THE ECOLOGY AND PRODUCTIVITY OF NEW CULTIVARS OF SUBTERRANEAN CLOVER (*Trifolium subterraneum L.*)

by

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February, 1990.

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ABSTRACT

The breeding, selection and release of new subterranean clover (*Trifolium subterraneum L*) cultivars is warranted if genotypes are limiting production: however, often pasture management and grazing management factors are the major constraints to production. In this thesis, two research priorities are identified and studied, viz. (i) the pasture and/or grazing management required to maximize herbage and seed production during the growing season and (ii) the effects of grazing management on seed survival over the summer-autumn period.

These research priorities were addressed in four experiments as follows:

1. Small-plot density experiment

The density experiment examined herbage and seed production of subterranean clover (hereafter referred to as sub clover) using the cultivars Yarloop, Trikkala, Esperance and Clare at six sowing rates (1, 4, 16, 64, 256, and 1024 kg/ha pure germinable seed) in the field at the Waite Institute. Two sowing times were used: Early = 17 May 1985 and Late = 7 June 1985). The main conclusions were: (i) Dry matter production is strongly related to plant density early in the season (i.e. the greater the plant number the greater the yield. (ii) Differences in the herbage yield of cultivars late in the season were due to differences in maturity. (iii) Seed production was positively correlated with herbage production at low and medium densities: however, high density swards (e.g. 14,000 plants/m^2) which were undefoliated had lowered herbage production and seed production and subsequent regeneration. (iv) Differences in the ability of cultivars to suppress weeds only occurred at high plant densities.

2. Grazing experiment

This paddock-scale experiment at the Mortlock Experiment Station, Mintaro, South Australia (hereafter MES) involved continuous grazing of sub clover pastures at three stocking rates (7, 11 and 15 sheep/ha) during two seasons 1986 and 1987. Five cultivars: Nungarin, Dalkeith, Trikkala, Junee, Clare and a mixture comprising all five were sown at two rates (10 and 200 kg/ha). The main findings and conclusions were: (i) low-density swards (e.g. 150 plants/m^2) had low productivity and could support only low stocking rates (7 to 11 sheep/ha) throughout the growing season and the summer-autumn period, whereas high-density pastures (1,500 to 2,000 plants/m^2) were more productive and could be grazed at higher stocking rates (e.g. 15 sheep/ha) during the growing season and at the beginning of summer. (ii) Changes in botanical composition were rapid and were influenced by initial sub clover plant density and further modified by stocking rate. (iii) Under grazing, cultivars did not show any differing ability to suppress weeds. (iv) Seed yield of some cultivars (e.g. Nungarin and Dalkeith) were significantly reduced if the initial sowing rate was 10 kg/ha compared to 200 kg/ha.

3. Summer-autumn seed intake experiment

The aim of the summer-autumn seed intake experiment was to identify and quantify the main effects of sheep on the seed reserves and the consequent seedling dynamics of sub clover-based pastures. The impact of sheep grazing dry sub clover pasture residues (comprising a mixture of five sub clover cultivars) was examined over a period of 70 days. The main findings were: (i) Sheep are efficient harvesters of sub clover burr and seed during the summer-autumn period. First they select the largest burr, containing the most seed and the largest seed leading to a progressive decline in burr weight, seeds/burr and seed size. (ii) Seedling emergence from faecal pellets was poor and would not contribute significantly to the regeneration of sub clover pastures in Mediterranean climatic zones. (iii) An estimated 1% (hard) seed of the total sub clover seed ingested survived passage through the digestive tract of sheep grazing dry pasture residues. These results indicate that summer-autumn grazing should be carefully managed and that the quantity of seed on the surface and in the top 2.5cm of the soil be monitored to ensure that there is sufficient seed to ensure regeneration of a high-density pasture.

4. Animal house feeding experiment

The animal house experiment involved the feeding of intact burrs from each of the cultivars used in the mixture at MES and the summer-autumn seed-intake experiment. The burrs of Nungarin, Dalkeith, Trikkala, Junee and Clare were fed at to individually-penned sheep fitted with faecal-collection harnesses at the rate of 50g (except Clare 40g) of burrs in a standard sheep diet. The main findings were: (i) The survival of seed in faeces was higher (2.9 to 5% hard) than the survival of seed ingested in the summer-autumn field experiment (1% hard). These differences possibly reflect the higher-quality feed in the animal house and consequent greater rate of passage. (ii) The percentage viable seed found in the faeces of pen-fed sheep did not differ between cultivars.

Overall, the findings from the research described in this thesis support the view that management factors have far greater impact than differences ascribed to various cultivars of sub clover.

STATEMENT

The studies presented in this thesis represents original work carried out by myself except where due acknowledgement has been made in the text. This thesis has not been previously submitted in full or part to any other University for any degree or diploma. I consent to the thesis being made available for photocopying and loan if accepted for the award of the degree.

C. T. de Koning

ACKNOWLEDGEMENTS

I wish to sincerely thank Mr. E. D. Carter, my supervisor, for his guidance, and expertise advice throughout this study and for his critical comments during the preparation of this thesis. I have learnt much as a result. I am also grateful to Dr. G. K. Mc Donald for his advice in the absence of Mr. E. D. Carter and his comments on drafts of this thesis.

Many people helped with field work and with laboratory analyses: Steve Challis, Mary Armstrong, Richard Knowles, Neville Sutherland, Kylie Le Leu and Diona Mobsby, provided technical assistance during the project which is greatly appreciated. The friendship of Deirdre Frappell and Paul Quigley have contributed to the enjoyment during my studies, and the encouragement and support of my family.

The farm staff at the Waite Institute and the Mortlock Experiment Station deserve special mention for their practical advice and assistance with field work which is much appreciated. Margaret Morris, a member of the Biometry department at the Waite Institute, deserves thanks for her statistical advice and assistance.

I wish to gratefully acknowledge The Australian Wool Corporation for their financial support with the provision of a postgraduate scholarship which enabled this research to take place.

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1
GENERAL INTRODUCTION

1. GENERAL INTRODUCTION

Subterranean clover (*Trifolium subterraneum L.*), hereafter refered to as sub clover, is the most important pasture plant in southern Australia. Sub clover forms the basis of about 20 million ha of sown annual pastures on neutral to acidic soils and helping to guarantee the quality and quantity of livestock feed during the green and dry stages (e.g. Rossiter and Pack 1956).

Sub clover probably originated in the Middle East, from where it spread throughout the Mediterranean basin and western Europe (Collins *et al*. 1984). In Australia, sub clover was recognized as an 'alien' plant and first recorded as naturalised in Victoria (Mueller 1888) but the exact introduction date is unknown. However, it was Amos Howard in 1889 who first recognized the potential value of sub clover as a pasture plant (Symon 1961). Mueller (1895) also commented on its value. Howard, an Adelaide nurseryman, first noticed a patch of sub clover in a field near Nairne, South Australia and publicised the merits of sub clover with well-founded enthusiasm (Howard 1906 a, b). This genotype was later named as the cultivar Mt. Barker. Throughout the early 1900's, Howard experimented and devised ways to harvest sub clover seed. The seed was difficult to harvest due to burr burial, and the burr structure itself proved difficult to thresh. The first sale of seed was in 1907, and by 1908, the demand for sub clover seed from farmers and graziers had increased.

Cook conducted experiments on sub clover at the Kybybolite Experiment Station in South Australia and made numerous reports from 1922 to 1951 on the value of sub clover as a pasture plant (cited by Symon 1961). The experiments reported by Cook over this period played a major part in promoting and extending the use of sub clover commercially throughout southern Australia. In Western Australia and Victoria, interest in sub clover was beginning to emerge at about the same time. The first public recognition of the value of the plant by the South Australian Department of Agriculture was in 1924, when Spafford wrote a major article on the virtues of sub clover, in which topics such as fertilizers and harvesting were described (Spafford 1924).

