6	9	4	7.0	***	6.4	NS	NS
26/9	2	1	1	2	4	3	1	3	1	1	2	1.9	*	1.8	NS	NS
16/11	2	1	0	1	2	2	1	1	1	1	1	1.2	***	0.98	*	NS

+ = Significance of within-treatment regressions on stocking rate

NS = P > 0.05   * = P < 0.05   ** = P < 0.01   *** = P < 0.001

Table 12

PROPORTION OF BROAD-LEAVED VOLUNTEERS IN THE PASTURE ON SIX OCCASIONS IN 1973-1974

(% dry weight)

	Pasture treatment means					Stocking rate means (sheep ha^{-1})						Grand mean	Hetero. Adjt. treat. means	LSD 5% treat. means	Sig. mean Reg. on SR.	Hetero. Reg. Coeff.
	A	B	C	D	E	10	11	13	14	15	17					
18/6/73	13	14	37	21	12	10	10	21	25	22	28	19.3	**	1.3	**	NS
17/9	9	4	17	9	19	12	9	17	11	9	11	11.7	NS	13.1	NS	NS
26/11	34	3	24	9	38	30	27	31	25	8	7	21.7	**	18.5	**	NS
10/6/74	48	17	36	26	46	37	27	54	40	29	20	35.0	NS	25.4	NS	NS
2/9	31	10	25	18	26	27	22	25	27	13	18	22.2	NS	16.5	NS	NS
18/11	18	3	6	8	5	10	6	11	12	4	4	7.8	*	6.6	NS	NS

NS = P > 0.05 * = P < 0.05 ** = P < 0.01 ***= P < 0.001

Table 13

PROPORTION OF NARROW-LEAVED VOLUNTEERS IN THE PASTURE ON SIX OCCASIONS IN 1971-1972

(% Dry Weight)

Date	Pasture treatment means					Stocking rate means (sheep ha^{-1})						Grand mean	Hetero. Adjt. treat. means	LSD 5% treat. means	Sig. mean Reg. on SR.	Hetero. Reg. Coeff.
	A	B	C	D	E	10	11	13	14	15	17					
2/6/71	77	1	6	3	65	35	25	27	31	33	32	30.4	-	-	NS	*
8/9	46	0	6	2	54*+	21	19	21	17	24	24	21.0	-	-	NS	**
24/11	72	8	28	20	48	40	34	33	36	28	39	35.0	***	15.5	NS	NS
27/6/72	56	7	6	5	50	15	25	31	22	26	28	24.7	***	14.4	NS	NS
26/9	64*	16	10	25*	59	35	29	33	42	32	36	34.6	-	-	NS	**
16/11	77	23	23	34	44	44	34	37	47	36	41	40.1	***	10.5	NS	NS

+ = Significance of within-treatment regressions on stocking rate

NS = $P > 0.05$ * = $P < 0.05$ ** = $P < 0.01$ *** = $P < 0.001$

Table 14

PROPORTION OF NARROW-LEAVED VOLUNTEERS IN THE PASTURE ON SIX OCCASIONS IN 1973-1974

(% dry weight)

Date	Pasture treatment means					Stocking rate means (sheep ha^{-1})						Grand mean	Hetero. Adjt. treat. means	LSD 5% treat. means	Sig. mean Reg. on SR.	Hetero. Reg. Coeff.
	A	B	C	D	E	10	11	13	14	15	17					
18/6/73	42	18	3	7	43	24	25	21	17	24	25	22.5	***	11.4	NS	NS
17/9	8	19	7	7	7	8	12	10	6	11	11	9.6	*	7.9	NS	NS
26/11	57	65	45	54 **+	32 **	43	45	46	44	66	60	50.6	*	18.5	*	NS
10/6/74	34	62	52	57	32	55	57	31	40	44	57	47.2	-	-	NS	*
2/9	38	66	45	48	37	53	66	43	33	48	38	46.6	NS	20.6	*	NS
18/11	63	65	53	46	32	53	61	57	45	44	48	51.7	-	-	*	**

NS = P > 0.05   * = P < 0.05   ** = P < 0.01   ** = P < 0.001

+ = Significance of within-treatment regressions on stocking rate.

PLATE 6

Typical density and size of hybrid phalaris plants in September 1971.

PLATE 7

Size of hybrid phalaris plants in September 1975 following 4 years continuous grazing at 10 wethers ha^{-1} and intermittent grazing during 1975.

PLATE 8

Treatment C (14 we.ha^{-1}) in August 1972. The clover-depleted pastures in the ryegrass treatments in 1971 were invaded by Yarloop in 1972 but ryegrass dominance still occurred in this treatment.

PLATE 9

Simultaneous photograph of the pasture in treatment B (14 we.ha^{-1}). Concurrent with the more rapid decline in the Wimmera component was a more marked invasion by Yarloop in this treatment resulting in clover dominance in 1972.

PLATE 10

Dense germination of Yarloop in treatment D (10 $we.ha^{-1}$) in April 1973.

PLATE 11

Simultaneous photograph of germinated Yarloop in the same treatment grazed at 17 wethers ha^{-1}. There was a significant depression in density of established Yarloop plants at the higher stocking rates in June 1973 in this treatment.

Although no data were collected on the botanical composition within either the broad- or narrow-leaved components it was obvious from visual observation that the proportion of barley grass, ripgut brome and capeweed was greatest at the lower stocking rates and *Vulpia* spp. and *Erodium* spp. at the higher stocking rates. During 1974, on no occasion was the botanical composition of either the broad-leaved component or the narrow-leaved component obviously different between pasture treatments at similar stocking rates.

8.4 Growth, crude utilization and availability of pasture

8.4.1 1971 Season

The significantly lower pasture production in treatment B and to a lesser extent in treatment D during the autumn (Figure 2) can be attributed to the poor growth rate of Wimmera ryegrass and Medea ryegrass respectively, as these components contributed over 90 per cent of total pasture production in their respective treatments (Table 5). However, total annual production was lowest in treatment D (Table 15), associated with this treatment having the smallest clover component during the spring period (Figure 1). Highest annual pasture production was recorded in treatments A and E (Table 15) associated with higher winter production from Yarloop subterranean clover in treatment A and higher spring production from Woogenellup and particularly Mt. Barker subterranean clovers[†] in treatment E (Figure 1).

The ranking of treatments based on the crude utilization of pasture was similar to that based on pasture growth rate in 1971 (Figure 2).

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† The partitioning of the subterranean clover component into contributions by the Woogenellup and Mt. Barker subterranean clover varieties was only assessed by visual observation.

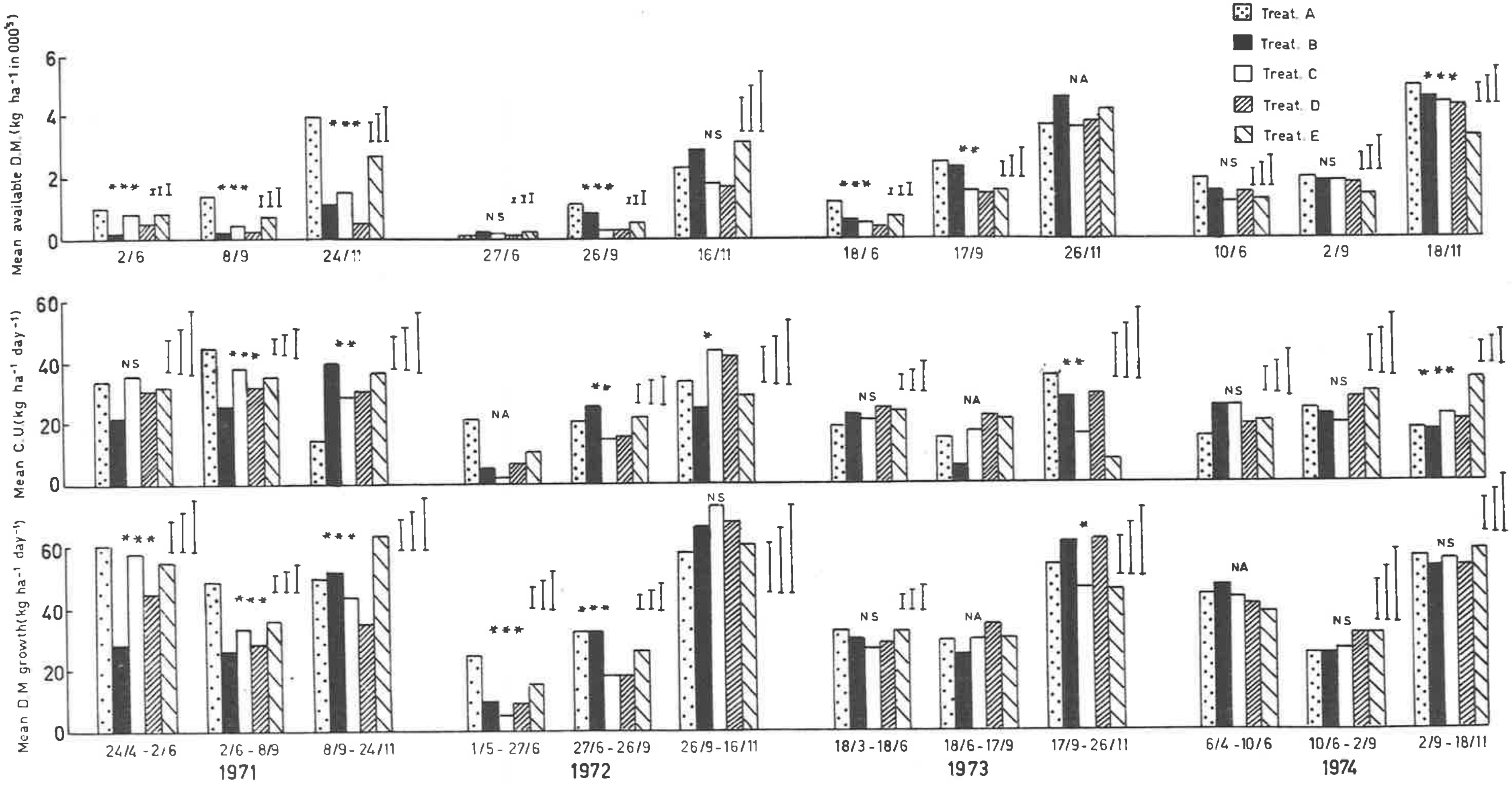


Figure 2. Mean rate of growth, mean rate of crude utilization and mean availability of pasture in all treatments during the experiment.

NA = not available, NS = P > 0·05 * = P < 0·05 ** = P < 0·01 *** = P < 0·001

Table 15

ANNUAL PASTURE PRODUCTION FOR THE EXPERIMENTAL PERIOD

(kg $ha^{-1} year^{-1}$ dry matter)

Date	Pasture treatment means					Stocking rate means (kg ha^{-1})						Grand mean	Hetero. Adjt. treat. means	LSD 5% treat. means	Sig. mean Reg. on SR.	Hetero. Reg. Coeff.
	A	B	C	D	E	10	11	13	14	15	17					
1971	10885	7570	8850	7235	10325	9000	9035	8350	9350	9420	8685	8970	***	1236	NS	NS
1972	7230	6875	5575	5665	6240	5950	7010	6515	6155	5625	6640	6320	*	1178	NS	NS
1973	9300 *+	9190	8230	10090	8885	8215	9235	8400	9610	9435	9955	9140	–	–	*	*
1974	9305	9180	9250	9280	9555	9010	9350	9425	9355	9705	9055	9320	NS	1081	NS	NS
MEAN	9180	8200	7980	8070	8750	8040	8660	8170	8620	8550	8580	8440	**	597	NS	NS

NS = P > 0.05   * = P < 0.05   ** = P<0.01   *** = P < 0.001

+ = Significance of within-treatment regressions on stocking rate

The one major exception was in treatment A during the spring period when the crude utilization was significantly (P <0.01) less than in the other four pasture treatments.

The availability of pasture on June 2 was significantly lower in treatment B (P <0.001) and treatment D (P <0.01) than in the other three pasture treatments and there was little difference in availability of pasture between these latter three pasture treatments (A, C and E). However, by September 8 (early spring), the availability of pasture in treatment A was significantly (P <0.001) greater than in any other pasture treatment and this advantage continued for the rest of the growing season (Figure 2).

No within-treatment effect of stocking rate on pasture production was evident, although a significant (P <0.05) mean (of all treatments) increase in pasture production with increased stocking rate was recorded for the period July 5 to September 8 (appendix Table 6). The mean (of all treatments) crude utilization of pasture significantly (P <0.01 and P <0.05) increased with increased stocking rate for the two periods June 2 to July 5 and July 5 to September 8 respectively, and also in all cumulative periods during the growing season (appendix Table 10).

Mean (of all treatments) pasture availability declined significantly (P <0.001) with increased stocking rate on all sampling occasions in 1971 with some within-treatment regressions reaching significance (P <0.05) on two occasions (appendix Table 14).

Only on one occasion (pasture growth during the period April 24 to July 5) was a significant (P <0.05) interaction between pasture treatment and stocking rate recorded for growth, crude utilization or availability of pasture in 1971 (appendix Tables 6, 10 and 14).

PLATE 12

Extremely dense stand of barley grass in treatment A (10 we. ha^{-1}) in December 1971. During this period of mature barley grass dominance there was a marked decline in the liveweight gain of the wethers grazing this treatment, particularly at this stocking rate.

PLATE 13

The same paddock in November 1974, depicting the continued dominance of barley grass at this stocking rate at this time of the year. However in 1974, at the higher stocking rates, other annual grasses, particularly silver grass and ripgut brome, were more prevalent.

8.4.2 1972 Season

Abnormal rains (170 mm) fell during the 1971/72 summer months (December 62, January 59 and February 49 mm, Table 2) resulting in a substantial germination of subterranean clover in all treatments and some growth of Victorian ryegrass and hybrid phalaris. No pasture measurements were taken but a considerable quantity of green pasture was available during this period. However, during March the clover plants died and all pastures dried off and new pasture growth was not evident again until the beginning of May.

Availability of pasture was extremely low during the first sampling period (May 1 to June 27) following almost complete utilization of pasture grown (Figure 2).

Most evident from Figure 2 is the substantially-higher growth rate of pasture in treatment A and, to a lesser extent, in treatment E during this period. This was associated with a dominant proportion of volunteer annual species in these two treatments compared to the dominance of rye-grass species in treatments B, C and D (Figure 1, Tables 5, 11 and 13). The different growth rate of pasture between treatments was not positively associated with the proportion of clover present in the pasture on June 27 as the largest mean clover component was recorded in treatment B rather than in treatments A or E (Table 9).

The extreme grazing pressure, particularly at the high stocking rates, resulted in very low levels of available pasture (Figure 2) during this period and significantly ($P < 0.05$) depressed pasture production was recorded with increased stocking rate in treatments C and D (appendix Table 7). However, over all treatments, no effect of stocking rate on pasture production or interaction between pasture treatment and stocking rate was recorded (appendix Table 7).

Lower pasture production in treatments C and D in the autumn-winter period resulted in only marginally less total annual pasture production in these treatments (Table 15). However, higher utilization of pasture during the spring resulted in less available pasture in treatments C and D at the end of the growing season (Figure 2) although differences between treatments in pasture availability on November 16 did not reach statistical significance (appendix Table 14).

No influence of stocking rate on mean (of all treatments) pasture growth was evident in any period in 1972 but crude utilization in two periods and availability on all occasions were significantly affected by stocking rate (appendix Tables 7, 11 and 14).

8.4.3 1973 and 1974 Seasons

Rainfall for these two seasons was above the average of 638 mm (Table 2) and excellent pasture growth (particularly in comparison to 1972) occurred in all treatments (Table 15, Figure 2).

Few differences due to pasture treatment were recorded in pasture production during 1973 and 1974. Some association of lowered pasture production with a higher broad-leaved component in some treatments was evident but inconclusive. The uniformity of pasture production between treatments in 1974 was associated with a four-year trend (1971 to 1974) toward like botanical composition in all pasture treatments (Figure 1) with the exception of a persistent hybrid phalaris component in treatment E.

In 1973 a significant increase ($P < 0.05$) in pasture production was recorded with increased stocking rate for the spring and total annual pasture production in treatment A, and for the mean of all treatments in these two periods (appendix Table 8). No such relationship was obvious in 1974.