In 1929 Adams selected Dwalganup, the first commercial strain in Western Australia (Adams 1929): however, it was first introduced as a contaminant of imported seed about 1890 on the property of the late Mr. P. D. Forrest at Boyup Brook, Western Australia. During the next 20 years there were only six strains of sub clover in commercial use, viz: Dwalganup, Yarloop, Clare, Bacchus Marsh, Mt. Barker and Tallarook. Bacchus Marsh and Tallarook arose from a collection of variants made by Aitken and Drake in Victoria (Aitken and Drake 1941). Many Australian agricultural scientists including C. M. Donald, C. A. N. Smith and D. E. Symon went to the Mediterranean basin on expeditions to collect sub clover and other pasture species. For about 70 years the commercial sub clovers were all regional ecotypes but later there were deliberate crosses e.g. the cultivars Howard (1964) and Uniwager (1967). The dates of first use or release of the newer cultivars are shown in Table 1. At the present time (1989) there are at least 22 commercial cultivars available. Many of the recently released cultivars were selected or bred at the National Subterranean Clover Improvement Program (N.S.C.I.P) in Western Australia.

Sub clover cultivars can be allocated to three different subspecies, each of which has a distinct ecological basis (Katznelson and Morley 1965): *Trifolium subterraneum subsp. subterraneum* (e.g. Tallarook), *T. subterraneum subsp. yanninicum* (e.g. Yarloop) and *T. subterraneum subsp. brachycalycinum* (e.g. Clare). A diversity of cultivars have been selected from these three subspecies to fill many ecological niches and to cover a range of agronomic situations. A wide range in maturity, relatively high tolerance to grazing, various levels of hard-seededness and burr burial have all contributed to the success of sub clover in southern Australia. However, insect pest resistance, disease resistance (e.g. to clover scorch, *Kabatiella caulivora*) and low oestrogen content are characteristics which are also important. Some of the important characters of registered sub clover cultivars in Australia are given in Table 1 (Collins *et al.* 1984).

Table 1: Data on subterranean clover cultivars, sub species Yanninicum (Y), Subterraneum (S) and Brachycalycinum (B).

	Days from sowing to flowering*	Flowering+ begins about	Seed set completed by	Relative** hard-seededness	Oestrogenic activity	Relative** Clover scorch resistance
Nungarin (1976) S	77	Early-mid Aug.	Late Sept.	10	Low	1
Northam (1972) S	78	Mid Aug.	Early-mid Oct.	8	Low	1
Dwalganup (1929) S	83	Mid Aug.	Mid-late Oct.	7	Very high	4
Geraldton (1959) S	97	Mid-late Aug.	Early Oct.	8	High	1
Daliak (1967) S	97	Late Aug.	Mid-late Oct.	6	Low	9
Dalkeith (1983) S	98	Late Aug.++	Mid-late Oct.	8-9	Low	1
Uniwager (1967) S	103	Mid-late Aug.	Early Oct.	5	Low	1
Yarloop (1939) Y	109	Early Sept.	Late Oct.	4	Very high	1
Seaton Park (1967) S	110	Early Sept.	Late Oct.	5	Low	1
Trikkala (1975) Y	112	Early Sept.	Early Nov.	3	Low	6
Dinninup (1962) S	113	Early Sept.	Early Nov.	7	Very high	3
Enfield (1982) S	118	Early Sept.++	Early-mid Nov.	1-2	Low to medium	6
Esperance (1978) S	120	Early Sept.	Early-mid Nov.	5	Low to medium	9
Clare (1950) B	129	Mid Sept.	Late Nov.	3	Low	6
Woogenellup (1959) S	130	Mid Sept.	Mid Nov.	3	Low	1
Howard (1964) S	93-135	Early-mid Sept.	Mid. Nov.	3	High	1
Bacchus Marsh (1947) S	131	Mid Sept.	Mid-late Nov.	1	Low	5
Mt. Barker (1935) S	137	Late Sept.	Late Nov.	1	Low	6
Larisa (1975) Y	142	Early Oct.	Early Dec.	2	Low	6
Nangeela (1961) S	143	Early Oct.	Early Dec.	1	Low	3
Meteora (1981) Y	148	Early Oct.	Early Dec.	8	Medium	8
Tallarook (1943) S	163	Mid Oct.	Mid Dec.	1	High	6

* Sown at Perth in early May — Source: Collins *et al.* 1984
+ In areas where the cultivar is commonly grown
++ Estimates based on existing cultivars
** Scale of 1 to 10 for both hard-seededness at the autumn seasonal break and resistance to clover scorch.
1 = Little or no hard-seededness/little or no resistance to clover scorch
10 = Very high level of hard-seededness/very high degree of resistance to clover scorch
In parentheses is the date of release or commercial registration in W.A., see Barnard 1972

Within the relatively short time that sub clover has been in Australia it has become widely distributed. An extensive survey of sub clover burrs collected from wool samples from a various locations in South Australia showed that the older cultivars had the widest distribution (Cocks and Phillips 1979). Variations from the original biotypes were also found. Despite this spread of sub clover there are three boundaries which do limit the distribution of sub clover in Australia, viz: alkaline soils, the 400mm rainfall isohyte (i.e the arid zone) and the frost and excessive cold boundary (1,220 m altitude in the Australian alps, Donald 1960). Morley (1961) and later Rossiter (1966, 1978) summarized research on the ecology of sub clover-based pastures.

While there has been considerable investment in breeding new cultivars of sub clover there is little merit in producing new cultivars if these are mis-managed. It is therefore important to understand the ecological basis of the productivity of sub clover-based pastures particularly when grazed by ruminant livestock. Pasture and/or grazing management will therefore become increasingly important in Australia. Recently, there has been re-newed interest in legume-based pastures in crop rotations as the value of cereal crops has decreased and wool prices have increased. However, over the past 20 years the productivity of sub clover pastures has declined because many of the necessary skills to manage them have diminished. Though medic and sub clover-based pastures have deteriorated in many regions (Carter 1976 *et seq.*), there is an urgent need for pasture renovation and re-establishment in higher-rainfall pasture zones.

There is also increasing interest in the use of complex mixtures which consist of several cultivars and/or species, to improve the productivity and persistence of sub clover-based pastures. This practice has been advocated by a number of researchers (Carter and Wigg 1963; Carter *et al.* 1982; Dear 1982; Carter 1983, 1987; Christian 1987; Obst 1987; Reed 1987; Reeves 1987 and Simpson and Culvenor 1987) because the dry matter production of complex mixtures (4 or more cultivars of differing maturity) is more stable and seed set is more assured under most adverse conditions, thereby helping to guarantee persistence.

A neglected area of pasture ecology that is crucial to the continued productivity of sub clover pastures is seed survival over the hot, dry summer months. In most areas of sub clover pastures in Australia, the dry pasture residue is grazed by livestock. The availability of these pasture residues is an integral part of sheep production in the cereal/livestock zone. However, despite its importance there is little information on sub clover seed survival during summer and autumn months.

Despite the millions of dollars spent on developing new cultivars of sub clover (and other pasture plants), there is a considerable lack of knowledge on the complex soil-plant-animal interrelations of the grazed pasture ecosystem. This is especially true with annual pastures based on self-regenerating legumes like sub clover. Precise recommendations for management of sub clover pastures to ensure maximum production of herbage and seed during the growing season do not exist or are inadequately defined. Furthermore, the optimum management of the dry pasture residues in summer and autumn to ensure adequate survival of seed for regeneration of a dense, productive sub clover pasture also requires definition.

The aims of this thesis are to improve knowledge of the ecological basis of sound management decisions related to sub clover-based pastures. The major area of the research described in this thesis is the management of sub clover-based pastures with emphasis on their ecology. The literature has many examples of the relationship between grazing management and animal production (e.g. Fitzgerald 1976) but very little emphasis on the impact of grazing on pasture production, changes in botanical composition and the seed-seedling dynamics of the pasture. Two research priorities were therefore addressed in this thesis. Firstly, the pasture and/or grazing management needed to maximize the herbage and seed production of sub clover during the growing season and secondly, the grazing management to ensure adequate seed survival over the dry summer-autumn period.

Chapters 3 and 4 concentrate on the first priority i.e. the various factors influencing herbage and seed production of sub clover in both ungrazed and grazed situations. Chapter 5 deals with the impact of summer-autumn grazing by sheep on seed survival of sub clover and complementary pen-feeding studies in the animal house to assess seed survival of five cultivars of sub clover after ingestion by sheep.