Pasture availability was marginally lower in treatment E during the autumn and winter of 1974 with a particularly marked depression during the spring (Figure 2). This was associated with significantly ($P < 0.01$) higher crude utilization of pasture in treatment E during the spring.

Pasture availability decreased as stocking rate increased in all treatments on all occasions in 1973 and 1974 and regressions of mean (of all treatments) pasture availability on stocking rate were always significant ($P < 0.05$) with one exception on June 10, 1974 (appendix Table 15).

8.5 Subterranean clover seed production and reserves

Hard seed reserves of subterranean clover, measured in August 1973, were significantly higher in treatments A and B compared to the other three pasture treatments (Table 16). This was associated with high availabilities of clover herbage in treatment A throughout 1971 and 1972 and in treatment B throughout 1972 (Table 17). However, regressions of the 1973 hard seed reserves measured in each paddock on the proportion (% dry weight), production and availability of clover herbage for each sampling period/occasion in 1971 and 1972 were performed and the only significant variate was the availability of clover herbage measured on September 26, 1972.

In treatment D, there was a significant decrease in the 1973 hard seed reserves with increased stocking rate and this was the only occasion on which stocking rate could be significantly ($P < 0.05$) correlated with any subterranean clover seed parameter, within any pasture treatment or over all pasture treatments, during the experimental period.

The proportions of black seed (non-Yarloop) in the overall pool of hard seed reserves sampled in August 1973 in treatments A, B, C, D and E were 1, 4, 8, 5 and 21 per cent respectively with approximately equal proportions of black and white seed sampled above and below ground.

Table 16

CLEAN SEED YIELD OF SUBTERRANEAN CLOVER SAMPLED ON FOUR OCCASIONS DURING THE EXPERIMENT

(kg ha^{-1})

Sampling Date	Pasture treatment means A	B	C	D	E	LSD 5%
Hard seed August 1973	389	349	164	185**+	139	94.6
Seed prod. below 1973	234	87	166	208	167	126.0
Seed prod. above 1973	57	31	46	54	43	25.2
Total seed prod. 1973	291	118	212	262	210	147.0
Hard seed August 1974	334	272	154	189	177	98.3
Seed prod. below 1974	-30	187	246	155	143	170.0
Seed prod. above 1974	85	55	74	41	66	32.5
Total seed prod. 1974	55	242	320	196	209	163.0

** = $P < 0.01$

+ = significance of within-treatment regression on stocking rate.

Table 17

AVAILABILITY OF SUBTERRANEAN CLOVER MEASURED ON SIX OCCASIONS IN 1971-1972

(kg ha^{-1} dry matter)

Date	Pasture treatment means					Stocking rate means (sheep ha^{-1})						Grand Mean	Hetero. Adjt. treat. means	LSD 5% treat. means	Sig. mean Reg. on SR.	Hetero. Reg. Coeff.
	A	B	C	D	E	10	11	13	14	15	17					
2/6/71	180	5	10	5	65	30	60	65	70	50	40	55	***	48.6	NS	NS
8/9/71	730	25	30	5	170	240	195	290	220	120	85	190	***	177	NS	NS
24/11/71	995	460	410	30	1180	465	655	750	480	950	390	615	***	531	NS	NS
27/6/72	25	55	10	10	30	20	40	25	25	30	20	25	*	27.8	NS	NS
26/9/72	330	555	120	120	145	195	380	270	245	220	215	255	***	141	NS	NS
16/11/72	480	1780	930	695	1015	725	2005	1165	640	690	645	980	*	910	NS	NS

NS = $P > 0.05$ * = $P < 0.05$ ** = $P < 0.01$ *** = $P < 0.001$

Table 18

AVAILABILITY OF SUBTERRANEAN CLOVER MEASURED ON SIX OCCASIONS IN 1973-1974

(kg ha^{-1} dry matter)

Date	Pasture treatment means					Stocking rate means (sheep ha^{-1})						Grand mean	Hetero. Adjt. treat. means	LSD 5% treat. means	Sig. mean Reg. on SR.	Hetero. Reg. Coeff.
	A	B	C	D	E	10	11	13	14	15	17					
18/6/73	520	185	170^{*+}	125^{*}	285^{**}	350	310	330	270	185	100	260	***	146	**	NS
17/9/73	1935	1285	985^{***}	1115^{***}	965	1805	1710	1130	1310	965	625	1260	**	543	***	NS
26/11/73	280	545	740	535	795	450	395	405	890	625	705	580	NS	486	NS	NS
10/6/74	285	110	100	130	115	65	50	105	205	235	220	150	*	124	**	NS
2/9/74	555	400	585	480	430	200	125	545	685	490	890	490	NS	452	**	NS
18/11/74	815	1060	1450	1390	1365	975	745	950	1410	1780	1440	1215	NS	608	*	NS

$^{+}$ = Significance of within-treatment regressions on stocking rate.

NS = P > 0.05   * = P < 0.05   ** = P < 0.01   *** = P < 0.001

PLATE 14

Treatment A paddocks in September 1971, depicting the typical appearance of Yarloop dominated pasture during the early spring period under lax grazing (11 $we.ha^{-1}$ left) and hard grazing (17 $we.ha^{-1}$ right).

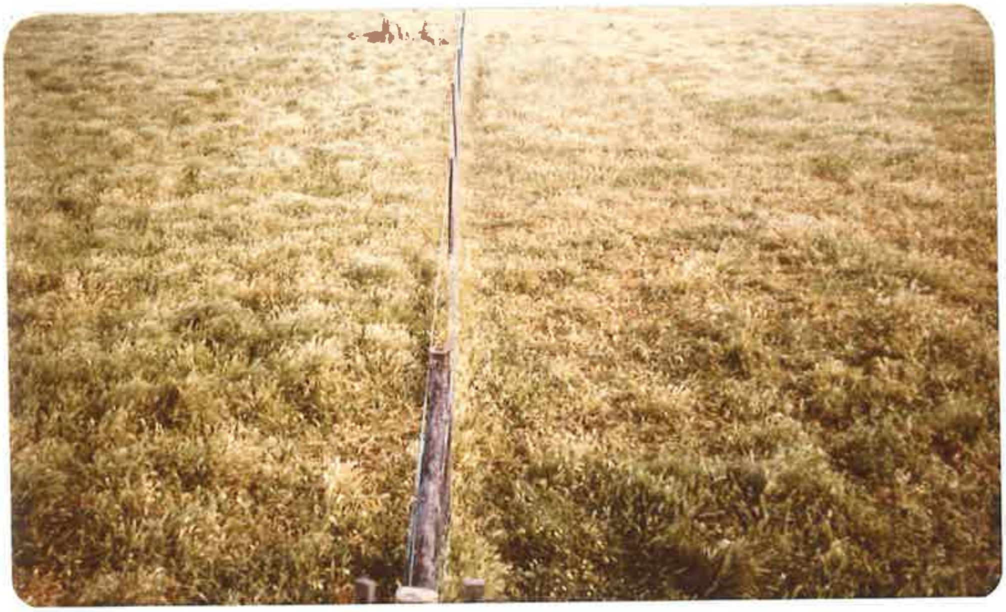


PLATE 15

The same paddocks in December 1971 following the typical early maturation and desiccation of Yarloop and enhanced dominance of barley grass. The effect of stocking rate on pasture availability is also less evident at this time.

PLATE 16

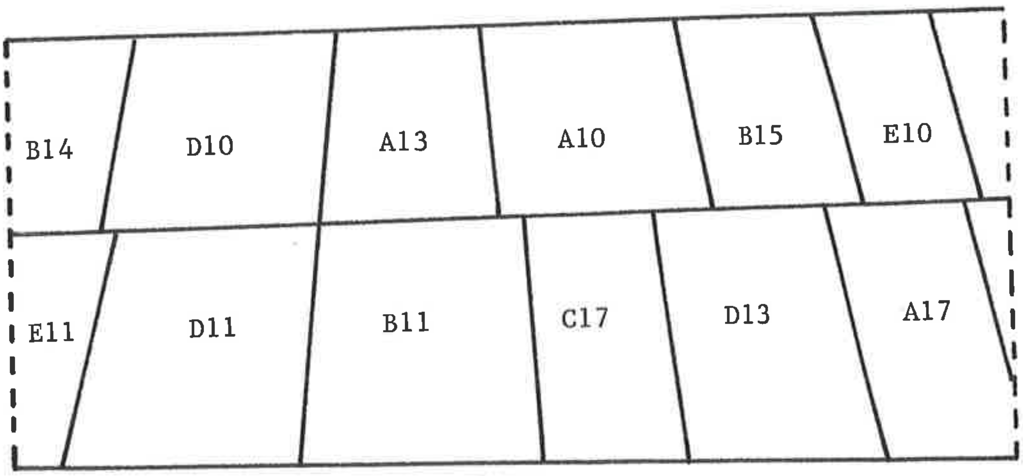
Barley grass dominant pasture in treatment A (10 we. ha^{-1}) in June 1972. Note the significant quantity of dry feed still remaining from the 1971 growing season.

PLATE 17

Simultaneous photograph of the pasture in treatment A grazed at 17 wethers ha^{-1}, depicting the severity of grazing pressure, even in this treatment. A comparison of plates 5 and 17 shows little difference in pasture availability between treatments A and C at this stocking rate even though significant differences existed in pasture growth.

PLATE 18

Infra-red photograph of some of the paddocks in September 1972. Increased intensity of pink colouration is associated with a general increase in pasture availability. Higher pasture availabilities in treatments A, B and E compared to treatments C and D at equivalent stocking rates (if shown) are evident. The protective pasture cages (dark dots) and experimental wethers (white dots) can be easily distinguished in each paddock.



Plan of paddocks shown in photograph. A,B,C,D and E indicate pasture treatments and postscripts stocking rate (we.ha^{-1}).

There was only a slight decline (c. 1%) in these proportions in the August 1974 sampling.

There was little between-year change in the hard seed reserves from 1973 to 1974, with the exception of a 22 per cent decline in treatment B (Table 16). The 'negative production' of below-ground seed in treatment A during 1974 would seem highly unlikely and must be attributed to sampling error, as there was no evidence of germination in the period August 1974 to January 1975 and the above-ground seed production was very similar to that in the other four pasture treatments (Table 16).

The data show that in both years in which the seed reserves were measured in January, by far the greatest proportion of seed present at that time was buried below ground† (Table 16) and appeared unrelated to treatment or stocking rate.

Regression analysis of clean clover seed produced in each paddock on seven pasture variates (measured in corresponding paddocks) was performed for the 1973 and 1974 data.

The pasture variates used were:

(1) Availability of clover herbage at the end of winter.

(2) Availability of clover herbage at the end of spring.

(3) Mean availability of clover during the spring.

(4) Proportion of clover (% dry weight) at the end of winter.

(5) Proportion of clover (% dry weight) at the end of spring.

(6) Mean proportion of clover (% dry weight) during the spring.

(7) The production of clover herbage during the spring.

Clean seed production in both years was significantly correlated

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† It is not to be implied that this was the actual ratio of seed produced above to that produced below during the growing season as no account has been taken of seed eaten or otherwise disappearing during the period August to January.

only with the availability of clover at the end of each respective spring according to the following equations

<u>1973</u> $y = 63.48 + 0.479x - 0.00024x^2$, $r^2 = 0.46$, $P < 0.001$

<u>1974</u> $y = 24.98 + 0.188x$, $r^2 = 0.52$, $P < 0.001$

where y = clean clover seed production (kg ha^{-1}) measured in 1973 and and 1974 respectively

and x = availability of clover (kg ha^{-1}) measured on the last sampling occasion in 1973 and 1974 respectively.

It is interesting to note here that, although there appeared to be an increase in the amount of clover seed produced with increased availability of clover herbage at the end of the 1974 growing season, there was no recorded effect of stocking rate on clover seed production in 1974. This was despite the significant ($P < 0.05$) mean (of all treatments) increase in the availability of clover with increased stocking rate recorded on November 18, 1974 (Table 18).

8.6 Sheep liveweight data

The following points are evident from Figure 3.

8.6.1 General Trends

a) The recorded pattern of liveweight change in the sheep is characteristic for the Mediterranean-type environment, with a decline in live weight during the summer and autumn (and in 1972, winter also) and increase during the winter and spring.

b) Minimum, and maximum, live weights were recorded simultaneously in all treatments in all years.

c) In the three years 1971, 1973, and 1974 minimum live weights were recorded during the same fifteen day, calendar period in each year (April 18 to May 3). In 1972, minimum live weights were not reached until July 12 following the late seasonal break.

d) A diminishing within-year magnitude of difference in live weight between pasture treatments over the experimental period (1971 to 1974) is obvious.

8.6.2 <u>1971</u>

In comparison to the other four pasture treatments the mean live weight in treatment B declined more rapidly prior to the opening rains in April, and during May all sheep died from undernutrition at the highest stocking rate (17 ha^{-1}) in this treatment (appendix Table 29). Treatment B ranked significantly ($P < 0.001$) lowest in mean live weight on all weighing occasions in 1971 and on the first weighing in 1972 (January 19) prior to shearing. However, once new pasture growth occurred in April, liveweight gain was greater in treatment B than in treatment D.

Five distinct periods of differential liveweight change between pasture treatments were recorded:

a) The initial period from the allocation of the sheep to their respective paddocks to the first paddock weighing (February 10). The decline in the live weights in treatment B was the most significant aspect in this period.

b) May 3 to June 23 - markedly superior liveweight gain was recorded in treatment A and, to a lesser extent, in treatments C and E.

c) June 23 to August 24 - superior liveweight gain was only recorded in treatments A and E.

d) August 24 to October 5 - substantial liveweight gain only occurred in treatment A.

e) October 5 to November 11 - liveweight gain in treatment A was the lowest of all pasture treatments.

A significant effect of stocking rate on the mean (of all treatments) live weight was first recorded on June 23 and an interaction between stocking rate and pasture treatment was recorded on November 11 (heterogeneity of regression coefficients was significant ($P < 0.001$)). This latter interaction was manifested in the different pattern of change (with time) in the value of the regression coefficient of the higher ranked pasture treatments (A, E and to a lesser extent C) compared to the lower ranked treatments (B and D) after August 24. The higher ranked pasture treatments recorded a marked maximum depression of live weight with increased stocking rate on August 24 compared to a less marked maximum on October 5 in treatments B and D.

8.6.3 1972 and 1973

Significant aspects evident in the mean liveweight response during 1972 and 1973 were:

a) The more rapid liveweight gain in treatments A and B compared to the other pasture treatments following the late start to the growing season (May 1, 1972). This superior liveweight gain in these two pasture treatments continued until the end of September. The mean live weight in treatment A was also significantly ($P < 0.05$) higher than in the other four pasture treatments on August 16 and September 28, 1972.

b) Treatment B increased in rank (liveweight basis) during the 1972/73 season from the lowest ranking on March 8, 1972 to the highest on January 17, 1973.

c) Following the seasonal break in 1972, treatment D ranked the lowest and treatment C the second lowest, in mean live weight throughout 1972 and 1973. The mean live weight in treatment D was significantly ($P < 0.05$) lower than the mean live weight in all other pasture treatments on two occasions (November 29, 1972 and January 17, 1973) and significantly ($P < 0.05$) lower than the higher ranked two pasture treatments (A and B) only on some other occasions.

d) A significant ($P < 0.05$ but usually $P < 0.001$) effect of stocking rate on the mean (of all treatments) live weight was recorded on all occasions in 1972 and 1973 except on November 20, 1973. In all cases increased stocking rate resulted in lower mean live weights of the sheep.

e) Although large differences existed between pasture treatments in the magnitude of the regression coefficient on many occasions in 1972 and particularly in 1973 (i.e. January 17 to July 17, 1973), significant differences ($P < 0.05$) were only recorded on three occasions i.e. April 18, 1972, August 21, 1973 and October 3, 1973, and in all cases, the decline in live weight with increased stocking rate was greatest in treatment D.

Also in treatment D, the maximum value of the regression coefficient was not reached until January 17, 1973 after the 1972 season although maxima were attained on September 28, 1972 in the other four pasture treatments. However in 1973, the pattern of change in value of the regression coefficient with time was similar in all pasture treatments.

8.6.4 <u>1974</u>

No significant ($P > 0.05$) difference in mean live weight between pasture treatments was recorded in 1974. Significant effects of stocking rate on live weight were only recorded (and then only in some pasture treatments) on three occasions i.e. immediately before, at, and immediately after the occurrence of minimum live weight (May 1, 1974). The value of the regression coefficient was again highest in treatment D for most of the season although a significant ($P < 0.05$) interaction between stocking rate and pasture treatment on live weight was only recorded on one occasion (June 6, 1974).

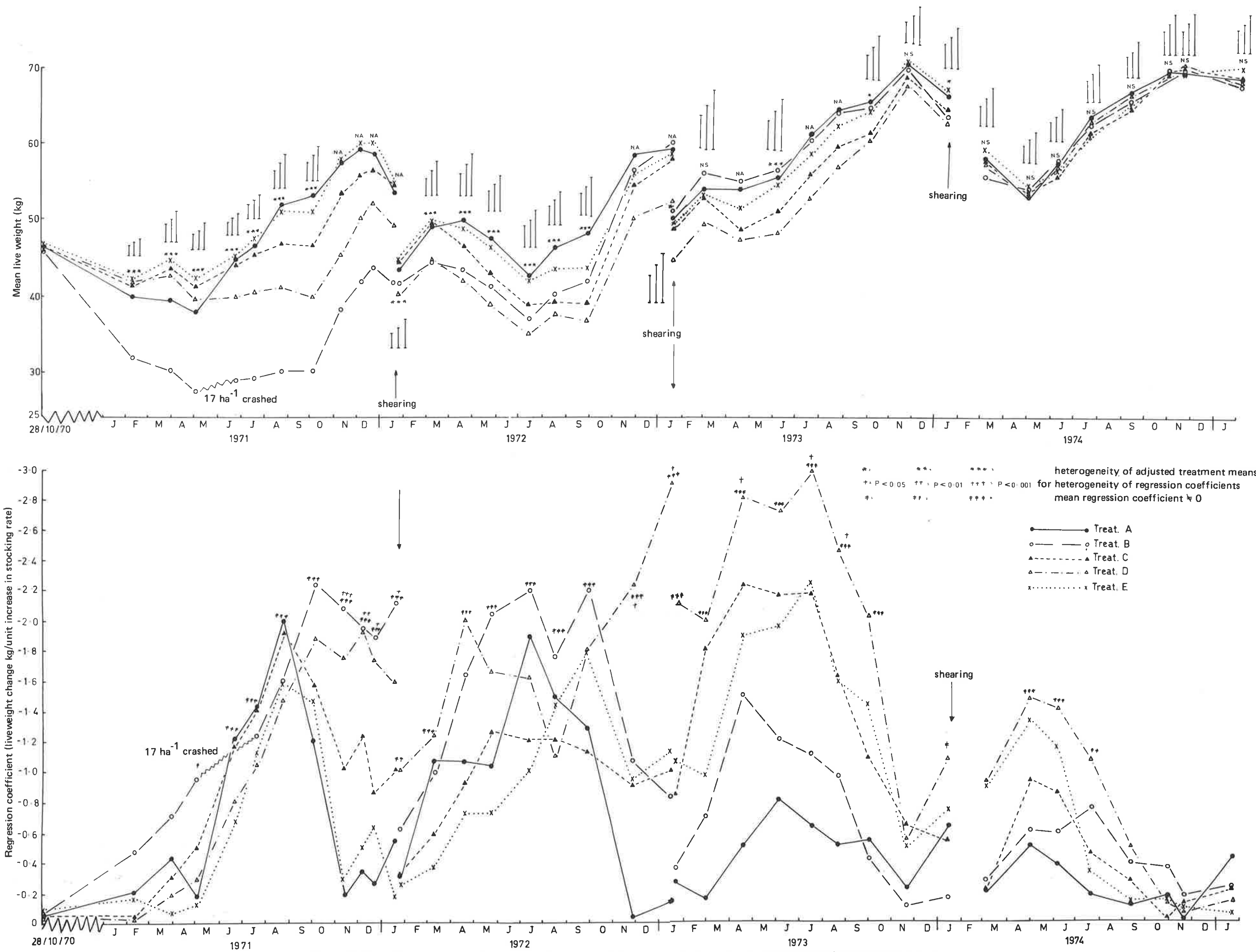

Figure 3: Mean live weight and linear regression coefficient of live weight on stocking rate for each pasture treatment.

PLATE 19

Poor condition of wethers (mean live weight≃ 28 kg) in treatment B (15 $we.ha^{-1}$) in July 1971. Three sheep in this paddock and all sheep in the 17 $we.ha^{-1}$ paddock died from undernutrition during 1971.

PLATE 20

Simultaneous photograph of the wethers (mean live weight ≃ 44 kg) in treatment E (15 $we.ha^{-1}$) depicting their superior condition. Marked differences in growth and availability of pasture existed between these treatments throughout 1971.

8.7 Annual wool production

Significant interactions between pasture treatment and stocking rate on the clean wool produced per head and per hectare were recorded in both 1971 and 1973 but not in 1972 and 1974 (Table 19, Figures 4 and 5). With the exception of the mean (of all treatments) clean wool produced per head in 1974, stocking rate significantly ($P < 0.001$) affected the mean (of all treatments) clean wool produced, both on a per head and per hectarebasis, in all years. The slopes of the mean regression lines were negative in the case of annual clean wool produced per head and positive in the case of annual clean wool produced per hectare (Figures 4 and 5).

The significance of individual within-treatment regressions of annual clean wool produced on stocking rate are given in Table 19. In no case could a polynomial relationship of higher order than a linear relationship be statistically justified over the range of stocking rates used in this experiment.

The mean annual clean wool produced was considerably lower in treatments B and D compared to the other treatments in 1971 (Table 19). The statistical significance of the difference in treatment means cannot be calculated due to the interaction between pasture treatment and stocking rate in 1971.

In 1972 treatment D produced the least, and treatment A the most, clean wool. The difference between these two treatments and the next ranked pasture treatment (above and below respectively) was significant ($P < 0.05$) in both cases.

Clean annual wool production was again lowest in treatment D in 1973, but there was no difference in production recorded between pasture treatments in 1974 (Table 19).

Table 19

ANNUAL CLEAN WOOL PRODUCTION
(kg)

		Pasture treatment means					Stocking rate means (sheep ha^{-1})						Grand Mean	Hetero. Adjt. treat. means	LSD 5% treat. means	Sig. mean Reg. on SR.	Hetero Reg. Coeff.
		A	B	C	D	E	10	11	13	14	15	17					
1971	per head	3.6	2.4‡	3.7 **‡	2.9 **	3.8	3.6	3.7	3.4	3.3	3.1	3.1	3.3	-	-	***	*
	per ha	47 *	31 **‡	49 *	37	50 ***	36	40	44	46	47	53	43	-	-	***	***
1972	per head	3.7 *	3.3 **	3.3 ***	3.0 *	3.4 *	3.8	3.9	3.4	3.2	3.1	2.7	3.3	***	0.26	***	NS
	per ha	48	43	43 ***	38	45	38	42	45	45	47	52	44	***	4.0	***	NS
1973	per head	5.7	5.7	5.6 *	5.2	5.6	5.9	5.7	5.6	5.5	5.4	5.3	5.6	-	-	***	*
	per ha	76 ***	75 **	73 *	69 **	74 **	59	63	72	76	81	89	74	-	-	***	*
1974	per head	4.5	4.5	4.6	4.6	4.6	4.8	4.6	4.7	4.5	4.5	4.5	4.6	NS	0.29	NS	NS
	per ha	60 ***	60 *	61 **	61 **	62 **	48	51	60	62	67	77	61	NS	4.0	***	NS

NS = P > 0.05 * = P < 0.05 ** = P < 0.01 *** = P < 0.001

‡ = mean of 5 lowest stocking rates only.

\+ = significance of within-treatment regressions on stocking rate.

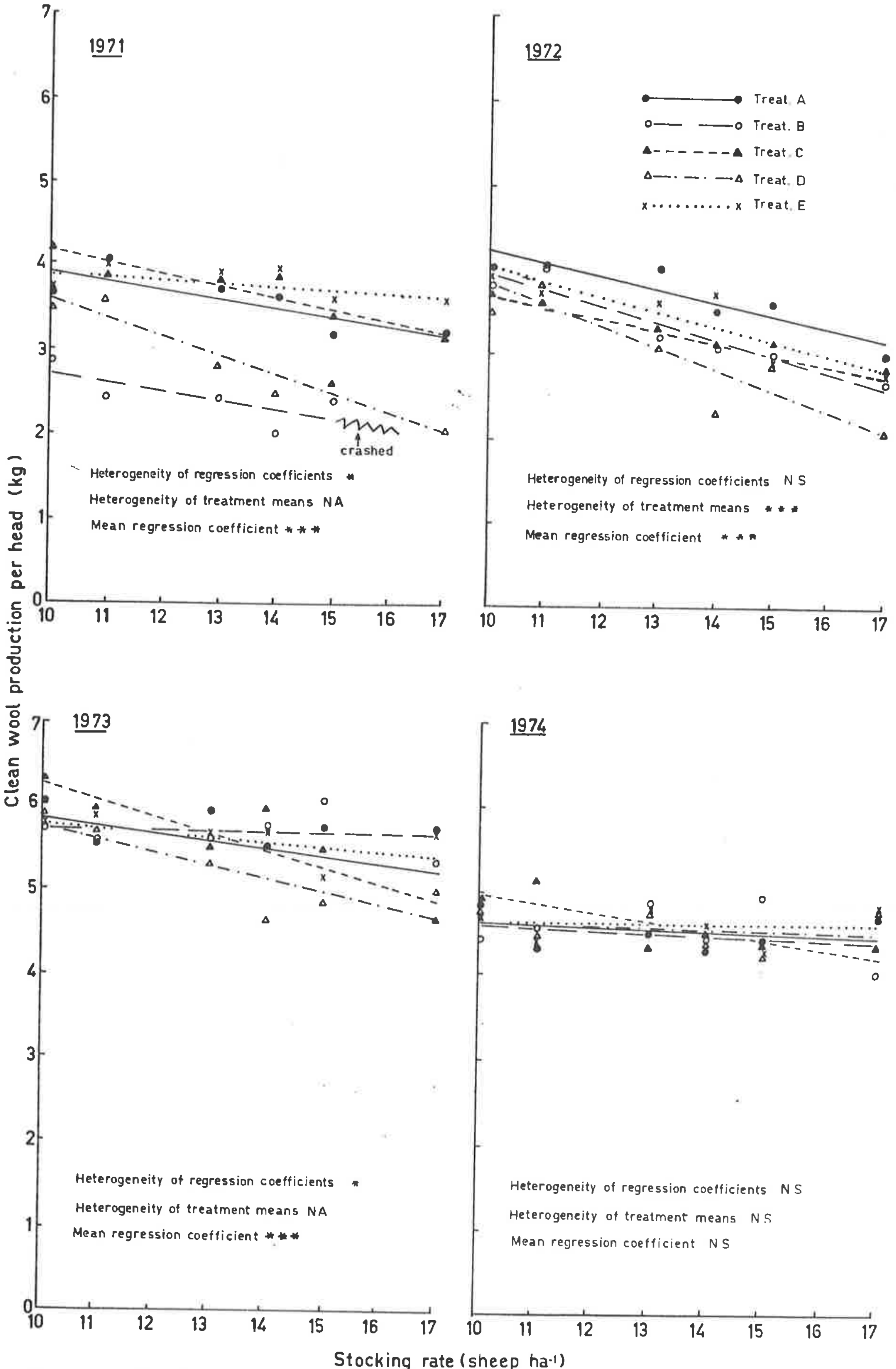

Figure 4. Relationship between clean wool produced per head and stocking rate.

NA = not available NS = P > 0·05 * = P < 0·05 ** = P < 0·01 *** = P < 0·001

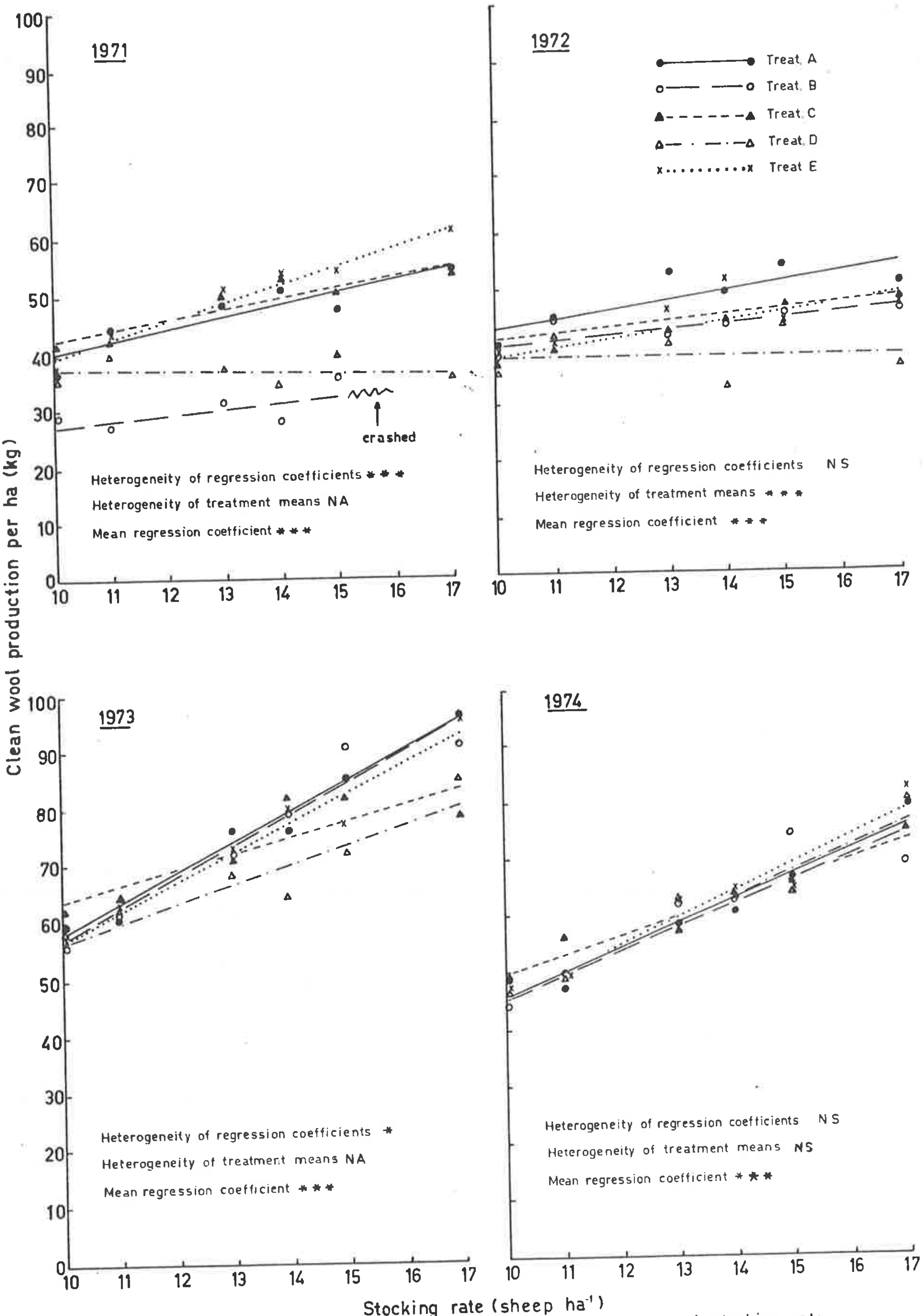

Figure 5. Relationship between clean wool produced per hectare and stocking rate.

NA = not available NS = $P > 0.05$ * = $P < 0.05$ ** = $P < 0.01$ *** = $P < 0.001$

The mean (of all treatments) quantity of clean wool produced was very similar in 1971 and 1972 and maximum annual production occurred in 1973 (Table 19).

8.8 Fleece characteristics

No significant interaction between pasture treatment and stocking rate was recorded for any of the fleece characteristics in any year (Tables 20 and 21). Significant (P <0.001) differences between pasture treatment means were recorded for staple length and fibre diameter and (P <0.05) for yield in 1971 only and not in any of the following three years (Tables 20 and 21). Treatments ranked (on a staple length and fibre diameter basis) as follows, with differing subscripts indicating a significant (P <0.05) difference between pasture treatment means.