2
LITERATURE REVIEW

2 LITERATURE REVIEW

2.0 Introduction

Despite the success of sub clover as a pasture plant, there are problems associated with sub clover-based pastures: for example, difficulties with pasture establishment, increased occurrence of insect pests (e.g. blue-green aphid, *Acyrthosiphon kondoi*) and fungal diseases (e.g. clover scorch, *Kabatiella caulivora*) (Gramshaw *et al.* 1989). In addition, the behaviour of sub clover under grazing is inadequately understood. In the past, research emphasis has been placed mostly on animal production from pastures with little regard to the growth and persistence of sub clover-based pastures or have involved defoliation by cutting, which is not representative of grazing.

Sub clover cultivars and plant density are important components of pasture production and therefore have relevance to research priority one (Chapter 1). Therefore, this literature review will cover differences in herbage and seed production between sub clover cultivars and the effects of sub clover plant density on both herbage and seed yield. The influences of defoliation by cutting and grazing ruminants on the production of sub clover-based pastures are also addressed in this review as this is also related to priority one. Finally, the fate of pasture seeds, including those of sub clover consumed by grazing ruminants is the focus of the final section of this literature review which has great bearing on research priority two (Chapter 1).

2.1 Differences in the productivity of subterranean clover cultivars

Differences in productivity between sub clover cultivars have been established in the earliest experiments with this species. Assessment of sub clover cultivars for production differences were first made at the Waite Agricultural Research Institute (WARI) during the 1930's (Anon. 1937 - 1938). Large differences in maturity of cultivars were demonstrated in this work (e.g. the cultivar Dwalganup flowered 99 days after sowing, cultivar Tallarook flowered 166 days after sowing). A positive correlation was found between late-maturity and herbage yield. Further trials at WARI including the cultivars Dwalganup, Mulwala, Seaton Park, Bacchus Marsh, Mt. Barker and Tallarook (Anon. 1939-40) showed that the cultivars Bacchus Marsh, Mt. Barker and Tallarook produced high densities of seedlings in the regeneration year. The early cultivars Dwalganup, Mulwala and Seaton Park had set a high proportion of hard seed, therefore herbage yield in the year of regeneration was not as high as the yield obtained by the late-maturity cultivars. Results from trials (Anon. 1941-42) found Bacchus Marsh was well adapted to the soil and climatic conditions at field sites located at the Waite Institute, Salisbury and Kangaroo Island in South Australia. At each of the field sites, Bacchus Marsh outyielded all other cultivars, particularly the white-seeded cultivar Yarloop from Western Australia. However, Yarloop did grow better than Bacchus Marsh under wetter conditions.

The series of experiments conducted at WARI demonstrate the need for several cultivars of varying maturity to be used in experiments involving the evaluation of sub clover. Late maturing cultivars have the potential to produce more herbage than early maturing cultivars if the seasonal conditions are favourable. However, early maturing cultivars can provide more feed in the earlier stages of the growing season provided the hard-seed levels are not too high. Hard seed levels which are too high could be detrimental to the regeneration because the number of seedlings at regeneration are indicative of the early herbage productivity.

Since the early 1950's, farmers and research workers have observed that some cultivars of sub clover within the three subspecies- *Trifolium subterraneum subsp. subterraneum*, *T. subterraneum subsp. yanninicum*, and *T. subterraneum subsp. brachycalycinum* grew more vigorously than others during the winter months (Carter 1954; Anon. 1955; Higgs 1958) which sometimes resulted in greater livestock productivity (Day 1963). Morley (1958), found that differences in productivity of cultivars in the early vegetative stage depended largely on leaf area. He grew Tallarook, Clare, Yarloop, Wenigup and Bacchus Marsh as spaced plants at constant temperatures of 16.8°C, 18.6°C and 24.2°C. Temperature x Cultivar interactions were found for relative growth rate, net assimilation rate and leaf weight during the early vegetative stages. Some differences in the productivity of sub clover cultivars can be attributed to density effects (Wolfe 1981) and seed size effects (Black 1959, Evers 1982). Lawson and Rossiter (1958) found that at a constant sowing rate, differences between sub clover cultivars in the early growth rate of tops could not be attributed to differences in seed size. Dwalganup had superior yield over Mt. Barker during winter and early spring.

Yarloop was shown to have outstanding winter production in waterlogged lateritic podzols on Kangaroo Island (Carter 1951, 1952; Anon 1955; Day 1963; Carter and Wigg 1963) and it was subsequently oversown into many sheep, beef and dairy pastures in the higher rainfall areas of southern Australia during the 1950's to increase winter production. Experiments at Rutherglen Research Station showed that the earlier-maturing cultivars (Bacchus Marsh, Burnley and Yarloop) produced more winter feed than the later-maturing cultivars (e.g. Mt. Barker). Similar results were found later by de Koning (1984) and de Koning and Carter (1987 a, b). The earlier-maturing cultivars promoted greater wool production: however, the total production for the season was the same for all cultivars (Anon. 1968). Cameron and McGowan (1968) also found that the winter productivity of earlier-maturing cultivars were mostly better than Mt. Barker. Bacchus Marsh produced more dry matter in autumn-winter than Mt. Barker and liveweight gains of sheep grazing Bacchus Marsh pasture were consequently superior to those on Mt. Barker. In a mowing experiment, both Yarloop and Burnley were found to have good winter yields as compared with Mt. Barker, Bacchus Marsh, Clare, Nangeela and Portuga (CPI 144 54). These studies indicate that early maturing cultivars are inherently more productive. However, plant numbers of early maturing cultivars in a comparison with late maturing cultivars would be required, particularly early in the season to ascertain whether productivity differences were due to higher densities at emergence.

Cameron and McGowan (1968) concluded that the superior growth of some cultivars need higher utilization by grazing animals to be reflected as a saleable product from those animals. There is no merit in having highly productive cultivars if they are not utilized by the grazing animal. However, not all research has shown that the highly productive sub clover cultivars are the best in terms of animal production. Intake by grazing livestock and subsequent liveweight gain is also dependent on the palatability and digestability of the sub clover. Dinninup, for example, has excellent winter production but is highly oestrogenic (Anon. 1973). It was found that sheep grazing Dinninup during mid to late winter did not gain weight as fast as sheep grazing other types of sub clover (Anon. 1973). This was attributed to reduced intake of Dinninup which was probably due to unpalabililty. The same study also found that Dwalganup and Geraldton were high in winter production but sheep grazing those cultivars did not gain bodyweight. Pastures based on Dinninup, Dwalganup and Geraldton all produced less wool than pastures based on other cultivars. These three cultivars are high in formononetin which would contribute to their unpalatability. Dunlop *et al.* (1984) also found that the liveweight of sheep grazing a grass-free Dinninup pasture were on average 6.0 kg per head lighter than sheep grazing grass-free pastures based on other cultivars.

The large differences in height of sub clover cultivars means that visual appearance of high herbage yield can be deceptive. This has resulted in controversy over potential winter production of various cultivars (Rossiter and Collins 1980; Wolfe 1982). The results obtained by Rossiter and Collins (1980) showed no significant difference in winter productivity between cultivars. This result conflicts with those of Morley (1958) who found differences in productivity between cultivars grown at low temperatures. However, Rossiter and Collins used three non-commercial genotypes of subterranean clover which had been observed to have poor winter growth and the cultivar Tallarook. They also compared spaced plants to swards and had alternating day/night temperatures (12^{o}C / 7^{o}C day/night and 22^{o}C /17^{o}C). No significant differences were found for sub clover plants growing as spaced plants or in swards. A decrease in regrowth of less than 20% exhibited by Phillip Island compared with Tallarook at the low temperature (12^{o}C / 7^{o}C) did not qualify Phillip Island as abnormally cold susceptible. It was concluded by Rossiter and Collins that poor winter growth may be due to factors other than a "winter dormancy" phenomenon.

Collins *et al.* (1983a) suggested that under good conditions of moisture, nutrition and plant density, substantial differences in winter production between sub clover strains were unlikely, particularly if swards were defoliated closely (2cm height at weekly intervals). However, in South Australia, there is evidence that cultivars do differ in productivity in winter when undefoliated and defoliated. Yarloop and Clare out-produced Larisa, Mount Barker and Trikkala in growth cabinet studies, raised-bed and field experiments (de Koning 1984; de Koning and Carter 1987a). The high productivity of Yarloop and Clare cannot be attributed to seed size effects because seed of constant size was used for all cultivars.

Differences between cultivars during early winter may also depend on the sowing date. Dear and Loveland (1984) found that when emergence occurred in March, Woogenellup and Seaton Park were slightly more productive than Nungarin and Mt. Barker. However, when the same sub clover cultivars emerged later (e.g. April and May) there were no differences between the cultivars during the early stages of growth. Dear and Loveland (1984) concluded that differences between cultivars in temperature response could be very relevant to winter production, especially if swards have a low leaf area index such as when they are grazed hard or growing slowly. Responses to low temperature will then reflect the response of individual plants within the sward.

Winter productivity differences between sub clover cultivars may also be influenced by the subspecies group to which the cultivar belongs. Reed *et al.* (1985) found that the *Trifolium subterraneum subsp. yanninicum* cultivars Trikkala and Yarloop were consistently more productive in winter than the *T. subterraneum subsp. subterraneum* cultivars Mt. Barker and Woogenellup. Production of the *T. subterraneum subsp. yanninicum* cultivars was similar at poorly-drained sites or well-drained sites, but the most productive *T. subterraneum subsp. subterraneum*, i.e. cv. Woogenellup, produced significantly less on the poorly drained sites compared to the well drained sites. Genotypes of *T. subterraneum subsp. yanninicum* are known for their adaptability to water-logged conditions (Katznelson 1970). Essentially, the field experiments in south west Victoria showed that the newer cultivars are more productive in winter than Mt. Barker and as a result they should compete better with winter-growing weeds (Reed *et al.* 1985).

Reed (1987) emphasized that much more remains to be done to improve winter growth even though at present we do have well proven species and cultivars available. Both the South Australian and New South Wales Departments of Agriculture are selecting *T. subterraneum subsp. brachycalycinum* lines for vigorous growth and good persistence. The potential use of new *T. subterraneum subsp. brachycalycinum* lines for northern N.S.W was assessed by Archer *et al.* (1987). The lines from *T. subterraneum subsp. brachycalycinum* compared well with the *T. subterraneum subsp. subterraneum* cultivars for dry matter yields. Clare, a *T. subterraneum subsp. brachycalycinum* cultivar was found to be highly productive during the winter of 1984 as compared with the most productive *T. subterraneum subsp. subterraneum* cv. Woogenellup. Some of the new lines of *T. subterraneum subsp. brachycalycinum* were also found to have better spring production than both Clare and Woogenellup.

The superior early growth of both Yarloop and Clare grown in growth cabinets, raised beds and in the field, was shown in experiments at the Waite Institute (de Koning 1984; de Koning and Carter 1987a). High dry matter production, although desirable, is not the only criterion used to select new sub clover cultivars. Disease and pest resistance, low formononetin content and high seed yields with a large proportion of hard seed are also considered important by the National Subterranean Clover Improvement Programme (Stern *et al.* 1981) .

Conclusions: As discussed in the literature, differences in the productivity of sub clover cultivars are due to factors such as maturity and sub-species group, and the growth of a cultivar is further modified by temperature. However, it is important to consider the grazing animal when examining differences in herbage productivity between cultivars. Superior herbage yield of a sub clover cultivar is of no advantage if sheep do not eat it because of unpalatability (Anon. 1973) or the utilization of that pasture by sheep is inefficient due to low stocking rates. Future research on sub clover-based pastures should place more emphasis on high winter production rather than high total seasonal production.

2.2 Effects of density on productivity of subterranean clover

As described in section 2.1, some cultivars of sub clover exhibit vigorous winter growth which could be due to high individual seedling vigour or high seedling density. Seedling density is of particular importance at the time of autumn break in the season as early growth per unit area is directly related to plant numbers. However, the growth per plant can also be important. Hence high density improves herbage yield in winter and, as feed scarcity in winter imposes limits on animal production, high density can increase year-round stocking rates. In contrast, in spring there is normally an abundance of feed for grazing animals and herbage production at this time is largely due to maturity of the sub clover cultivar (Wolfe 1981). Wolfe (1981) concluded that the assessment of sub clover cultivars in the field should emphasize population characteristics such as seedling density (measured at the start of the season) and seed yield measured at the end of the growing season (Carter 1981; Carter *et al.*. 1982).

Donald (1954) showed that sub clover plants of the cultivar Mt. Barker grown at the lowest density (12 plants/m^2) were the largest (31.3 g/plant) and became progressively lighter as density increased, until at the highest density (18,510 plants/m^2) individual plants only weighed 0.04 grams (plants sown 21 April 1949 and harvested 12 Dec. 1949). Racemes per plant, seeds per plant and weight of seed per plant followed similar decreases as plant density increased. Overall, maximum dry matter production occurred at intermediate densities and was maintained at the higher densities. Stern (1960) found that for high-density swards of sub clover (36 plants/dm^2) the ceiling Leaf Area Index (LAI) was reached 100 days after emergence as compared with 146 days for plants grown at the low density of 4 plants/dm^2. The medium density (16 plants/dm^2) was intermediate and the ceiling LAI was reached at 123 days. He also found that individual plant weight increasingly became a function of density after 34 days, the largest plants being found at the lowest density. He attributed this partly to the survival of all branches while the number of branches decreased at the medium and high densities. Both studies by Donald (1954) and Stern (1960) showed that high densities greatly reduced the individual plant size, therefore intermediate densities used by both researchers were best in terms of increasing and maximizing dry matter production.

Yates (1961), found that the dry matter production varied between sub clover cultivars (Dwalganup, Yarloop, Bacchus Marsh, Burnerang and Tallarook) at the lower plant densities. As density increased, differences between strains were reduced. The early-maturing cultivars were stemmy when grown as single plants: however, as density increased there were morphological changes such as increased height of the sward due to petiole elongation.

Plant density is the first important factor in determining the leaf area and dry matter present (Spedding 1971). Responses to light and particularly temperature depend on the amount of dry matter present (Cocks 1973; Fukai and Silsbury 1977). Cocks (1973), showed that when the LAI was low (0.2), growth rate was found to increase with increasing temperature up to 22^{o} day/17^{o}C night. Higher density swards (LAI 3.0) were not influenced by temperatures in the range tested (12^{o}C day/7^{o}C night to 27^{o}C day/22^{o}C night), while at a higher LAI (5.5) the growth response became negative with increasing temperature. Silsbury and Fukai (1977) showed similar results. In general, plant density influences the stage at which competition commences between and within species. As density increases, the growth stage at which competition begins will be earlier (Donald 1951). Competition is often for light, usually when other factors such as nutrients and water are abundant (Davidson 1954). Given sufficient time both low density and high density swards tend toward a similar LAI and yield (Davidson and Donald 1958; Prioul and Silsbury 1982). The ability of low density swards to eventually attain similar yields to that of high density swards can be attributed to higher growth rates than for those at high density swards but the relative growth rate decreases with increasing density (Donald 1951).

A plant that effectively utilizes the factors necessary for growth will also be a strong competitor when growing in association with other species and sometimes when growing in monocultures. The reason for intense competition between members of the same species is due to the plants having a similar requirement for the necessary factors for growth (e.g. light and moisture). Therefore, in pure swards of sub clover, inter-plant competition can be intense. Burch and Andrews (1976) found that the contrasting behaviour of the sub clover cultivars Yarloop, Larisa, Y111, Y136 and 39313Y grown in monoculture or in binary mixtures was more pronounced at the low density (20 plants/dm^2) than at the high density (40 plants/dm^2). Yarloop produced larger plants than Larisa even when the proportion of Yarloop to Larisa was 1:4. However, genotype was shown to be more important than density for herbage production. The density only influenced individual plant size. Silsbury and Fukai (1977) found that the maximum crop growth rate (g/m^2/day) with sowing in May for sub clover decreased from 13.1 to 9.8 as density increased from 1,000 plants/m^2 to 4,000 plants/m^2 for ungrazed swards. This also occurred at each density for June and August sowings. In later research, Prioul and Silsbury (1982) found that a low density, ungrazed sward of sub clover had a higher crop growth rate than the high density sward.