Staple length - Ea > Ca > Aab > Db > Bc

Fibre diameter - $A_a > E_{ab} > C_b > D_c > B_c$

Highly significant (P <0.001) mean (of all treatments) regressions (negative in slope) of staple length and fibre diameter on stocking rate were recorded in 1971 and 1972 and with less significant correlation in 1973. Significant negative correlations between stocking rate and both yield in 1972 and crimp frequency in 1973 were also recorded (Tables 20 and 21).

Fibre diameter increased and both crimp frequency and yield decreased between years from 1971 to 1974 (Tables 20 and 21). In each case, the mean (of all treatments) regression of fleece characteristic on year was significant (P <0.05).

8.9 Seasonal wool production

Season had a far greater influence on wool growth rate than did pasture treatment. This is clearly demonstrated in Figure 6 by the amplitude of fluctuations in the changing rate of wool growth compared to the magnitude of between-treatment differences in wool growth rate during the experimental period.

During 1971 and 1972 the mean wool growth rate varied in a similar pattern to the mean liveweight change in the sheep (Figures 3 and 6) with periods of maximum rate of wool growth approximately coinciding with periods of maximum liveweight gain in the sheep.

In 1971 the mean live weights of the sheep increased throughout the spring and early summer but the mean wool growth rate declined from the end of October. However in 1973 and 1974 the mean wool growth rate declined from the beginning of August and the beginning of July respectively with a plateau and peak in mid-November and mid-December respectively. In both these years (1973 and 1974) this decline in wool growth rate during the spring occurred despite constant liveweight gain of the sheep during this period (Figure 3).

With large, seemingly random, fluctuations in the value of the regression coefficient (wool growth rate change per unit increase in stocking rate) with time (Figure 6), significant ($P < 0.05$) Stocking rate x Pasture treatment interaction in respect of wool growth rate was only recorded in the first three growth periods in 1971 (Figure 6). In these three periods, wool growth rate in treatments E and A was less depressed by the higher stocking rates than in treatments C, B and D (the latter three treatments being ranked on increasing absolute value of the regression coefficient). In all other growth periods in 1971 and 1972, significant ($P < 0.01$) and usually $P < 0.001$) differences in the mean wool growth rate between pasture treatments were recorded (Figure 6). The only two exceptional periods were during the mid-summer of 1971/72 and 1972/73.

However in 1973 and 1974, only in two consecutive growth periods, was a significant difference in wool growth rate between pasture treatments recorded (during the spring of 1973).

The ranking of pasture treatments based on mean wool growth rate was consistent with the ranking of treatments based on mean live weight on most occasions in 1971 and 1972. This applied in the case of treatments D and B even though, on the basis of liveweight gain, the order was reversed. Treatments E and B during most of 1971 and treatments A and D in 1972, ranked highest and lowest respectively in terms of both wool growth rate and live weight (Figures 3 and 6).

In all growth periods in 1971 and 1972 the mean (of all treatments) depression of wool growth rate with increased stocking rate was significant ($P < 0.05$ and usually $P < 0.001$) but in 1973 and 1974 a similar relationship was only recorded significantly ($P < 0.05$) in some growth periods during the late winter and spring (Figure 6).

Table 20

FLEECE CHARACTERISTICS 1971 AND 1972

	Pasture treatment means					Stocking rate means (sheep ha^{-1})						Grand Mean	Hetero. Adjt. treat. means	LSD 5% treat. means	Sig. Mean Reg. on SR.	Hetero. Reg. Coeff.
	A	B	C	D	E	10	11	13	14	15	17					
1971																
Staple leng. (cm)	9.5	‡8.3**	9.8	9.1*	9.9	9.5	9.8	9.5	9.1	9.3	9.2	9.3	***	0.44	***	NS
Fibre diam (μm)	20.4	‡18.2*	19.7**	18.7**	20.2	20.2	19.8	19.9	19.5	19.0	18.8	19.4	***	0.69	***	NS
Crimp per cm	3.4	‡3.7	3.7	4.1	3.5	3.7	3.5	3.6	3.6	4.0	3.7	3.7	NS	0.49	NS	NS
Yield (%)	75.0	‡76.4	79.0	77.1	77.6	77.3	77.0	78.1	76.3	75.7	77.5	77.0	*	2.46	NS	NS
1972																
Staple leng. (cm)	8.5	8.4	8.6	8.3	8.7*	8.7	9.3	8.8	8.3	8.2	7.8	8.5	NS	0.63	***	NS
Fibre diam (μm)	20.6*	20.3*	20.0	20.0	20.2	21.0	21.0	20.6	19.9	20.0	18.7	20.2	NS	0.92	***	NS
Crimp per cm	3.5	3.1	3.3	3.4	3.3	3.5	3.2	3.2	3.3	3.3	3.5	3.3	NS	0.34	NS	NS
Yield (%)	73.2	73.8	76.1	75.6	75.0	76.1	75.7	75.5	73.5	72.8	74.4	74.7	NS	2.25	*	NS

NS = P>0.05   * = P< 0.05   ** = P< 0.01   *** = P< 0.001

+ = Significance of within-treatment regressions on stocking rate

‡ = Mean of 5 lowest stocking rates only.

Table 21

FLEECE CHARACTERISTICS 1973 AND 1974

	Pasture treatment means					Stocking rate means (sheep ha^{-1})						Grand Mean	Hetero. Adjt. treat. means	LSD 5% treat. means	Sig. mean Reg. on SR.	Hetero. Reg. Coeff.
	A	B	C	D	E	10	11	13	14	15	17					
1973																
Staple leng. (cm)	10.0	10.2	9.8	9.8	10.1	10.2	10.3	10.2	9.7	9.8	9.6	10.0	NS	0.55	*	NS
Fibre diam (μm)	23.0	23.4	22.6	22.7	22.9 *+	23.8	23.1	23.1	22.6	22.8	21.9	22.9	NS	0.95	**	NS
Crimp per cm	3.2	3.2	3.1	3.0	3.1	3.3	3.1	3.1	3.2	3.1	3.0	3.1	NS	0.20	**	NS
Yield (%)	73.3	75.0	75.4	74.4	74.3	75.7	74.4	75.5	73.9	73.6	74.3	74.5	NS	2.78	NS	NS
1974																
Staple leng. (cm)	9.8	9.9	9.8	9.8	9.6	9.8	9.8	10.2	9.6	9.5	9.8	9.8	NS	0.66	NS	NS
Fibre diam (μm)	23.3 **	24.2	23.2	24.0	23.9	24.6	23.7	24.0	22.9	24.0	23.2	23.7	NS	1.10	NS	NS
Crimp per cm	3.1	2.9	3.0	3.1 *	2.9	3.1	3.0	3.1	3.1	2.9	2.9	3.0	NS	0.23	NS	NS
Yield (%)	71.1	73.1	73.2	73.5	73.2	73.5	72.3	74.0	72.7	72.1	72.5	72.8	NS	2.72	NS	NS

NS = P>0.05 * = P<0.05 ** = P<0.01 *** = P<0.001

+ = Significance of within-treatment regressions on stocking rate

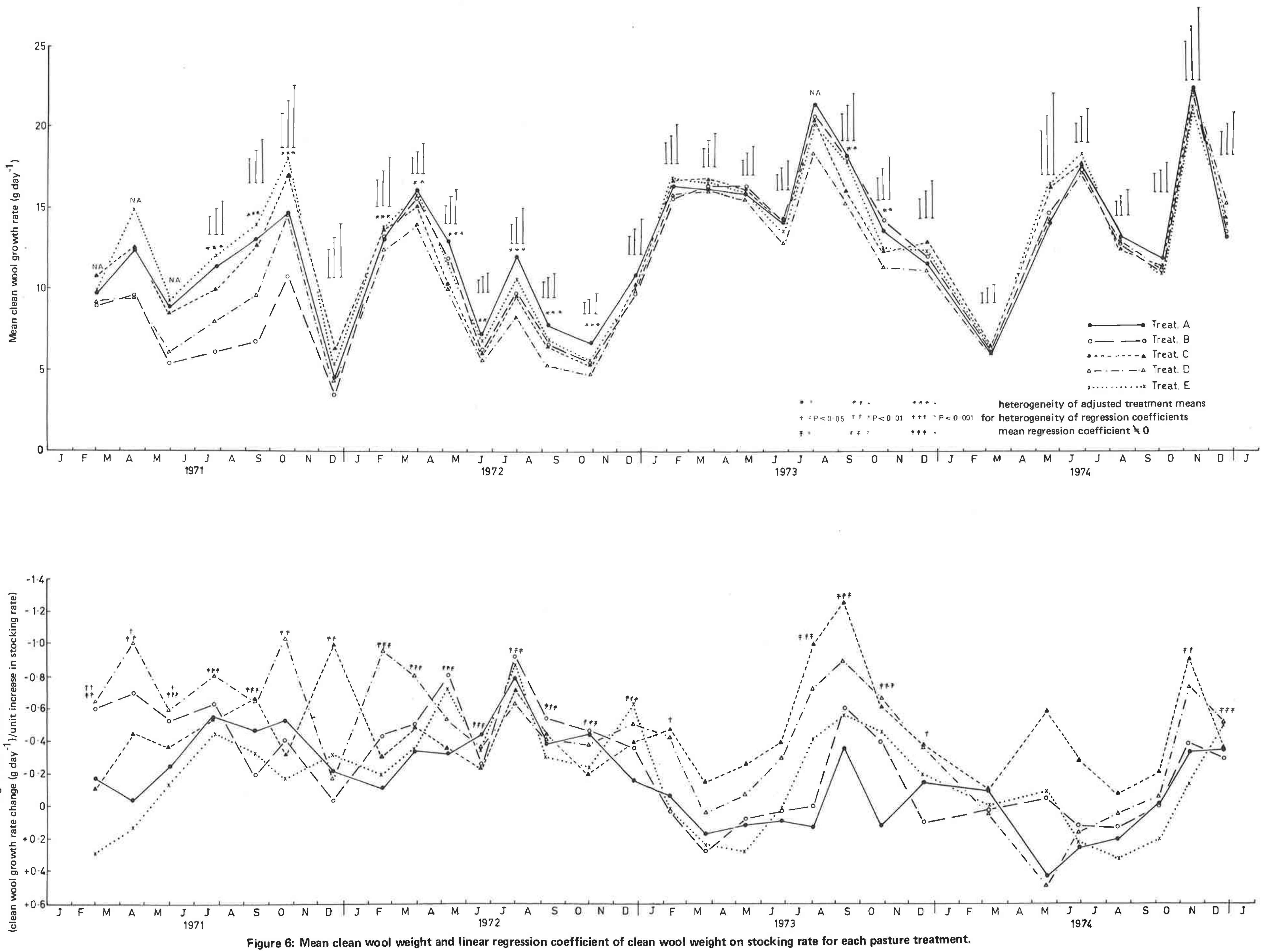

Figure 6: Mean clean wool weight and linear regression coefficient of clean wool weight on stocking rate for each pasture treatment.

DISCUSSION AND CONCLUSION

9. DISCUSSION AND CONCLUSION

9.1 Animal production in relation to botanical composition

It is necessary to first refer to the fact that treatment A did not have the tillage and seedbed preparation, or the sowing of new species. While it is acknowledged that in some respects this has a confounding influence, the pasture treatments are best regarded as 'mini systems' which can be validly extrapolated to the farm situation. In this respect, the various pasture treatments or pasture systems, with superimposed stocking rate treatments, are quite valid.

9.1.1 The importance of subterranean clover

The outstanding result from this experiment is that the renovation of the existing volunteer annual grass - Yarloop subterranean clover pasture by the tillage, seedbed preparation and sowing of the four grass - subterranean clover mixtures did not result in either increased live weight or wool production from the grazing wethers during the set-stocked experimental period of four years. In fact, lower pasture and animal production occurred in the three ryegrass treatments during the first and, to a lesser extent, the second and third years of set stocking.

The differences in productivity+ can be attributed to the extensive differences in availability of clover that existed between pasture treatments in 1971 and, to a lesser extent, in 1972 and 1973, following the renovation and pasture management procedures carried out in 1970.

It is difficult to ascribe animal productivity to the quantity and quality of particular botanical components of grazed pasture and the quantitative and qualitative intake of pasture by the grazing animal may be related (Conrad 1966). The most important single determinant of

+in terms of plant and animal

ruminant production at a particular time is the quantity of feed being harvested by the animal, and this is very often the immediate limiting factor to animal production. Demonstration of qualitative differences can only be accomplished when allowance has been made for differences in quantity of feed eaten (Lambourne 1969).

In the comparison of treatments cited below, quality and quantity of pasture are confounded because total pasture production was usually higher in those treatments with a higher clover component.

Nevertheless, the data that have been presented, strongly implicate the availability of the subterranean clover component as being the dominant factor in the determination of animal production in this experiment. It may be argued that the differences in animal performance in any of the treatment comparisons cited below, may be due to the higher quality of the non-legume component. However this is unlikely to be true as there is little evidence in the literature for substantially-superior nutritional value of any of the volunteer or sown grass species comprising the pastures in this experiment. For example, McIvor and Smith (1973c) reported little difference in the dry matter content, nitrogen content of leaves and *in vitro* digestibility of a number of temperate annual pasture species including ripgut brome, barley grass and annual ryegrass. Thus during the autumn of 1971, for example, it is unlikely that the superior liveweight gain recorded in treatment A was due to the higher nutritional value of the barley grass-dominant pasture compared to the pasture comprising dominant ripgut brome and hybrid phalaris in treatment E or Victorian ryegrass in treatment C, but rather to the higher proportion and availability of subterranean clover. Certainly there was no substantial difference between these pasture treatments in pasture production, crude utilization or availability of pasture during this period. This example quoted is the only one in which superior quality *per se* of the clover herbage was clearly demonstrated because equivalent levels of production,utilization and availability of total pasture were recorded.

Further examples implicating the availability of clover as the main determinant of animal production in this experiment are as follows:

(1) The proportion and availability of clover, together with the total availability of pasture, were significantly greater in treatment A during the winter of 1971, and only in this treatment did the mean live weight increase substantially during this period.

(2) Comparing the three ryegrass treatments B, C and D during the growing season of 1971, the lowest availability of clover was recorded in treatment D and this was associated with the lowest liveweight gain being recorded in this treatment.

(3) During the winter and spring of 1972 the rapid liveweight gain in treatment B was associated with maximum proportion and availability of clover being recorded in this treatment. The increased performance of the sheep in treatment B during 1972 is demonstrated by the change in rank (liveweight basis) of this treatment, from the lowest on March 8, 1972 to the highest on January 17, 1973 and this was associated with this treatment having the greatest between-year increase in the size of the subterranean clover component of all the pasture treatments from 1971 to 1972.

(4) The lower liveweight gain during the winter of 1972 in treatments C, D and E was associated with lower availabilities of subterranean clover during this period.

(5) The decline in live weight with increased stocking rate was greatest in treatment D throughout 1973 and 1974 and only in this treatment was a decrease in the proportion of clover with increased stocking rate recorded.

9.1.2 The role of other species

Apart from the role of subterranean clover, no other consistent relationship between the size or presence of a particular pasture component and animal performance was evident in this experiment although two isolated instances are worthy of note.

(1) The greater liveweight loss in treatment B, prior to the opening of the season in 1971, can only be explained by the poor nutritional value of the available feed in this treatment over the summer period. The availability of pasture at the end of the 1970 growing season was similar in treatments B and E and even lower in treatment A.

Reasons for this poor quality of feed in treatment B are possibly:

a) A lower clover component in the dry summer residue resulting from suppression of this component by the Wimmera ryegrass during the spring of 1970, even though an attempt had been made to prevent this happening by the strategic grazing of the pasture at that time.

b) Lower nutritional value of the Wimmera ryegrass itself, due to a lower number of seed heads being available to the sheep in comparison to the previously ungrazed Victorian and Medea ryegrasses. However, these latter two treatments also had higher availabilities of pasture at the end of the 1970 growing season.

In comparison to treatments A and E the Wimmera ryegrass may have been of lower nutritive value than the dominant barley grass and ripgut brome components that comprised treatments A and E respectively. Radcliffe and Cochrane (1970) reported that in Wimmera ryegrass the digestibility declined at the rate of 0.9 units per day in the month following flowering compared to an average of 0.3 to 0.5 units per day for phalaris, brome grass, silver grass, barley grass, Yarloop subterranean clover and barrel medic. They also recorded a low crude protein content in Wimmera ryegrass in mid-December.

(2) During 1971 and 1972, the decline in rate of liveweight gain in treatment A during mid to late spring and marked decline in wool growth rate during the spring of 1971 compared to the other pasture treatments could be attributed to an excessive production of, and aggravation by, barley grass inflorescences (Campbell *et al.* 1973).

9.2 Persistence of sown species

9.2.1 Grasses

The almost total failure of Medea ryegrass to demonstrate any perennial characteristics under continuous grazing in this experiment was both unexpected and difficult to explain and repudiates the original claims of increased individual plant persistence by this cultivar, at least under the conditions imposed in this experiment. Certainly, Medea ryegrass demonstrated adequate seed production and an ability (marginally greater than Wimmera and Victorian ryegrasses) to regenerate from self-sown seed following two summers in this environment.

However, as has frequently been demonstrated in the past, the behaviour of plant species under continuous grazing may differ from that demonstrated under cutting or short, periodic grazing regimes (Davidson 1969).

Subsequent to the completion of this experiment, reports of wide variability in the summer dormancy and persistence of Medea ryegrass have been received in South Australia (Higgs, personal communication).

An experiment (Gibson, unpublished) carried out in 1971 and 1972 on Kangaroo Island to define the best first year grazing management practice for Medea ryegrass demonstrated that this species could exhibit a marked degree of perenniality when intermittently grazed during the spring and summer in this environment, but not when under continuous grazing by sheep.

The lack of persistence of Victorian ryegrass over more than three summers in this environment agrees closely with the findings of Carter and Day (1970), on Kangaroo Island. These authors attributed the decline in the perennial ryegrass component, in their experiment, to the dry spring and summer conditions. The death of the Victorian ryegrass plants in this experiment occurred predominantly over the 1972/73 summer which also followed the driest spring and summer encountered during the experimental period: the total rainfall during the 1970/71, 71/72, 72/73 and 73/74 spring/summer periods being 172, 354, 91 and 247 mm respectively.

The influence of increased stocking rate in hastening the between-year decline in density of Victorian ryegrass plants, and the proportion of this species in the pasture, was clearly demonstrated in this experiment. Decreased persistence of perennial ryegrass with increased stocking rate has also been reported by Cameron and Cannon (1970) in Victoria.

In this Kangaroo Island experiment the species failed to persist even at the lowest stocking rate and it seems likely that the dry spring/summer conditions, possibly in combination with continuous grazing during this period,probably caused the lack of persistence of this species in this environment.

The high degree of persistence of the hybrid phalaris during the experimental period, irrespective of stocking rate, is in marked contrast to that of the ryegrass species and demonstrates the ability of this species to persist under variable management and environmental influences. This finding is in accordance with that of Hutchinson (1970) at Armidale, New South Wales, in a different environment and with that of Reed (1974) in a more similar environment at Glenormiston, Victoria. Both of these workers also demonstrated an interaction between survival of perennial grass species and stocking rate in their experiments.

Although stocking rate did not influence the density of hybrid phalaris plants, it did influence their size and also the proportion of this species in the pasture, however, statistical significance could not be demonstrated during the experimental period. Visual appraisal of the pastures during the spring of 1975 and 1976 (after intermittent grazing during these two years) revealed a continuation of the between-year trend towards increasing plant size and proportion of the hybrid phalaris in the pasture. In some paddocks the proportion was estimated to be between 30 and 40 per cent of the total available pasture. This highlights the problem of evaluating pasture species only over a relatively short period (4 years) when the long term (at least 10 years) changes in botanical composition may be important.

A further grazing experiment (Gibson, unpublished) in which the same hybrid phalaris has been compared with perennial ryegrass and Demeter fescue under grazing at three stocking rates in a higher rainfall environment, has since demonstrated high pasture production from the hybrid phalaris at the higher plant densities obtained in that experiment. However there was no advantage over the other pasture species in terms of animal production.

9.2.2 Subterranean clover

The partial replacement only of Yarloop with Mt. Barker and Woogenellup subterranean clovers in the renovated treatments in 1970, proved unsuccessful in maintaining a low proportion of Yarloop subterranean clover in the overall clover component after a period of four to five years.

Although, in 1970, the growth and seed set of the introduced subterranean clovers was suppressed to some degree by the vigorous growth of the ryegrass in treatments B, C and D, this did not occur in treatment E, yet Yarloop successfully invaded this treatment. This is highlighted by the level of hard seed reserves present in August 1973 in treatment E (c. 140 kg ha^{-1}) of which only 21 per cent was non-Yarloop seed. However, as the level of subterranean clover seed reserves was not measured in 1970, it is uncertain to what extent any initial reserves were important in enabling the rapid invasion of Yarloop into the pastures to take place in subsequent years.

Beale (1974) found that germination of hard and soft seed of Yarloop from an initial reserve on Kangaroo Island, continued at a very high level in the second and third years and only began to fall off in the fourth year. This is in contrast to the findings of Donald (1959) and Taylor (1972) who found that the majority of subterranean clover seed germinated in the first year after the seed was set and that the level of regeneration fell rapidly in subsequent years. However, these latter two workers did not include Yarloop in their experiments and Beale (1974) suggests that Yarloop has a greater capacity for continual regeneration from seed than has been observed in Geraldton, Dwalganup, Bacchus Marsh, Mt. Barker and Tallarook subterranean clovers.

In this thesis experiment the levels of hard seed reserves were similar in treatments A and B by August 1973 indicating that any decline in Yarloop seed reserves in treatment B, following the pasture renovation and management procedures performed in this treatment, were only temporary.

Experiments evaluating the possibility of replacing Yarloop with low-oestrogenic lines of subterranean clover are presently in progress on

Kangaroo Island. Particular attention is being paid to minimizing the germinable pool of Yarloop seed, prior to the sowing of new cultivars. Various tillage practices, such as mouldboard ploughing to deep-bury the seed and/or repeated cultivation to kill successive germinations of Yarloop are being evaluated (Beale *et al.* 1976).

The lack of evidence for the influence of stocking rate on the hard seed reserves and the seed production measured in 1973 and 1974 in this experiment, indicates that adequate levels of Yarloop seed reserves can be maintained, irrespective of the level of set stocking; at least over the time period and range of stocking rates used in this experiment.

The proportion of clover in the pasture on many occasions and particularly on the final sampling occasion in the spring of each year (except 1972), and the availability of pasture on nearly all sampling occasions during the experiment, were respectively positively and negatively correlated with stocking rate. Hence the net influence of stocking rate on the availability of clover herbage is dependent on the degree to which stocking rate influences both the proportion of clover in the sward and the total availability of pasture. In 1971 and 1972, there was no evidence of stocking rate influencing the availability of clover on any occasion and in 1973 and 1974,negative and positive relationships were recorded respectively.

In 1973 and 1974,only c. 50% of the variability in clover seed production was accounted for by the availability of clover at the end of the growing season. This is not surprising considering the possible variability in both the seed production and clover availability data due to sampling. This latter point is highlighted by the anomolous result obtained in 1974 when clover seed production was not influenced by stocking rate even though the former was related to the availability of clover, and stocking rate influenced the availability of clover.

Nevertheless, it is clear from both the pasture production data and the data on clover seed production and reserves that Yarloop is extremely well adapted to this environment with its outstanding growth during the winter and early spring and with its ability to set copious supplies of seed when grazed at both high and low stocking rates.

9.3 Invasion of non-leguminous species

The invasion of the renovated treatments B, C and D by volunteer annual species proceeded concurrently with the decline in the ryegrass component, and by 1974 obvious changes in botanical composition due to stocking rate were evident. The higher proportion of ripgut brome, capeweed and barley grass at the lower stocking rates, and *Vulpia* and *Erodium* spp. at the higher stocking rates, agrees with the findings of other workers (Sharkey *et al.* 1964, Davies 1965, Carter 1968b).

The occurrence of cluster clover and winter grass at the highest stocking rates as reported by Carter (1968b) and Brown (1976a) was not evident. However, it is possible that the effective grazing pressure (in addition to the actual stocking rate) at the highest stocking rate in this experiment was lower than in the above two experiments where there was need for regular supplementary feed in Brown's experiment and sheep deaths at the highest stocking rate in Carter's experiment. In this thesis experiment, sheep that died from undernutrition were from mainly one treatment (B) and these deaths occurred in only one year (1971).

The dominance of ripgut brome in the absence of grazing in treatment E during 1970 supports the observations of the Californian workers (Talbot and Biswell 1942, Jones and Evans 1960) and also those of Rossiter and Pack (1956) in Western Australia.

9.4 Interaction of stocking rate and botanical composition in the determination of animal production

It has been clearly demonstrated that the differences in animal production recorded in this experiment involving various pasture treatments and stocking rates were usually associated with the qualitative and quantitative presence of subterranean clover in the pasture. The presence or absence of other species (whether sown temperate, perennial or annual species, or volunteer, broad-leaved or narrow-leaved annual species) could not consistently be associated with changes in animal productivity in this experiment. The marked invasion of Yarloop into the renovated pasture treatments occurred at all stocking rates and, although the availability of clover may be influenced by stocking rate within any one season, in the longer term the presence of Yarloop appears independent of stocking rate. Hence the excellent adaptation of Yarloop in this environment, with its rapid growth during the winter and early spring and its ability to set copious supplies of seed with potential for germination over a number of years, seems to have guaranteed these pastures a degree of quantitative and qualitative independence of stocking rate. It therefore is important to state, that in the long term, there appears to be no obvious interaction of stocking rate and botanical composition in the determination of animal production in this environment. This is not to say that no such interaction occurred in this experiment (as it obviously did in 1971) but the difference in botanical composition was primarily a result of the pasture renovation practice rather than as a direct result of imposed stocking rates. The obvious effects of the renovation practice in terms of botanical composition were only evident in the short term.

The short term interaction of pasture treatment and stocking rate in determining animal production is best seen by comparing the quantity of clean wool produced per hectare in 1971 in treatments A and D. The absence of a significant component of Yarloop in treatment D during 1971 and most of 1972 resulted in an almost constant quantity of clean wool per hectare being produced over the range of stocking rates. Only in 1973 was there a significant increase in clean wool produced per hectare with increased stocking rate. In contrast, maximum clean wool per hectare was produced at the highest stocking rate in treatment A in all years with no indication (except perhaps in the poorest pasture year of 1972) that the potential maximum clean wool per hectare had been attained. However, in 1974 there was no difference between these pasture treatments in the relationship of clean wool produced per hectare and stocking rate; a result of a significant legume component comprising the pastures of both pasture treatments.

9.5 Wool production and fleece characteristics

Clear evidence has been produced for an inverse relationship between the clean fleece weight and stocking rate of the wethers in this experiment. This result is to be expected in the light of previously reported experiments with wethers (Arnold and McManus 1960, Cannon 1969, Carter and Day 1970, Brown 1976b) and with ewes (Davies 1962a, Morley *et al.* 1969). The reduction in fibre diameter and staple length with increased stocking rate, as recorded in this experiment, has also been reported in previous experiments (Sharkey *et al.* 1962, Cannon 1972, Langlands and Bennett 1973, Lipson and Bacon-Hall 1974, White and McConchie 1976, Brown 1976b). However, McManus *et al.* (1964) in the Canberra environment, found no significant effect of stocking rate on the fibre diameters, staple lengths and subjective characteristics of Merino fleeces. However these workers did observe stocking rate effects on the seasonal changes in fibre diameter and staple length during their experiment. Similar seasonal trends have been recorded by Roe *et al.* (1959) and Sharkey *et al.* (1962).

The observed decrease in staple crimp frequency with increased stocking rate in 1973, and the lack of response of this characteristic to stocking rate in other years in this experiment, is in contrast to the positive relationship reported by White and McConchie (1976), Cannon (1972) and Langlands and Bennett (1973).

Cannon (1972) reported both increases and decreases in yield of clean wool with increased stocking rate (depending on the level of superphosphate application in his experiment) while Langlands and Bennett (1973) and White and McConchie (1976) reported no relationship. However in this thesis experiment, a negative relationship was recorded in 1972 which is in accordance with the findings of Brown (1976b) who recorded a similar relationship in four consecutive years.

Although no significant interaction between pasture treatment and stocking rate was recorded for any of the fleece characteristics in any year, significant differences between pasture treatments were recorded in this experiment in 1971.

There appears to be no experiment reporting a significant effect of pasture type on the fleece characteristics of grazing sheep. In one study reported from Canberra, A.C.T. (McManus *et al.* 1964) in which the fleece characteristics of Merino wethers grazing either a phalaris-subterranean clover pasture or an annual pasture comprising subterranean clover, *Bromus* spp. and barley grass were compared, no effect of pasture type on any fleece characteristic was recorded. However, large differences in the proportion and availability of the pasture legume component did not exist in that experiment and hence the result is not in discord with this Kangaroo Island experiment.

In most experiments reported, the fleece characteristics of the grazing sheep have been insensitive, not only to botanical composition but also to pasture management practices (other than stocking rate). For example, isolated instances only (and then in only one year) have been reported where the level of superphosphate application (Cannon 1972, White and McConchie 1976) or grazing management (Brown 1976b) have significantly affected any fleece characteristic.

9.6 Efficiency of high stocking rates

There is no doubt that the use of higher stocking rates on the annual-type pasture typical of the Mediterranean-type climate in southern Australia will usually result in increased animal production, particularly wool production[+] as recorded in this experiment (Lloyd Davies and Humphries 1965, Carter 1965, Carter and Day 1970, Carter 1973, Brown 1976b).

The efficiency of wool production in relation to pasture production and rainfall, was clearly dependent on stocking rate (Table 22) and this experiment highlights the biological and economic inefficiency of low stocking rates. The indices of total clean wool production, in relation to rainfall, show a close parallel with that for pasture production, and emphasize the improved efficiency of water use at higher stocking rates. The percentage crude utilization of green pasture ranged from 57% to 73% at the lowest and highest stocking rates respectively (Table 22). Total annual crude utilization of pasture (including the pasture utilized or otherwise disappearing over the summer months) would be much higher. Carter (1973) reported total annual crude utilization values of 96.2% at a stocking rate of 22.2 sheep ha^{-1} in his stocking rate experiment on annual pasture at the Waite Institute, South Australia. Those stocking rates in which a crude utilization value of 82% was recorded were perfectly safe resulting in no undue stress on the experimental wethers under the

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[+]However, increased stocking rate often does not increase meat or milk production.

conditions of his experiment.

This experiment has demonstrated an approximate linear response of wool production to increase in stocking rate up to the maximum of 17 wethers ha^{-1} imposed in this experiment without any obvious adverse effects on the productivity of the grazed pastures. This is not to say that all pastures in this environment should be stocked at this level as allowance must be made for the additional requirements of breeding sheep and young growing sheep. In addition, the social and risk factors associated with high stocking rates must also be taken into account (Carter and Day 1970, McArthur 1970, McArthur and Dillon 1971) and it must be realized that probably three out of the four years of set stocking in this experiment, experienced above-average seasonal rainfall.

9.7 Conclusion

Although one cannot extrapolate the results of this relatively short-term experiment to the longer-term without some degree of uncertainty, this experiment has indicated that in the past undue emphasis may have been placed on minimizing the contribution of many of our volunteer annual grasses and herbs and attempting to stabilize botanical composition by sowing temperate perennial species rather than ensuring that an adequate legume component is present.

Provided that the problem of clover-induced infertility in ewes can be overcome, either by sheep selection and/or managerial means or by the replacement of Yarloop subterranean clover with an equally-productive and well adapted legume, high animal production should be maintained from the annual pastures in this environment.

Certainly, change in botanical composition resulting from various stocking rates *per se* is no cause for alarm, but rather it indicates the weaknesses of our sown species and the strengths of many of our naturally-occurring volunteer annual species.

This experiment clearly showed that a suitable Yarloop-volunteer annual grass pasture will give high levels of animal production and, as yet, there is no evidence that any alternate pasture will perform better in this environment.