It is not always possible to specify precisely the most desirable seedling density for sub clover-based pastures because of the range of environmental conditions and management practices. However, Taylor *et al.* (1984) have suggested that a density of at least 1000 to 5000 plants/m^2 is necessary to produce good pastures for a wide range of grazing management systems in medium to high rainfall environments. More recently, Carter (1989), has emphasized the importance of total weight of readily germinable (soft) seed; 200 kg/ha should provide a good level of regeneration.

Conclusions: Plant density has a large influence on both the individual plant yield and sward yield. Density mostly influences the stage at which competition begins and its severity. Therefore, it is essential to include various density levels in experiments involving the comparison and assessment of different sub clover cultivars. Most of the density and competition studies have focussed on sub clover and the grass relations of mixed pastures (e.g. Stern 1960). Little attempt has been made to examine the effects of density on the growth and persistence of different cultivars of sub clover in pure and mixed swards consisting of several cultivars (de Koning 1984). None of the plant density experiments described here have involved defoliation by grazing. Since plant density has such an important influence on the productivity of sub clover it is surprising that it has received very little attention under grazing conditions.

2.3 Effects of mechanical defoliation on subterranean clover

In grazed communities of plants there is a continual likelihood of defoliation. The success of a pasture therefore partly depends on its ability to cope and recover from frequent defoliation. The effects of defoliation on the growth of plants is influenced by the height of defoliation, the frequency of defoliation, the stage of growth at which defoliation occurs and the species or cultivar being defoliated (e.g. Motazedian 1984). It is well established that cutting management can influence yield of harvested material (Spedding 1971).

The amount of foliage, in particular leaf material, present prior to defoliation and the amount remaining following defoliation are the key to the responses to defoliation (Brougham 1956; Davidson and Donald 1958). In addition, climatic conditions at the time of defoliation also influence the response.

Brougham (1956) imposed three defoliation intensities on a pasture of short rotation ryegrass, red clover and white clover by cutting to 25, 75 and 125mm. Measurements were made of the herbage dry matter, leaf area index and percentage light penetration 25 mm above ground level. The pasture defoliated to 25mm required 24 days after defoliation to redevelop a canopy to intercept 93% of the incoming radiation, while pastures defoliated to 75 and 125mm could intercept almost all incident radiation after 16 and 4 days respectively. In summary, during recovery from defoliation, the most severe defoliation resulted in the lowest initial growth rate and the longest interval taken to reach the maximum growth rate.

Davidson and Donald (1958) sowed Bacchus Marsh sub clover at different densities (25, 99, 346 and 1236 plants/m^2). The control swards were not defoliated while the other swards were subjected to a single defoliation at various dates (50% of herbage removed on a fresh weight basis). Dry matter production slightly increased for those swards defoliated near the ceiling LAI. Yet swards defoliated at very low LAI (below 3) or high LAI (8.7) showed marked reductions in both dry matter production and leaf production. Therefore, the growth stage (i.e. LAI) at which defoliation occurred is very important in this experiment.

Black (1963a) examined the effects of a single severe defoliation on six commercial cultivars of sub clover. He proposed three categories of cultivars based on the reaction to defoliation as follows: (i) the tall cultivars such as Yarloop and Clare which recovered slowly following defoliation, (ii) the prostrate cultivars with many small leaves such as Dwalganup and Tallarook which recovered rapidly following defoliation and (iii) an intermediate group of cultivars including Mt. Barker and Bacchus Marsh which recovered from defoliation at a reasonable rate.

Black concluded from this study, that prostrate cultivars were favoured by low cutting height, mainly because they had more leaf remaining following defoliation. The height of the cultivar being defoliated was the main factor determining the response to defoliation in this experiment. Black (1963b) also studied the inter-relationship between defoliation and sub clover cultivars Yarloop and Tallarook in pure and mixed swards. Yarloop recovered slowly from severe defoliations, while Tallarook recovered relatively quickly. However, Yarloop leaves did re-establish above the Tallarook canopy. Black concluded that the response of pure swards to severe defoliation was not a good guide to their behaviour when grown in mixtures. The research by Black was important to demonstrate the differences between sub clover cultivars in their response to defoliation: however, his research on sub clover during early vegetative growth does not fully relate to the field situation.

Most tall cultivars of sub clover can adjust to defoliation if it is more frequent and not too severe (i.e. the height of defoliation is high). Sub clover can adapt to weekly cutting by the development of a prostrate network of runners and dense sites of leaf production. For example, in one study, 70% of defoliated sward herbage was leaf as compared with 25% for uncut swards (Davidson and Birch 1972).

Rossiter (1976) found that defoliated swards yielded less than uncut swards. A possible reason proposed by Rossiter was that there was a lower LAI for defoliated swards. If so, this result is similar to that found earlier by Davidson and Donald (1958). Swards of sub clover cultivars Blackwood, Dwalganup and Daliak were grown outdoors and defoliated to 1.5 cm every 14 days or every 3 to 4 days (Rossiter 1976). Defoliated swards had developed smaller and more numerous leaves than the uncut swards. The compact, small leaved varieties with high branch and leaf number are more tolerant to frequent defoliation than the taller varieties. Burch and Andrews (1976) found dominance of the sub clover cultivar Yarloop over Larisa when grown in binary uncut swards but this dominance disappeared when the sward was cut frequently. Taylor *et al.* (1979), found that maximum forage yield was achieved by taking a single late cut.

Collins *et al.* (1983a), conducted defoliation experiments at Perth, Western Australia and Wagga Wagga, New South Wales. The productivity during the winter months was compared for selected cultivars of sub clover at the two locations. At Perth, cv. Woogenellup, Esperance and genotype 209.8.19.1 were grown in an open-sided glass shelter. Five cultivars were grown at Wagga Wagga in the open. The cultivars included Woogenellup and Esperance but also Nungarin, Larisa and Yarloop. Selection of cultivars was based on a range of growth habits and reputed differences in winter growth. However, results indicated that there was very little difference between productivity of the cultivars at both sites.

Differences of productivity between different pasture species under defoliation are common. For example, Motazedian (1984) conducted field studies in which perennial ryegrass (*Lolium perenne L.*) and sub clover pasture was defoliated every 7, 21, 35, or 49 days to the stubble heights 70, 55 and 40mm. Total dry matter production increased as the frequency of defoliation decreased. The erect growing perennial ryegrass produced more dry matter with a high stubble height while sub clover gave greater yields with low stubble heights. Therefore, the effect of defoliation in this experiment depended on the growth habit of the plant and the height of defoliation.

Conclusions: Defoliation has an important influence on the productivity of sub clover cultivars. There are examples of differences in the response to defoliation which are mostly due to the growth habit of the cultivar. Prostrate cultivars are normally more tolerant to defoliation than tall cultivars, although the frequency of defoliation is also important. Threrefore, it is important to incorporate some form of defoliation (i.e. cutting or grazing) after herbage production has been assessed under non-defoliated conditions. In some situations defoliation may nullify any production differences between cultivars (Collins *et al.* 1983a). Although defoliation by mechanical methods has provided a great deal of information about the basic responses of sub clover to defoliation. Mechanical defoliation is not representative of the field situation under the influences of grazing livestock. Interactions between sub clover plant density and defoliation in relation to herbage production are little understood, yet both factors have great influence on the herbage production of sub clover - based pastures.

2.4 Defoliation by grazing

For the evaluation of legumes, like sub clover cultivars, frequent defoliations by cutting are more realistic than a single defoliation. Cutting or mowing is rapid and complete which is not representative of the field situation where the grazing animal is consuming selected herbage. Therefore, plant responses after mowing may not be the same as those after grazing (Matches 1968, Curll and Davidson 1983).

The various effects of the grazing animal on pastures, viz: treading, defoliation, re-cyling of nutrients and the spread of seed, are well established. Mowing and other forms of cutting are rapid and remove most (or all) herbage, while grazing animals selectively remove herbage. Not only is there selection of which plants to consume but also between plant parts. Leaves, for example, are eaten in preference to stems; and green herbage in preference to dry (Sheath and Rattray 1985). Sheep have even been found to select *Trifolium repens* leaves without markings in preference to leaves with markings (Cahn and Harper 1976). Also, grazing animals do not necessarily select the most abundant species in a pasture. For example, when total pasture availability was very low, sheep ignored the two most abundant species (*Arctotheca calendula* and *Erodium botrys*) and preferred the more palatable species Wimmera ryegrass and sub clover (Broom and Arnold 1986). The type of grazing animal also has an influence on pasture recovery. Sheep graze close to the ground while cattle graze further from the ground. Consequently, sheep remove more growing points from pasture plants than do cattle.

During grazing, livestock not only ingest feed, but also indiscriminately damages the pasture by treading, causing poaching and pugging. Under rainfed conditions Carter and Sivalingam (1977) showed that 98 days after sowing severe treading by sheep caused a 46% reduction in plant numbers and 51% reduction in yield of sub clover and corresponding reduction of 51% reduction in plant numbers and 32% reduction in yield of Wimmera ryegrass. Treading also caused a 33% reduction in late winter production from irrigated sub clover-Wimmera ryegrass pasture (Witschi and Michalk 1979). Treading damage is also common on many pastures in high rainfall zones. Ultimately the grazing animal returns some mineral nutrients back to the pasture *via* defaecation and urination. Defaecation may also return some viable seed from pasture species and weeds. (See Section 2.6)

In the higher-rainfall areas of southern Australia, early and mid-winter are the main period of feed shortage (due to low availability) and sub clover pastures are heavily grazed at this time. Therefore, the ability of sub clover cultivars to recover from heavy grazing is important for continued productivity and persistence. Grazing tolerance of some species can be explained by their ablility to retain relatively high residual leaf area after defoliation (Simpson and Culvenor 1987). However, it is important for the residual leaf area to have high carbohydrate content to enable rapid leaf production following defoliation (Alberda 1966). Francis *et al.* (1976) emphasized the need for more research of grazing recovery and stated in relation to cultivar differences "that these be considered in conjunction with winter growth because the two may in fact be antagonistic... rapid growing types with leafy growth may not recover as well as other types and persist less well in mixed swards". The literature has much on the general effects of grazing and more often significance is placed on the productivity of the animal, with little reference to the productivity and persistence of the pasture. Comparatively little is known about the growth and persistence of various sub clover cultivars under grazing conditions and the influence that grazing management may have on various cultivars.

2.4.1 Grazing management

Management decisions have an impact by modifying the production or composition of the plant biomass (Morley 1981). Stocking rate, the type or breed of livestock and the method of grazing (i.e. continuous, rotation, deferment etc.) are the factors which can be manipulated by livestock producers. Stocking rate is still a major determinant of livestock productivity (Carter 1965, 1968 b, 1977; Obst 1987) and affects the economic return from grazed pastures (Bransby and Conrad 1985). The main objective is to make herbage production fit the nutritive requirements of livestock (Morley 1966). Another important objective is to maximize the intake of digestible organic matter (Christian 1987) which does not necessarily mean maximum weight of pasture. In Australia, much emphasis is placed on the management of stock rather than on the management of pastures: in New Zealand more emphasis is placed on pasture management and the differences between various management practices (Stern 1984).

McMeekan (1956) reviewed grazing management and animal production experiments undertaken with dairy cattle at Ruakura Research Station, Hamilton, New Zealand. The three major grazing management factors under farmer control: namely, grazing method, type of livestock and stocking rate, were examined in a series of experiments set up in the following manner: (i). Same animals, same stocking rates, but *different grazing method*. (ii). *Different animals*, same stocking rates and same grazing method. (iii). Same animals, *different stocking rates* and same grazing method. Grazing method had little impact on animal production if the type of livestock and stocking rate were kept constant. However, dairy pastures rotationally grazed were found to be more vulnerable to pugging and drought because of the more open sward structure compared to the dense sward structure of continuously grazed pastures. The type of livestock (eg. sheep vs. cattle) can have large effects on the efficiency of converting grass to animal products. Stocking rate was found to be the most important factor influencing the efficiency of production on a unit area basis and was described as the most "powerful weapon" of the three management options (McMeekan 1956). Because stocking rate is one of the most influential factors (Carter 1968 a, b), differing levels of stocking intensity should be considered in grazing experiments (Bransby *et al.* 1988).

2.4.2 Stocking rate effects

Stocking rate can affect the botanical composition and productivity of the pasture, as well as animal production per unit area and per head, as do the level and type of grazing.

(i) Botanical composition changes: Rossiter and Pack (1956) monitored changes in botanical composition of a Dwalganup-based pasture over seven years. Continuously-grazed pastures were clover dominant with capeweed whereas ungrazed pasture on the same site was soon dominated by annual grasses and *Erodium botrys*. The legume content of the ungrazed pastures rapidly declined to only 5% after 2 years. The authors stated that the experiment was an example of the profound effect that differential grazing pressure can have on the botanical composition of a sub clover-based pasture. Changes in botanical composition induced by stocking rate can be rapid. On a Wimmera ryegrass (*Lolium rigidum*)- sub clover-based pasture grazed at the stocking rates 2.5, 7.4, 14.8 sheep/ha, differences in botanical composition of pastures were found within a year (Sharkey *et al.* 1964). Both Wimmera ryegrass and sub clover declined under high grazing pressure and soil seed reserves of both species declined. However, in the low stocking rate plots, the amount of Wimmera ryegrass increased, while sub clover declined.

Carter (1966, 1977), also found a direct link between stocking rate and changes in the grass/clover balance over a five year period at the Waite Institute, South Australia. At the beginning of the experiment, the pasture consisted mostly of the sub clover cv. Yarloop and Dwalganup with Wimmera ryegrass. Merino wethers were continuously grazed for five years at 7.4, 12.4, 14.8, 17.3 and 22.2 sheep/ha. Low stocking rates led to barley grass (*Hordeum spp.*) becoming dominant (Carter 1966) while high stocking rates led to successful invasion by winter grass (*Poa annua*) and volunteer small-seeded legumes mainly cluster clover (*Trifolium glomeratum.*). Intermediate stocking rates led to capeweed (*Arctotheca calendula*) dominance (Carter 1966, 1977; Carter and Lake 1985).

However, Carter and Day (1970) found there was no distinct effect of stocking rate or superphosphate on botanical composition. Nevertheless, there was a trend for sub clover percentage to increase as the season progressed. Perennial ryegrass was found to be depressed by higher stocking rates, while *Poa annua*, *Trifolium glomeratum* and *Erodium botrys* were found to invade heavily stocked treatments with low superphosphate application (94 kg/ha).

The invasive species may not affect pasture and animal productivity (Carter 1966, Allden 1968). Cameron and Cannon (1970) found that a *Lolium perenne*/sub clover pasture, continuously stocked at 4.9, 7.4, 9.9, 12.4, 14.8, 17.3 and 19.8 sheep/ha, showed major changes in botanical composition but this did not affect animal productivity. High stocking rates, for example, increased the amount of *Trifolium glomeratum*, *T. dubium* and *T. campestre* in the sward but the appearance of these clovers did not affect the wool production even though the amount of sub clover decreased (Carter and Lake 1985). However, decreases in stocking rate during winter can increase the frequency of broadleaf weeds such as *Arctotheca calendula* (Dunlop 1985).

Some invasive species reduce the productivity of pastures. High stocking rates (29.7 Merino wethers/ha) greatly reduced the total pasture production by the third year at Kybybolite, South Australia because of the increased invasion of *Poa annua* and *Juncus bufonius* (Brown 1976a). Appearance of both these species could therefore be useful as indicators that the grazing pressure is too high. They are also indicators of loss of soil structure (i.e. soil compaction) and prevalence of waterlogging. Therefore, the type of invasive species will determine whether pasture productivity will be adversely affected.

Earlier, Cameron and Cannon (1970), Carter (1977) and Carter and Lake (1985) found no detrimental influences on the pasture productivity when the invasive species were small-seeded legumes.