Table 22

MEAN PRODUCTION DATA AND INDICES OF CLEAN WOOL PRODUCED IN RELATION TO PASTURE PRODUCTION AND APRIL-NOVEMBER RAINFALL, PARNDANA EAST 1971-74

Stocking Rate (sheep ha^{-1})	Pasture grown kg ha^{-1} D.M.	Annual green C.U. kg ha^{-1} D.M.	Proportion green pasture utilized during growing season %	Clean Wool grown kg ha^{-1}	Wool grown kg/1000 kg DM.	Wool grown kg ha^{-1}/ 100 mm Ap.-Nov. rainfall.
	Mean of four years x five pasture treatments					
10	8040	4610	57	45	5.6	7.5
11	8660	4650	54	49	5.7	8.2
13	8170	5030	62	55	6.7	9.2
14	8620	5790	67	57	6.6	9.5
15	8550	5720	67	61	7.1	10.2
17	8580	6240	73	68	7.9	11.4

APPENDICES

Appendix Table 1

METEOROLOGICAL RECORDS FROM THE KANGAROO ISLAND RESEARCH CENTRE, PARNDANA EAST

1970

Climatic Data	MONTHLY MEANS JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	MEAN
Cloud Cover^{+}	0.60	0.57	0.61	0.65	0.55	0.53	0.58	0.70	0.80	0.68	0.60	0.61	0.62
Wind Speed(km hr^{-1})	22.1	22.6	19.4	18.4	16.6	19.2	17.0	20.6	20.5	22.6	21.0	24.5	20.4
Sea level Pressure (m b)	1015.4	1017.5	1017.1	1016.9	1022.4	1015.3	1019.3	1017.8	1015.4	1016.3	1016.2	1013.6	1016.9
Dry Bulb Temp.(^{o}C)	17.7	19.3	16.8	15.8	11.7	11.2	10.1	9.5	10.3	13.4	16.4	18.5	14.2
Dew Pt. (^{o}C)	10.9	11.8	10.8	11.5	9.4	9.0	8.1	6.9	7.2	8.1	8.8	9.8	9.3
Max. Temp (^{o}C)	23.1	25.9	22.5	20.9	15.9	14.7	14.3	12.8	13.7	17.5	21.0	23.4	18.8
Min Temp. (^{o}C)	11.3	12.9	10.9	11.1	7.9	8.0	7.1	5.8	6.5	6.6	8.3	10.9	8.9
Rainfall (mm)‡	40.3	2.8	21.7	51.0	49.6	93.0	49.6	111.6	81.0	18.6	27.0	27.9	570.7^{S}
No. of Wet Days	12	1	11	14	19	24	21	28	21	16	11	10	188^{S}
Sunshine (hrs day^{-1})	8.1	8.9	6.7	4.9	3.8	3.3	4.5	3.5	3.0	7.2	8.1	7.3	5.8

$^{+}$ 0 = no cloud cover 1 = maximum cloud cover

‡ monthly totals. ^{S} = annual total.

Appendix Table 2

METEOROLOGICAL RECORDS FROM THE KANGAROO ISLAND RESEARCH CENTRE, PARNDANA EAST

1971

Climatic Data	MONTHLY MEANS												MEAN
	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	
Cloud Cover^{+}	0.61	0.64	0.63	0.60	0.66	0.74	0.64	0.57	0.59	0.64	0.75	0.70	0.65
Wind Speed(km hr^{-1})	21.0	21.7	22.6	18.9	15.9	14.7	14.8	18.7	19.7	23.8	20.6	24.5	19.8
Sea Level Pressure (mb)	1015.1	1013.3	1017.4	1017.4	1014.7	1020.8	1019.9	1014.4	1013.9	1011.5	1011.9	1011.6	1015.1
Dry Bulb Temp (^{o}C)	19.0	19.5	19.7	16.6	12.4	10.8	9.8	9.9	11.8	13.3	14.3	16.4	14.5
Dew Pt. (^{o}C)	12.9	12.9	14.1	12.4	10.2	9.0	8.1	7.6	8.8	8.0	9.4	11.2	10.4
Max Temp (^{o}C)	24.6	26.0	24.4	22.2	15.8	14.2	13.2	13.5	14.9	17.0	17.7	20.5	18.7
Min Temp (^{o}C)	12.4	13.6	14.6	12.0	9.1	7.7	6.5	6.3	7.0	7.5	9.4	10.2	9.7
Rainfall (mm)‡	6.2	11.2	34.1	138.0	96.1	66.0	62.0	142.6	66.0	37.2	81.0	62.0	791.5^{S}
No. of Wet Days	5	6	10	14	26	24	18	29	22	21	16	12	203^{S}
Sunshine (hr day^{-1})	7.7	6.9	5.9	5.9	3.9	2.5	3.0	4.4	5.2	5.0	4.6	5.9	5.1

$^{+}$ 0 = no cloud cover   1 = maximum cloud cover

‡ monthly totals ^{S} = annual total.

Appendix Table 3

METEOROLOGICAL RECORDS FROM THE KANGAROO ISLAND RESEARCH CENTRE, PARNDANA EAST

1972

Climatic Data	MONTHLY MEANS												
	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	MEAN
Cloud Cover$^+$	0.64	0.54	0.51	0.52	0.56	0.50	0.66	0.55	0.58	0.63	0.61	0.60	0.57
Wind Speed (km hr^{-1})	18.8	19.2	19.1	18.1	13.9	15.4	17.8	16.6	19.7	21.2	18.2	21.1	18.3
Sea Level Pressure (mb)	1013.9	1016.3	1018.5	1021.1	1027.9	1022.9	1017.1	1013.6	1020.2	1019.1	1018.3	1016.4	1018.8
Dry Bulb Temp (°C)	18.1	20.4	17.6	16.2	14.0	9.5	10.0	10.8	12.6	13.3	14.1	18.2	14.6
Dew Pt. (°C)	12.6	12.2	9.8	10.9	8.8	6.8	7.8	8.0	8.0	8.9	9.3	10.1	9.4
Max Temp (°C)	22.0	25.6	22.6	21.5	19.2	15.4	13.4	13.9	16.6	17.8	19.6	25.5	19.4
Min Temp (°C)	12.8	13.4	11.5	10.4	8.8	5.2	7.5	7.1	7.6	8.0	8.3	11.5	9.3
Rainfall (mm)‡	58.9	49.3	6.2	24.0	21.7	63.0	148.8	124.0	18.0	40.3	12.0	6.2	571.0^S
No. of Wet Days	8	9	5	10	10	18	28	22	10	14	5	4	143^S
Sunshine (hr day^{-1})	6.8	7.1	6.2	6.1	4.9	4.5	2.6	4.4	5.1	6.2	6.5	8.2	5.7

$^+$0 = no cloud cover   1 = maximum cloud cover

‡ monthly totals ^{S} = annual total.

Appendix Table 4

METEOROLOGICAL RECORDS FROM THE KANGAROO ISLAND RESEARCH CENTRE, PARNDANA EAST

1973

Climatic Data	MONTHLY MEANS JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	MEAN
Cloud Cover^{+}	0.67	0.44	0.63	0.59	0.45	0.59	0.37	0.59	0.56	0.63	0.59	0.52	0.55
Wind Speed(km hr^{-1})	19.4	17.2	17.2	21.3	19.2	15.5	15.3	18.9	26.2	21.2	14.6	21.3	18.9
Sea Level Pressure (mb)	1014.0	1015.7	1018.8	1017.0	1018.5	1017.6	1021.5	1016.3	1015.2	1017.0	1015.2	1013.3	1016.7
Dry Bulb Temp.(^{o}C)	19.5	18.4	17.1	16.2	13.3	9.2	10.3	11.1	12.7	14.7	14.6	17.6	14.5
Dew Pt. (^{o}C)	12.5	13.1	11.4	11.4	10.9	7.2	8.5	8.9	9.2	10.6	10.2	11.7	10.4
Max.Temp. (^{o}C)	26.8	25.7	22.4	20.7	17.3	13.5	14.3	14.5	16.4	18.5	19.7	24.3	19.5
Min.Temp (^{o}C)	14.6	12.4	11.8	11.4	8.9	6.3	6.5	7.2	8.0	8.5	8.7	11.6	9.7
Rainfall (mm)‡	6.2	8.4	71.3	42.0	62.0	108.0	89.9	139.5	72.0	55.8	18.0	43.4	699.3^{S}
No. of Wet Days	9	7	11	15	15	17	16	24	20	16	16	12	178^{S}
Sunshine (hr day^{-1})	6.2	7.9	5.0	5.5	5.7	3.7	5.3	4.6	4.9	5.2	6.8	6.8	5.6

$^{+}$0 = no cloud cover   1 = maximum cloud cover

‡ monthly totals ^{S} = annual total.

Appendix Table 5

METEOROLOGICAL RECORDS FROM THE KANGAROO ISLAND RESEARCH CENTRE, PARNDANA EAST

1974

Climatic Data	MONTHLY MEANS												MEAN
	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	
Cloud Cover+	0.53	0.54	0.66	0.71	0.62	0.54	0.61	0.47	0.72	0.63	0.64	0.54	0.60
Wind Speed (km hr^{-1})	24.5	20.9	22.3	18.0	13.1	15.6	19.9	19.6	22.4	22.0	19.9	20.5	19.9
Sea Level Pressure (mb)	1010.9	1016.1	1017.5	1017.3	1020.5	1021.2	1013.0	1016.4	1018.5	1014.6	1015.9	1012.7	1016.2
Dry Bulb Temp. (^oC)	20.0	17.2	19.6	15.2	12.7	11.0	10.5	10.9	11.4	13.5	13.9	16.4	14.4
Dew Pt. (^oC)	14.7	13.9	14.9	12.8	11.2	9.7	8.2	9.2	8.1	10.0	9.7	10.1	11.0
Max. Temp. (^oC)	26.2	23.9	25.3	19.0	16.1	14.6	13.5	14.7	14.5	17.3	18.2	22.1	18.8
Min. Temp. (^oC)	14.9	13.5	15.1	11.8	9.8	7.7	7.5	7.3	6.2	8.7	7.9	9.9	10.0
Rainfall (mm)‡	49.6	8.4	24.8	60.0	108.5	66.0	161.2	80.6	72.0	93.0	27.0	9.3	761.7[S]
No. of Wet Days	9	7	9	19	17	17	28	23	22	16	12	10	189[S]
Sunshine (hr day^{-1})	7.2	7.5	4.8	1.7	3.2	3.4	2.7	5.2	4.0	5.5	9.0	9.2	5.3

+0 = no cloud cover   1 = maximum cloud cover

‡monthly totals   S = annual total.

Appendix Table 6

MEAN PASTURE PRODUCTION MEASURED IN SEVEN PERIODS IN 1971

($kg\ ha^{-1}$ dry matter)

Period	Pasture treatment means					Stocking rate means (sheep ha^{-1})						Grand mean	Hetero. Adjt. treat. means	LSD 5% treat. means	Sig. mean Reg. on SR.	Hetero. Reg. Coeff.
	A	B	C	D	E	10	11	13	14	15	17					
24/4-2/6	2350	1035	2205	1710	2090	2030	1730	1795	1820	2030	1860	1875	***	200	NS	NS
2/6-5/7	675	1085	905	1235	755	815	935	1040	1155	900	745	930	**	321	NS	NS
5/7-8/9	4105	1490	2455	1645	2635	2210	2255	2365	2575	2650	2730	2640	***	506	*	NS
8/9-24/11	3760	3955	3285	2645	4850	3945	4110	3145	3805	3840	3350	3700	***	751	NS	NS
24/4-5/7	3025 *+	2120	3115	2945	2845	2840	2665	2840	2975	2930	2605	2810	–	–	NS	*
24/4-8/9	7125 *	3610	5565	4590	5480	5050	4925	5205	5550	5580	5335	5270	***	724	NS	NS
24/4-24/11	10885	7570	8850	7235	10325	9000	9035	8350	9350	9420	8685	8970	***	1236	NS	NS

+ = Significance of within-treatment regressions on stocking rate.

NS = P > 0.05   * = P< 0.05   ** = P < 0.01   *** = P < 0.001

Appendix Table 7

MEAN PASTURE PRODUCTION MEASURED IN FIVE PERIODS IN 1972

(kg ha^{-1} dry matter)

Period	Pasture treatments means					Stocking rate means (sheep ha^{-1})						Grand mean	Hetero. Adjt. treat. means	LSD 5% treat. means	Sig. mean Reg. on SR.	Hetero. Reg. Coeff.
	A	B	C	D	E	10	11	13	14	15	17					
1/5-27/6	1365	590	270 *+	500 *	835	795	760	755	655	565	745	710	***	427	NS	NS
27/6-26/9	2885	2925	1595	1680	2340	2225	2310	2320	2415	2070	2375	2280	***	464	NS	NS
26/9-16/11	2980	3355	3705	3485	3065	2930	3940	3445	3090	2985	3520	3320	NS	846	NS	NS
1/5-26/9	4250	3515	1870	2180	3190	3015	3070	3075	3065	2640	3140	3000	***	707	NS	NS
1/5-16/11	7230	6875	5575	5665	6240	5950	7010	6515	6155	5625	6640	6320	*	1178	NS	NS

+ = Significance of within-treatment regressions on stocking rate

NS = P > 0.05   * = P < 0.05   ** = P < 0.01   *** = P< 0.001

Appendix Table 8

MEAN PASTURE PRODUCTION MEASURED IN FIVE PERIODS IN 1973

(kg ha^{-1} dry matter)

Period	Pasture treatment means					Stocking rate means (sheep ha^{-1})						Grand mean	Hetero. Adjt. treat. means	LSD 5% treat. means	Sig. mean Reg. on SR	Hetero. Reg. Coeff.
	A	B	C	D	E	10	11	13	14	15	17					
18/3-18/6	2925	2700	2400	2610	2920	2580	2580	2805	2795	2620	2890	2710	NS	454	NS	NS
18/6-17/9	2615	2195*+	2605	3115	2730	2535	3355	2200	2940	2405	2480	2650	-	-	NS	*
17/9-26/11	3760**	4295	3225	4365	3235	3105	3295	3400	3875	4405	4585	3780	*	929	***	NS
18/3-17/9	5540	4895	5010	5725	5650	5110	5935	5000	5735	5025	5370	5360	NS	1002	NS	NS
18/3-26/11	9300*	9190	8230	10090	8885	8215	9235	8400	9610	9435	9955	9140	-	-	*	*

+ = Significance of within-treatment regressions on stocking rate.

NS = P > 0.05   * = P < 0.05   ** = P < 0.01   *** = P < 0.001

Appendix Table 9

MEAN PASTURE PRODUCTION MEASURED IN FIVE PERIODS IN 1974

(kg ha^{-1} dry matter)

Period	Pasture treatment means					Stocking rate means (sheep ha^{-1})						Grand mean	Hetero. Adjt. treat. means	LSD 5% treat. means	Sig. mean Reg. on SR.	Hetero. Reg. Coeff.
	A	B	C	D	E	10	11	13	14	15	17					
6/4-10/6	2880	3080*+	2775	2655	2490	2690	2830	2665	2950	2725	2795	2780	-	-	NS	**
10/6-2/9	2130	2130*	2210	2565	2585	1755	1870	2835	2435	2610	2435	2320	NS	1151	NS	NS
2/9-18/11	4295	3970	4270*	4065	4480	4565	4645	3925	3970	4370	3820	4220	NS	864	NS	NS
6/4 -2/9	5010	5210	4985	5215	5075	4445	4700	5500	5385	5335	5230	5100	NS	1087	NS	NS
6/4-18/11	9305	9180	9250	9280	9555	9010	9350	9425	9355	9705	9055	9320	NS	1081	NS	NS

+ = Significance of within-treatment regressions on stocking rate.