However, Taylor (1985) stated that in field experiments it is almost impossible to show without any doubt that defoliation by animals was the sole cause of changes in botanical composition. Long-term studies on the effects of grazing have shown that grasses replace the herbaceous species at low stocking rates (Carter 1966; Dunlop *et al.* 1984; Dunlop 1985). This is probably due to shading by taller growing grasses and variations in survival of seed from different pasture species eaten by livestock.

Overseas studies have also shown the general trend toward grassy pastures under low stocking intensities. Rosierie (1987) found an increase in sub clover with increased grazing intensity, while soft chess (*Bromus mollis L.*) decreased with increased grazing intensity. A reduction in total herbage yield of grasslands was found to occur under the heaviest grazing and this was attributed to the reduction of soft chess which was replaced by sub clover. Low frequency of defoliation is not always beneficial to grasses. Motazedian and Sharrow (1987) found in a perennial ryegrass-sub clover pasture that mortality of perennial ryegrass occurred when defoliation was infrequent.

(ii) Response of mixed pasture swards to grazing: Stocking rate affects the abundance, structure and relative composition of pasture on offer to animals in mixed swards. Increasing stocking rate reduces plant morphological variation in the sward while minimizing the negative effects of plant structure on the selection process (Stuth *et al.* 1985). Certainly, grazing can overide the influence that tall vigorous pasture plants can have in mixed sward situations. For example, in the ungrazed situation, rose clover (*Trifolium hirtum*) and cupped clover (*T. cherleri*) shaded sub clover (Rossiter *et al.* 1972; Taylor and Rossiter 1974). However, sub clover (cvv. Geraldton, Dwalganup, Northam A and Carnamah) can dominate in some pasture mixtures with rose and cupped clovers when continuously grazed by sheep. Different cultivars of sub clover may produce different results because of the different growth habits of cultivars. It was also found that rose and cupped clover pastures failed when the stocking rate was increased to 8 sheep/ha (Rossiter *et al.* 1972). Competition between sub clover cultivars also occurs and the response is dependent on grazing pressure. Rossiter and Pack (1972) found that increasing the stocking rate on a pasture of Geraldton, Woogenellup and Bacchus Marsh sub clovers, restricted shading effects caused by the taller Woogenellup cultivar, thereby improving the competitiveness of Geraldton.

The growth habit of a plant can affect its ability to persist in a mixed pasture which is grazed. As discussed earlier, defoliation can change the growth habit of plants although there is evidence to suggest that some species are more responsive than others. Smith *et al.* (1972) found that of the five annual species examined during autumn and winter, Wimmera rye grass (*Lolium rigidum Gaud.*) changed the least under continuous grazing at a stocking rate of 10 sheep/ha. However, sub clover cultivar Woogenellup, silver grass (*Vulpia fasiculata*) and *Erodium spp* . rapidly developed a prostrate habit. As a result the apparent intake of herbage was restricted. Sub clover was also found to adopt a prostrate habit in response to deferred grazing (Smith *et al.* 1973). Legume species differ markedly in their response to continuous close grazing (Watkin and Clements 1978). The grazing tolerance of erect types such as Clare and other members of *T. subterraneum subsp. brachycalycinum* are poor under heavy grazing pressures, whereas prostrate, densely-leafed cultivars such as Daliak, Seaton Park, Dinninup and Geraldton are well proven under high grazing pressure (Francis *et al.* 1976; de Koning 1984; de Koning and Carter 1987 b).

(iii) Response of pasture availability and total productivity to stocking rate: Total seasonal pasture production is also affected by stocking rate which may reflect changes in density and/or changes in botanical composition. Recovery of pasture plants from defoliation becomes slower as the severity of defoliation increases and eventually the productivity of an area can be reduced or destroyed (Carter 1966, 1977; Christian 1987). Total annual pasture production was reduced from 7.5 to 4.0t DM/ha with an increase in stocking rate from 5.6 to 16.3 sheep/ha (Dunlop *et al.* 1984). At the highest stocking rate, total pasture production was 54% that of pastures at the lowest stocking rate. This is in contrast to the findings of Carter (1968 a, 1977), who found that in the first three years that pasture production at the Waite Institute was greatest for the highest stocking rate (22.2 sheep/ha). However, the highest stocking rate was unstable. After a false break to the season in the fourth year, there was a reduction in plant densities later in the season and subsequent death of sheep. The situation was much the same in the fifth year of this experiment. However, it should be emphasized that the lowest stocking rate produced the least feed for the duration of the experiment. This was ascribed to wastage of light and water. Brown (1977) also found the highest total production on continuously grazed pastures grazed at high stocking rates. Dunlop *et al.* (1984) found that pasture availability was always lower at the highest stocking rate than at the lowest stocking rate. Reductions in pasture production by increased stocking rates may be due to changes in botanical composition. Seasonal conditions may have been more favourable during the studies by Carter (1977) compared with Dunlop *et al.* (1984), this may explain the differences in results.

High total productivity of pastures needs to be utilized effectively by grazing livestock to be beneficial to animal productivity. Birrell (1981) made observations of animal and pasture characteristics under various grazing pressures (10, 15, 20 and 25 sheep/ha). The amount of herbage was important to animal production at the high stocking rates whereas the quality changes in herbage influenced animal performance at the two lowest stocking rates. Birrell (1981) concluded that intake was the major factor in determining animal performance but diet quality and time spent grazing also altered the response to intake. Later, Birrell (1987) related wool production to intake of pasture at several stocking rates. Observations were made in various environments with different pasture plant genotypes. His results indicated that the efficiency of conversion of pasture to wool were affected by the overall quality of pasture and not by the genotype of pasture plant. The botanical composition of the pasture in terms of palatable species is more important than the genotype or cultivar.

2.4.3 Grazing method and interactions with stocking rate

Different grazing strategies may not confer an advantage in animal production (M[c] Meekan 1956), but they can influence the response of pasture species to grazing method. For example, a major effect of early grazing, is that it substantially delays the attainment of the optimum LAI when the LAI of the sward is low (Donald and Black 1958). Furthermore, once the optimum LAI is reached, the management strategy should be one which would enable the pasture to remain at this level. M[c] Kinney (1972) found that pasture availability at the beginning of winter was far more important than either pre-winter weight of sheep or winter pasture growth rate. There was a larger influence on weight of sheep at the end of winter if the early winter availability was high.

Autumn deferment of grazing is one option available to increase the amount of winter feed. Deferment is most successful when coupled with fodder conservation and supplementary feeding programmes. Rotational grazing may also be advantageous during the late autumn/winter to early spring when the availability of pasture is low (Morley 1968). The main advantage of both methods is that they allow the pasture to develop a sufficient leaf area before the commencement of grazing and greater pasture availability in winter (Smith *et al.* 1973; Brown 1976 a,b; Brown 1977 and Davies 1987). However, the main disadvantage in both cases, when grazing animals are excluded from one area, it automatically increases the grazing pressure on the remaining area. However, deferment is important in the first year of pasture establishment, or to protect regenerating seedlings. Pasture was found to benefit through increased seed reserves at the end of summer and the number of plants which re-established at the beginning of the next season (Smith *et al.* 1973). Losses in animal production can result from keeping livestock off deferred areas (Fitzgerald 1976). These losses were not always compensated later in spring and this was dependant on the grazing strategy used and the area set aside for deferment. However, the emphasis of most grazing strategy experiments have been on animal productivity. The experiments conducted by Davies and Southey (1985) and Davies (1987) highlighted the connection between pasture production and animal production.

Conclusions: In a similar way to defoliation by cutting, grazing tolerance of sub clover cultivars is also determined by growth habit. However, the system involving grazing animals is more complex because grazing tolerance will not only be influenced by the sub clover cultivar but also the plant density and the grazing management (i.e. stocking rate and grazing method). Research on grazed sub clover-based pastures needs not only to examine changes in yield and botanical composition, but also to examine the sub clover seed yield and the regenerative abilities of that pasture. High seed yields under grazed conditions should maintain high plant density in the following season provided a relatively high proportion of that seed is soft (germinable) and sufficient seed remains after summer and autumn grazing of pasture residues.