NS = P = > 0.05   * = P < 0.05   ** = P < 0.01   ***=P < 0.001

Appendix Table 10

MEAN CRUDE UTILIZATION OF PASTURE MEASURED IN SEVEN PERIODS IN 1971

(kg ha^{-1} dry matter)

Period	Pasture treatment means					Stocking rate means (sheep ha^{-1})						Grand mean	Hetero. Adjt. treat. means	LSD 5% treat. means	Sig. mean Reg. on SR.	Hetero. Reg. Coeff.
	A	B	C	D	E	10	11	13	14	15	17					
24/4-2/6	1320*+	845	1390	1210	1255	1220	870	1280	1155	1405	1285	1200	NS	443	NS	NS
2/6-5/7	625*	590	710	680	755	365	565	700	930	715	750	670	NS	258	**	NS
5/7-8/9	3790	1930	3000	2440	2725	2575	2675	2500	2800	3115	2985	2775	***	421	*	NS
8/9-24/11	1155	3060	2230	2370	2885	2310	2365	1880	2560	2210	2720	2340	**	855	NS	NS
24/4-5/7	1945*	1435	2100	1890	2005	1590	1435	1980	2085	2120	2035	1875	NS	494	**	NS
24/4-8/9	5730*	3365	5100	4325	4730	4165	4110	4480	4890	5235	5020	4650	***	767	**	NS
24/4-24/11	6885	6425	7330	6700	7610	6475	6480	6360	7445	7440	7740	7000	NS	137	*	NS

+ = Significance of within-treatment regressions on stocking rate.

NS = $P > 0.05$ * = $P < 0.05$ ** = $P < 0.01$ *** = $P < 0.001$

Appendix Table 11

MEAN CRUDE UTILIZATION OF PASTURE MEASURED IN FIVE PERIODS IN 1972

(kg ha^{-1} dry matter)

Period	Pasture treatment means					Stocking rate means (sheep ha^{-1})						Grand mean	Hetero. Adjt. treat. means	LSD 5% treat. means	Sig. mean Reg. on SR.	Hetero. Reg. Coeff.
	A	B	C	D	E	10	11	13	14	15	17					
1/5-27/6	1255	360	150	415	610	500	555	620	550	460	665	560	-	-	NS	*
27/6-26/9	1940	2365	1405	1460^{*+}	2005	1980	1545	1895	1850	1675	2060	1830	**	522	NS	NS
26/9-16/11	1715	1295	2265^{**}	2120	1465^{*}	1480	1085	1580	1955	2005	2520	1770	*	605	***	NS
1/5-26/9	3195	2720	1555	1875^{**}	2610	2475	2100	2515	2395	2140	2725	2390	***	739	NS	NS
1/5-16/11	4910	4015	3820^{**}	3995	4075^{*}	3955	3185	4095	4355	4145	5245	4160	NS	1042	**	NS

$^{+}$ = Significance of within-treatment regressions on stocking rate

NS = $P > 0.05$ * = $P < 0.05$ ** = $P < 0.01$ *** = $P < 0.001$

Appendix Table 12

MEAN CRUDE UTILIZATION OF PASTURE MEASURED IN FIVE PERIOD IN 1973

(kg ha^{-1} dry matter)

Period	Pasture treatment means					Stocking rate means (sheep ha^{-1})						Grand mean	Hetero. Adjt. treat. means	LSD 5% treat. means	Sig. mean Reg. on SR.	Hetero. Reg. Coeff.
	A	B	C	D	E	10	11	13	14	15	17					
18/3-18/6	1750 *+	2100 *	1940	2275	2220	1705	1675	2030	2175	2155	2605	440	NS	486	***	NS
18/6-17/9	1390	505 *	1575	2020	1895	885	1340	1230	1955	1605	1855	1480	-	-	*	**
17/9-26/11	2475	1970	1120	2015	575	1295	1940	1240	1815	1585	1915	1630	**	983	NS	NS
18/3-17/9	3145 *	2605	3520	4295	4110 **	2590	3010	3260	4125	3765	4455	3530	*	1007	***	NS
18/3-26/11	5620 *	4575	4640	6310	4685	3885	4955	4495	5940	5345	6370	5160	NS	1425	**	NS

+ = Significance of within-treatment regressions on stocking rate

NS = P > 0.05   * = P < 0.05   ** = P < 0.01   *** = P < 0.001

Appendix Table 13

MEAN CRUDE UTILIZATION OF PASTURE MEASURED IN FIVE PERIODS IN 1974

(kg ha^{-1} dry matter)

Period	Pasture treatment means					Stocking rate means (sheep ha^{-1})						Grand mean	Hetero. Adjt. treat. means	LSD 5% treat. means	Sig. mean Reg. on SR.	Hetero. Reg. Coeff.
	A	B	C	D	E	10	11	13	14	15	17					
6/4-10/6	1000	1615	1640	1250	1280	1035	930	1285	1500	1730	1665	1360	NS	579	**	NS
10/6-2/9	2045	1830 *+	1560	2240	2465	1965	1930	2270	2070	2210	1715	2030	NS	988	NS	NS
2/9-18/11	1320	1210	1705 **	1510	2555	1140	1130	1615	1845	2005	2225	1660	***	502	***	NS
6/4-2/9	3045	3445 *	3200	3490	3740	3000	2860	3555	3570	3940	3380	3380	NS	1092	NS	NS
6/4-18/11	4365	4655	4905	5000	6295	4140	3990	5170	5415	5945	5605	5040	*	1163	**	NS

+ = Significance of within-treatment regressions on stocking rate.

NS = P > 0.05   * = P < 0.05   ** = P < 0.01   *** = P < 0.001

Appendix Table 14

AVAILABILITY OF PASTURE MEASURED ON SEVEN OCCASIONS IN 1971-1972

(kg ha^{-1} dry matter)

Date	Pasture treatment means					Stocking rate means (sheep ha^{-1})						Grand mean	Hetero. Adjt. treat. means	LSD 5% treat. means	Sig. mean Reg. on SR.	Hetero. Reg. Coeff.
	A	B	C	D	E	10	11	13	14	15	17					
2/6/71	1030	195	820	500	835	805	860	520	665	625	575	675	***	182	***	NS
5/7/71	1080	685	1015	1060	840	1255	1230	860	890	810	570	935	**	218	***	NS
8/9/71	1395	250	465*+	265	750	885	810	735	660	345	315	625	***	330	***	NS
24/11/71	4000	1145	1520*	540	2715	2525	2555	1990	1905	1980	950	1985	***	691	***	NS
27/6/72	105	230	120	90	225	295	200	135	105	105	85	155	NS	146	**	NS
26/9/72	1055	795	310	310	560	540	970	560	670	500	400	605	***	232	*	NS
16/11/72	2320	2860	1755	1670	2165	1990	3830	2425	1800	1480	1395	2155	NS	1163	**	NS

+ = Significance of within-treatment regressions on stocking rate

NS = P > 0.05   * = P < 0.05   ** = P < 0.01   *** = P < 0.001

Appendix Table 15

AVAILABILITY OF PASTURE MEASURED ON SIX OCCASIONS IN 1973-1974

(kg ha^{-1} dry matter)

Date	Pasture treatment means					Stocking rate means (sheep ha^{-1})						Grand mean	Hetero. Adjt. treat. means	LSD 5% treat. means	Sig. mean Reg. on SR	Hetero. Reg. Coeff.
	A	B	C	D	E	10	11	13	14	15	17					
18/6/73	1170	600*+	460	335	705***	875	905	775	620	465	285	655	***	227	***	NS
17/9/73	2395*	2290	1490*	1430*	1540***	2520	2925	1745	1610	1260	915	1830	**	564	***	NS
26/11/73	3680	4615*	3590	3780	4200*	4330	4280	3905	3665	4085	3580	3975	–	–	*	*
10/6/74	1880	1465*	1135	1400	1215	1655	1905	1360	1450	995	1130	1415	NS	636	*	NS
2/9/74	1965	1765	1780	1730	1335	1440	1840	1945	1815	1395	1850	1715	NS	669	NS	NS
18/11/74	4940*	4525*	4345**	4280	3260	4865	5355	4255	3940	3760	3450	4270	***	650	***	NS

NS = P > 0.05   * = P < 0.05   ** = P < 0.01   *** = P < 0.001

+ = Significance of within-treatment regressions on stocking rate.

Appendix Table 16

MEAN LIVE WEIGHTS ON EIGHT OCCASIONS IN 1970-1971
(kg)

Date	Pasture treatment means					Stocking rate means (kg ha^{-1})						Grand mean	Hetero. Adjt. treat. means	LSD 5% treat. means	Sig. mean Reg. on SR.	Hetero. Reg. Coeff.
	A	B	C	D	E	10	11	13	14	15	17					
28/10/70	46.3	45.9	46.1	46.1	46.4	46.5	45.4	46.8	45.8	46.5	46.0	46.2	NS	-	NS	NS
10/2/71	39.9	31.8	41.3	41.5	42.2	40.9	41.1	40.9	39.9	41.1	40.7	40.8	***	1.26	NS	NS
31/3/71	39.4	30.1	43.7	42.8	44.9	42.4	42.3	41.3	40.5	42.4	41.8	41.8	***	2.20	NS	NS
3/5/71	38.0	27.3	41.4	39.7	42.3	40.7	39.1	39.1	37.9	39.9	39.4	39.3	***	1.95	*	NS
23/6/71	44.6 **+	28.8	44.2 *	39.9 ***	45.1 *	44.7	43.3	42.6	41.4	40.7	40.7	42.2	***	1.56	***	NS
20/7/71	46.6 **	29.2 **	45.5 **	40.6 **	47.7	47.5	44.9	43.9	43.2	41.7	41.0	43.7	***	1.75	***	NS
24/8/71	52.0 *	30.1 *	47.0 **	41.2 **	51.2 *	51.3	48.2	46.7	45.8	43.3	42.1	46.2	***	2.40	***	NS
5/10/71	53.1	30.1 **	46.7 *	39.7 **	51.0 **	49.6	50.0	45.9	44.9	43.0	43.6	46.2	***	2.48	***	NS

+Significance of within-treatment regressions on stocking rate

NS = P > 0.05   * = P < 0.05   ** = P < 0.01   *** = P < 0.001

Appendix Table 17

MEAN LIVE WEIGHTS ON SEVEN OCCASIONS IN 1971-1972
(kg)

Date	Pasture treatment means					Stocking rate means (kg ha^{-1})						Grand mean	Hetero. Adjt. treat. means	LSD 5% treat. means	Sig. mean Reg. on SR.	Hetero. Reg. Coeff.
	A	B	C	D	E	10	11	13	14	15	17					
11/11/71	57.6	38.1***	53.6	45.4**+	58.0	54.6	55.0	51.8	52.8	51.0	51.8	52.8	-	-	***	***
6/12/71	59.2	41.9***	55.9	50.2***	60.1*	58.1	58.1	55.6	55.3	53.3	53.8	55.7	-	-	***	**
22/12/71	58.7	43.7**	56.5	52.2**	60.0	58.0	59.2	56.2	56.5	54.7	53.7	56.4	-	-	***	*
19/1/72	53.6	41.7***	54.4	49.2***	54.7	54.5	54.8	53.1	53.3	51.1	49.1	52.7	-	-	***	*
SHEARING January 25, 1972																
25/1/72	43.4	41.5*	44.4	40.3**	44.5	44.1	44.0	43.3	43.3	42.3	40.8	43.0	***	2.04	**	NS
8/3/72	49.1	44.4	49.9	44.6**	49.7*	50.0	49.6	47.8	47.4	47.5	43.8	47.7	***	2.44	***	NS
19/4/72	50.0*	43.1	46.3	42.0**	48.9	49.6	49.9	46.4	44.6	46.0	41.0	46.2	***	3.06	***	NS

+Significance of within-treatment regressions on stocking rate

NS = P> 0.05   * = P< 0.05   ** = P<0.01   *** = P < 0.001

Appendix Table 18

MEAN LIVE WEIGHTS ON SEVEN OCCASIONS IN 1972-1973

(kg)

Date	Pasture treatment means					Stocking rate means (kg ha^{-1})						Grand mean	Hetero. Adjt. treat. means	LSD 5% treat. means	Sig. mean Reg. on SR.	Hetero. Reg. Coeff.
	A	B	C	D	E	10	11	13	14	15	17					
25/5/72	47.5	40.9**	43.0*+	38.9**	46.1*	47.1	47.7	43.2	42.4	42.1	38.9	43.6	***	2.65	***	NS
12/7/72	42.6***	36.9*	38.8*	35.0*	41.9*	44.1	44.2	38.4	37.5	36.9	34.3	39.2	***	2.71	***	NS
16/8/72	46.3*	40.3*	39.4***	37.7	43.4**	45.3	46.2	41.2	40.0	40.4	36.5	41.6	***	2.39	***	NS
28/9/72	48.1	42.0**	39.2**	36.9*	43.7***	46.0	47.5	42.4	41.3	40.1	35.8	42.2	***	2.84	***	NS
29/11/72	58.4	56.3**	54.6*	50.1*	56.0	57.4	57.9	56.3	54.8	54.8	50.3	55.3	–	–	***	*
17/1/73	59.1	60.1	58.0	52.3*	58.5	59.9	60.3	59.5	57.5	58.5	50.7	57.7	–	–	***	*
						SHEARING January 18, 1973										
18/1/73	50.1	51.1	49.0	44.7*	49.2	51.1	50.3	50.1	48.2	49.3	44.0	48.8	*	3.87	***	NS

+Significance of within-treatment regressions on stocking rate

NS = P > 0.05. * = P < 0.05 ** = P < 0.01 *** = P < 0.001

Appendix Table 19

MEAN LIVE WEIGHTS ON EIGHT OCCASIONS IN 1973-1974

(kg)

Date	Pasture treatment means					Stocking rate means (kg ha^{-1})						Grand mean	Hetero. Adjt. treat. means	LSD 5% treat. means	Sig. mean Reg. onSR.	Hetero. Reg. Coeff.
	A	B	C	D	E	10	11	13	14	15	17					
28/2/73	53.9	56.1	52.9	49.4**+	53.1	55.2	55.9	55.1	52.0	53.1	47.6	53.2	NS	4.39	***	NS
18/4/73	54.0	55.1**	48.8*	47.4**	51.6**	55.5	56.1	53.6	50.1	49.6	43.6	51.4	–	–	***	*
5/6/73	55.5	56.5*	51.2*	48.2**	54.6*	58.2	57.4	54.9	51.6	50.9	46.4	53.2	***	3.85	***	NS
17/7/73	61.3	60.5**	56.1*	52.9**	58.6*	63.7	61.2	59.8	56.4	55.6	50.7	57.9	–	–	***	*
21/8/73	64.5	64.2	59.8*	56.9**	62.5*	66.2	64.4	62.3	60.7	59.7	56.3	61.6	–	–	***	*
3/10/73	65.6	64.9	61.6	60.5**	64.4*	67.8	64.6	64.2	61.8	62.7	59.2	63.4	*	3.26	***	NS
20/11/73	70.8	70.0	68.9	67.8	70.9	72.5	68.6	69.6	69.6	69.4	68.2	60.6	NS	2.83	NS	NS
15/1/74	66.4	63.8	64.8	63.0**	67.5	68.3	64.4	66.4	64.7	63.5	63.2	65.1	*	3.12	*	NS
	SHEARING January 15, 1974															

+Significance of within-treatment regressions on stocking rate

NS = P > 0.05   * = P < 0.05   ** = P < 0.01   *** = P < 0.001

Appendix Table 20

MEAN LIVE WEIGHTS ON EIGHT OCCASIONS IN 1974-1975

(kg)

Date	Pasture treatment means A	B	C	D	E	Stocking rate means ($kg\ ha^{-1}$) 10	11	13	14	15	17	Grand mean	Hetero. Adjt. treat. means	LSD 5% treat. means	Sig. mean Reg. on SR.	Hetero. Reg. Coeff.
5/3/74	58.0	55.9	58.0	57.7 *+	59.5	59.6	57.4	58.7	57.4	57.0	56.7	57.8	NS	2.86	NS	NS
1/5/74	53.9	54.1	53.4	53.8 ***	54.3 **	57.7	56.2	53.7	52.9	52.4	50.8	54.0	NS	2.30	***	NS
6/6/74	57.6	58.0 *	56.1	57.3 **	57.1 *	60.8	58.8	57.4	56.1	55.4	54.6	57.2	NS	2.39	***	NS
18/7/74	63.6	62.5	61.6	62.7	61.6	64.7	63.1	62.4	63.2	60.1	60.8	62.4	NS	2.83	**	NS
11/9/74	67.1	65.7	64.7	66.4	65.4	67.8	65.1	65.8	66.2	64.7	65.2	65.8	NS	2.70	NS	NS
30/10/74	69.5	70.0	69.7	69.8	69.7	70.6	68.3	69.8	70.6	69.5	69.4	69.7	NS	3.11	NS	NS
21/11/74	69.6	70.5	69.8	70.3	70.9	71.4	68.5	70.8	69.9	70.3	70.0	70.2	NS	3.12	NS	NS
23/1/75	68.7	68.0	68.9	68.5	70.2	70.7	66.6	70.1	69.0	68.5	68.2	68.9	NS	3.02	NS	NS
						SHEARING January 23, 1975										

+ = Significance of within-treatment regressions on stocking rate

NS = $P > 0.05$ * = $P < 0.05$ ** = $P < 0.01$ *** = $P < 0.001$

Appendix Table 21

REGRESSION COEFFICIENTS OF LIVE WEIGHT ON STOCKING RATE ON 20 OCCASIONS DURING 1971-1973

Date	Pasture treatments				
	A	B	C	D	E
10/2/71	-0.20	-0.47	-0.04	+0.02	-0.16
31/3/71	-0.43	-0.70	-0.31	-0.19	+0.06
3/5/71	-0.18	-0.95	-0.50	-0.29	-0.12
23/6/71	-1.21	-0.40	-1.16	-0.80	-0.67
20/7/71	-1.42	-1.23	-1.41	-1.04	-1.12
24/8/71	-1.98	-1.59	-1.91	-1.47	-1.58
5/10/71	-1.20	-2.22	-1.56	-1.88	-1.46
11/11/71	-0.19	-2.06	-1.02	-1.75	-0.29
6/12/71	-0.34	-1.93	-1.23	-1.91	-0.50
22/12/71	-0.26	-1.87	-0.86	-1.73	-0.63
19/1/72	-0.54	-2.10	-1.01	-1.59	-0.17
		SHEARING			
25/1/72	-0.32	-0.62	-0.32	-1.00	-0.25
8/3/72	-1.07	-0.99	-0.59	-1.24	-0.37
19/4/72	-1.06	-1.63	-0.92	-1.99	-0.72
25/5/72	-1.03	-2.02	-1.26	-1.66	-0.72
12/7/72	-1.88	-2.18	-1.21	-1.62	-1.01
16/8/72	-1.49	-1.75	-1.20	-1.10	-1.42
28/9/72	-1.28	-2.18	-1.13	-1.79	-1.78
29/11/72	+0.04	-1.06	-0.91	-2.22	-0.94
17/1/73	+0.13	-0.83	-1.00	-2.89	-1.13
		SHEARING			

Appendix Table 22

REGRESSION COEFFICIENTS OF LIVE WEIGHT ON STOCKING RATE ON 17 OCCASIONS DURING 1973-1975

Date	Pasture treatments A	B	C	D	E
18/1/73	-0.26	-0.36	-0.84	-2.09	-1.05
28/2/73	+0.15	-0.69	-1.80	-1.99	-0.97
18/4/73	-0.50	-1.50	-2.22	-2.80	-1.88
5/6/73	-0.80	-1.21	-2.16	-2.71	-1.94
17/7/73	-0.63	-1.10	-2.17	-2.96	-2.23
21/8/73	-0.52	-0.96	-1.62	-2.44	-1.58
3/10/73	-0.53	-0.41	-1.08	-2.01	-1.43
20/11/73	-0.22	-0.10	-0.65	-0.55	-0.49
15/1/74	-0.64	+0.15	-0.54	-1.08	-0.74
		SHEARING			
5/3/74	-0.20	+0.27	+0.20	-0.92	-0.89
1/5/74	-0.50	-0.60	-0.94	-1.47	-1.32
6/6/74	-0.38	-0.59	-0.85	-1.40	-1.15
18/7/74	-0.18	-0.75	-0.45	-1.07	-0.33
11/9/74	-0.11	-0.39	-0.27	-0.49	-0.13
30/10/74	+0.17	-0.36	-0.02	-0.12	+0.13
21/11/74	+0.01	-0.17	+0.12	-0.06	-0.08
23/1/75	-0.42	-0.23	+0.22	-0.14	-0.05

Appendix Table 23

MEAN GROWTH RATE OF CLEAN WOOL IN SEVEN PERIODS IN 1971-1972

($g\ day^{-1}$)

Period	Pasture treatment means					Stocking rate means ($kg\ ha^{-1}$)						Grand mean	Hetero. Adjt. treat. means	LSD 5% treat. means	Sig. mean Reg. on SR.	Hetero. Reg. Coeff.
	A	B	C	D	E	10	11	13	14	15	17					
28/1-31/3	9.7	9.0*+	10.8	9.1**	9.8	10.5	10.4	9.8	9.7	9.7	9.2	9.7	NS	-	**	**
31/3-3/5	12.4	9.6*	12.5	9.5*	15.0	12.4	14.0	12.2	11.9	11.6	11.6	11.8	-	-	**	*
3/5-24/6	8.9	5.4*	8.6**	6.1**	9.4	9.0	9.2	8.2	7.9	7.2	7.5	7.7	-	-	***	*
24/6-25/8	11.4	6.1*	10.0***	8.0**	12.1	11.7	11.4	10.5	10.0	9.1	8.2	9.5	***	1.15	***	NS
25/8-5/10	13.1	6.7	12.7**	9.6*	14.0	13.2	13.3	12.7	11.9	10.1	11.1	11.2	***	1.52	***	NS
5/10-11/11	14.7*	10.8	17.0	14.6*	18.1	17.0	17.7	15.9	15.9	14.1	13.9	15.1	***	2.2	**	NS
11/11-28/1/72	4.5	3.5	6.3	4.3	5.3*	5.4	5.3	4.9	4.9	4.3	3.4	4.8	NS	1.89	**	NS

+ Significance of within-treatment regressions on stocking rate

NS = $P > 0.05$ * = $P < 0.05$ ** = $P < 0.01$ *** = $P < 0.001$

Appendix Table 24

MEAN GROWTH RATE OF CLEAN WOOL IN EIGHT PERIODS IN 1972-1973

(g day^{-1})

Period	Pasture treatment means					Stocking rate means (kg ha^{-1})						Grand mean	Hetero. Adjt. treat. means	LSD 5% treat. means	Sig. mean Reg. on SR.	Hetero. Reg. Coeff.
	A	B	C	D	E	10	11	13	14	15	17					
28/1-8/3	13.1	13.2	13.7	12.4*+	13.7	14.1	14.1	13.8	13.0	13.2	11.0	13.2	***	1.70	***	NS
8/3-19/4	16.1	15.6***	15.1**	14.0*	15.9	16.6	16.7	15.9	14.8	14.8	13.2	15.3	**	1.03	***	NS
19/4-25/5	13.0	11.9***	10.3*	10.0	11.6**	12.3	13.4	11.9	11.1	10.3	9.0	11.3	***	1.23	***	NS
25/5-12/7	7.2**	6.2**	6.0	5.6	6.8*	7.3	7.2	6.8	5.8	6.3	4.9	6.4	**	0.73	***	NS
12/7-16/8	12.0*	9.7**	9.6**	8.3	10.6**	12.5	12.5	9.7	9.5	9.1	7.4	10.0	***	1.23	***	NS
16/8-28/9	7.8*	6.5*	6.5*	5.3*	6.9**	7.8	8.1	6.4	6.4	6.1	5.2	6.6	***	0.92	***	NS
28/9-29/11	6.7	5.4	5.3	4.7	5.5	6.5	6.6	5.5	5.6	4.9	4.4	5.5	***	0.66	***	NS
29/11-18/1/73	10.8	9.8	10.2	10.1	10.0	11.3	11.5	10.2	9.8	9.8	8.4	10.2	NS	1.28	***	NS

+ = Significance of within-treatment regressions on stocking rate

NS = P > 0.05   * = P < 0.05   ** = P < 0.01   *** = P < 0.001

Appendix Table 25

MEAN GROWTH RATE OF CLEAN WOOL IN EIGHT PERIODS IN 1973-1974

($g\ day^{-1}$)

Period	Pasture treatment means					Stocking rate means ($kg\ ha^{-1}$)						Grand mean	Hetero. Adjt. treat. means	LSD 5% treat. means	Sig. mean Reg. on SR.	Hetero. Reg. Coeff.
	A	B	C	D	E	10	11	13	14	15	17					
18/1-28/2	16.3	15.6	16.7***+	15.7	16.8	17.3	16.1	16.6	16.2	15.5	15.7	16.2	NS	1.33	*	NS
28/2-18/4	16.1	16.4	16.8	16.1	16.5	16.5	15.6	16.2	16.3	16.4	17.1	16.4	NS	1.10	NS	NS
18/4-5/6	15.9	16.3	16.1	15.6	16.0	16.4	15.7	15.7	15.7	16.0	16.5	16.0	NS	1.03	NS	NS
5/6-17/7	14.1	14.1	14.1*	12.8	13.6	14.4	13.9	13.3	13.8	13.4	13.6	13.7	NS	1.04	NS	NS
17/7-21/8	21.4	20.6	20.4*	18.4	20.3	22.1	20.9	19.9	19.7	19.9	18.8	20.2	–	–	***	*
21/8-3/10	18.2**	18.1*	16.2**	15.3*	17.9	19.9	18.5	17.3	16.8	15.8	14.5	17.2	**	1.68	***	NS
3/10-20/11	13.6	14.3	12.4*	11.4*	12.5*	13.5	14.3	13.2	12.7	12.4	11.0	12.8	**	1.47	***	NS
20/11-15/1/74	11.6	12.0	12.9	11.1	12.4	12.0	12.9	12.7	11.4	12.4	10.7	12.0	NS	1.25	*	NS

+ = Significance of within-treatment regressions on stocking rate

NS = P > 0.05   * = P < 0.05   ** = P < 0.01   *** = P < 0.001

Appendix Table 26

MEAN GROWTH RATE OF CLEAN WOOL IN SEVEN PERIODS IN 1974-1975

(g day^{-1})

Period	Pasture treatment means					Stocking rate means (kg ha^{-1})						Grand mean	Hetero Adjt. treat. means	LSD 5% treat. means	Sig. mean Reg. on SR.	Hetero. Reg. Coeff.
	A	B	C	D	E	10	11	13	14	15	17					
15/1-1/5	6.0	6.0	6.3	6.0	6.3	6.3	5.8	6.6	5.9	6.1	6.0	6.1	NS	0.64	NS	NS
1/5-6/6	14.1	14.7	16.3	14.2	16.4	14.3	15.6	16.5	14.1	14.2	15.8	15.1	NS	2.81	NS	NS
6/6-18/7	17.7	17.4	17.7	17.2	18.4	17.7	17.2	17.5	17.7	17.6	18.3	17.7	NS	1.17	NS	NS
18/7-11/9	13.1	13.0	12.5	13.0	13.0	12.7	12.7	12.4	13.2	13.1	13.5	12.9	NS	0.89	*	NS
11/9-30/10	11.9	11.3	11.3	11.3	11.0 **+	11.7	11.5	10.8	11.4	11.2	11.6	11.4	NS	1.06	NS	NS
30/10-21/11	22.4	22.1	22.2	22.1	21.3	24.3	22.9	22.7	20.6	20.6	20.9	22.0	NS	2.54	**	NS
21/11-23/1/75	13.2	13.5	14.4	15.3	14.0	15.7	14.8	14.4	13.4	13.7	12.5	14.1	NS	1.49	***	NS

+ = Significance of within-treatment regressions on stocking rate

NS = P > 0.05 * = P < 0.05 ** = P < 0.01 *** = P < 0.01

Appendix Table 27

REGRESSION COEFFICIENTS OF CLEAN WOOL GROWTH RATE ON STOCKING RATE IN 15 PERIODS (1971-1973)

Period	Pasture treatments				
	A	B	C	D	E
			1971/72		
28/1-31/3	-0.17	-0.60	-0.11	-0.65	+0.29
31/3-3/5	-0.03	-0.70	-0.45	-1.01	+0.14
3/5-24/6	-0.24	-0.53	-0.37	-0.60	-0.13
24/6-25/8	-0.55	-0.64	-0.54	-0.81	-0.45
25/8-5/10	-0.47	-0.19	-0.67	-0.66	-0.33
5/10-11/11	-0.54	-0.41	-0.32	-1.04	-0.17
11/11-28/1/72	-0.22	-0.03	-0.97	-0.17	-0.32
			1972/73		
28/1-8/3	-0.11	-0.44	-0.31	-0.96	-0.20
8/3-19/4	-0.35	-0.51	-0.49	-0.81	-0.35
19/4-25/5	-0.33	-0.81	-0.37	-0.55	-0.73
25/5-12/7	-0.45	-0.26	-0.24	-0.36	-0.36
12/7-16/8	-0.79	-0.93	-0.72	-0.64	-0.87
16/8-28/9	-0.39	-0.55	-0.45	-0.42	-0.31
28/9-29/11	-0.45	-0.47	-0.21	-0.39	-0.25
29/11-18/1/73	-0.17	-0.37	-0.43	-0.52	-0.64

Appendix Table 28

REGRESSION COEFFICIENTS OF CLEAN WOOL GROWTH RATE ON STOCKING RATE ON 15 OCCASIONS (1973-75)

Period	Pasture treatments				
	A	B	C	D	E
			1973/74		
18/1-28/2	-0.06	+0.03	-0.49	-0.43	+0.02
28/2-18/4	+0.17	+0.28	-0.15	+0.04	+0.24
18/4-5/6	+0.12	+0.08	-0.26	-0.08	+0.28
5/6-17/7	+0.09	+0.03	-0.40	-0.30	+0.01
17/7-21/8	+0.13	-0.01	-1.06	-0.72	-0.41
21/8-3/10	-0.36	-0.60	-1.26	-0.90	-0.56
3/10-20/11	+0.12	-0.40	-0.62	-0.67	-0.46
20/11-15/1/74	-0.15	+0.10	-0.38	-0.37	-0.20
			1974/75		
15/1-1/5	-0.09	+0.03	-0.10	+0.05	0.00
1/5-6/6	+0.43	-0.05	-0.59	+0.49	-0.09
6/6-18/7	+0.25	+0.12	-0.29	+0.16	+0.22
18/7-11/9	+0.20	+0.13	-0.08	+0.04	+0.32
11/9-30/10	-0.01	0.00	-0.21	-0.06	+0.20
30/10-21/11	-0.34	-0.39	-0.91	-0.74	-0.14
21/11-23/1/75	-0.35	-0.29	-0.36	-0.52	-0.50

Appendix Table 29

NUMBER AND CAUSE OF DEATHS OF EXPERIMENTAL WETHERS 1970-1974.

Date	Cause of Death	No. Deaths	Treatment+	Liveweight range at Death (kg)
1971				
April	Unknown	1	B11	26.3
May	Undernutrition	3	2xB17, B15	28.7 - 33.4
May	Unknown	1	C17	40.0
June	Undernutrition	3	2xB17, B14	27.6 - 35.0
July	Undernutrition	2	B17, B15	28.3 - 28.6
August	Undernutrition	1	B15	27.6
September	Unknown	1	B14	31.8
September	Undernutrition	2	2xD17	28.6 - 31.5
October	Undernutrition	1	D14	30.4
December	Flystrike	1	E10	49.6
Annual Total		16		
1972				
March	Shearing wounds	2	A17, C17	34.2 - 41.6
April	Undernutrition	2	D17, D15	32.4 - 37.2
May	Ruptured bladder	1	B17	44.5
July	Undernutrition	5	C17,B17,B15, D15, D14	24.4 - 36.0
June	Unknown	1	D14	
Annual Total		11		
1973				
January	Heat exhaustion	2	B11,A10	54.2 - 61.7
April	Unknown	1	D11	59.1
May	Unknown	1	E13	52.0
October	Unknown	1	D17	50.7
December	Urinary infection	1	A10	62.2
Annual Total		6		
1974				
January	Unknown	1	B10	65.0
January	Shearing wounds	3	B10,B14,C14	56.4 - 63.6
February	Unknown	1	D15	60.8
August	Unknown	1	A11	45.8
Annual Total		6		

+ = A, B, C, D and E indicate pasture treatments and postscripts indicate stocking rate (sheep ha^{-1}).

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