From the literature, it can be seen that there are no simple generalizations regarding the effects that grazing animals have on pastures, or for the effects that pastures can have on grazing animals. There is a multitude of different variables involved. Since the objectives of grazing systems are seldom simple, one should aim for long term stability as well as immediate profit (Morley 1981). The main problem associated with grazing experiments is the complexity of the factors involved and as a result, this limits the number of factors which can be examined at any one time. Therefore, it is not suprising that many of the stocking rate experiments are primarily concerned with animal production. Efforts have been made to examine pasture production in relation to animal production (e.g. Carter 1966, 1977; Davies and Southey 1985; Davies 1987) but no study involved the use of different cultivars of sub clover grown at contrasting plant densities. Yet both cultivar and plant density are important factors in determining pasture productivity. In addition, there is no real account of the impact of grazing on sub clover (e.g. Carter 1966, 1968, 1987; Carter, Wolfe and Francis 1982; Carter and Lake 1985; de Koning and Carter 1987). Therefore, both the cultivar and density factors need to be integrated into experiments which involve grazing.

2.5 Seed production of subterranean clover

2.5.1 Burr burial

Sub clover is almost unique among pasture legumes in that it can bury some of its seed in the soil (i.e. geocarpism). The sub clover inflorescence has 3-5 flowers borne on an erect peduncle. Following fertilization the young pods reflex against the peduncle. Downward bending and lengthening of the peduncle carries the developing burr with seed towards the soil surface. Several sterile calyces develop from the apex of the peducle and form the burr around the seed. Once the sterile calyces have penetrated the soil they reflex which aids burr burial.

Part of the success of sub clover as a pasture plant may be attributed to burr burial (Rossiter 1966, 1978). This characteristic may have developed as a grazing escape mechanism, to protect some of the seed from grazing animals. Burr burial may also be a protective mechanism against low relative humidity and high temperatures (Yates 1957, 1958). The early-maturing strains most probably evolved in areas where the growing season is short and the conditions less favourable for seed production. Generally, cultivars which exihibit strong geocarpism are short-seasoned and are most commonly found and used in areas which have hot, dry conditions during the period of seed set and development (Barley and England 1970). The early-season cultivar, Dwalganup, can bury 50 to 80% of its seed (Barley and England 1970) and Yarloop can have 90% of its burrs buried (Yates 1958). The late-maturing cultivars Burnerang and Tallarook set nearly all seed above ground (Yates 1961).

Yates (1957) tested the assumption that burr burial is a protective mechanism. The strain Red Leaf was chosen, because it matures some seed above and below ground. Spaced plants were grown in the field. Some plants were allowed to bury burrs freely in the soil, others were prevented from burying burrs by placing asbestos sheeting on the soil while a third group of plants buried burrs in foam rubber placed on the soil surface. The best seed set was achieved by plants which could develop their burrs at or below the soil surface, or when burrs were enclosed in foam rubber. Seed set above the surface had lower individual seed weight and poor germination. In contrast, seeds that developed within buried burrs (soil or foam rubber) were much heavier with a higher percentage germination. Seeds formed at the soil surface had intermediate seed weight and germination. On heavy-textured soils which form an impermeable crust, Quinlivan *et al.* (1973) found that the cultivar Daliak was prevented from burying burrs and as a result, mean seed weight and total seed yield were reduced.

In a further study by Yates (1958), it was postulated that the extent of burr burial depended on the interaction between cultivar, environment and the condition of the soil surface. Hot, dry conditions were found to promote burr burial but only if the soil conditions were favourable (moist soil). A range of sub clover cultivars were tested which represented differing maturity types. They were grown as single plants under two different environmental conditions, cool and moist, and hot and dry with frequent watering of the roots. Under the mild conditions, early-maturing cultivars buried a high proportion of their burrs, while the late-maturing cultivars buried only a few burrs. However, under more severe conditions, the late-maturing types were found to bury a high proportion of their burrs. The ability to set seed above the soil varied depending on the strain. Even within a strain, the ability to set seed above ground was greater in the mild environment. Buried burrs normally had good seed set.

Yates (1961) later found that plants growing in sward conditions could change the micro-environment sufficiently to affect burr burial. He used the cultivars Dwalganup, Yarloop, Bacchus Marsh, Burnerang and Tallarook and grew them at five densities (4.9, 24.7, 123.6, 618.0, 3,090.0 plants/m^2). Increasing plant cover increased the humidity and decreased temperature in the canopy micro-environment resulting in a reduced burr burial. Similarly, leafy foliage of late-maturing strains may also modify the micro-environment of the burr (Yates 1958) and reduce burial. The cultivars Burnerang and Tallarook, which are late-maturing cultivars, set nearly all seed above ground irrespective of plant density. Differences in seed production between cultivars grown as single plants were reduced markedly in sward conditions. Nevertheless, differences in the percentage burr burial between cultivars did exist when plants were grown under sward conditions.

Generally, early flowering cultivars are selected for districts with short growing seasons. For example, the early flowering cultivar Dwalganup extended into areas of short growing seasons in southern Australia: however, Geraldton, which flowers ten days later but matures seed 6 - 9 days earlier than Dwalganup, is known to persist better than Dwalganup in lower-rainfall areas (Tennant 1965). Therefore, it could be a inherited character which enables a cultivar to set viable seed early but the actual period required is influenced by burr burial. Dwalganup was found to have the heaviest individual seed weight when the burrs were buried. Geraldton also had heavier seed as a result of burr burial but not to the same extent as Dwalganup which has inherently large seeds. The benefits of early flowering on the survival of sub clover in dry regions would only be useful if combined with a short flowering duration, ensuring that viable seed is set before the end of a short growing season. The ability to produce viable seed quickly would appear to be a more important character than time of flowering in dry environments.

Even though burial of seed is seen as important, not all environmental conditions will allow successful burr burial to occur. Regions which have short growing seasons present many problems, particularly on the heavier-textured soils which form hard crusts in spring. For this reason, Quinlivan and Francis (1971) sought cultivars with the ability to set viable seed on the soil surface. When testing the seven cultivars - Norham A, Geraldton, Dwalganup, Daliak, Dinninup, Mount Helena A and Seaton Park, they found a highly significant Cultivar x Treatment (prevention of burr burial) interaction for the amount of viable seed produced. The prevention of burr burial affected the cultivars Northam A and Dwalganup the most by reducing the amount of viable seed set. Daliak, in contrast, was able to produce a reasonable quantity of viable seed above ground. Nevertheless, buried seed still had the greatest viability and the highest levels of impermeability. Quinlivan and Francis (1971) made reference to the fact that cultivars such as Woogenellup and Mount Barker both have poor burr burial, yet are successful in terms of their persistence. They suggested that most likely both cultivars were capable of setting reasonable quantities of viable seed above ground. Poor burr burial but high quantities of viable seed set on the soil surface for the cultivars Woogenellup and Mount

Barker indicates that both cultivars probably evolved in cool, moist environments. It should be possible to select mixtures of sub clover cultivars with a range of burr-burying abilities because there are sufficient differences between genotypes and within sub species (Walton 1975).

Sub clover genotypes vary in their ability to set seed above ground. The extent of cultivar differences in burr burial was examined by Francis *et al.* (1972). The strength of burr burial was measured by counting the number of burrs that had penetrated a standard polythene mesh. The strongest degree of burr burial was exhibited by cultivars within the *T. subterraneum subsp. subterraneum* : *T. subterraneum subsp. yanninicum* was next, while *T.subterraneum subsp.brachycalycinum* had the weakest tendency to bury burrs of the three subspecies. Differences between cultivars within a subspecies were strongly correlated with maturity with earlier-maturing cultivars having the greater quantity of penetration through the mesh. Strong geotropism was also associated with strong peduncles, which enabled forceful penetration through the mesh. These results agree with those found earlier by Barley and England (1970).

Francis and Gladstones (1974) found that from the 24 clover strains tested, seed size was unrelated to strain maturity. Three characteristics were found to be significantly related to seed yield, viz. rate of inflorescence production, number of seeds per burr and seed size. Generally, the seeds from small-seeded and fast-flowering strains, produced viable seed quicker than the large-seeded and slow-flowering strains. Rapid flowering may be advantageous for seed production. Francis and Gladstones concluded that rapid flowering and high seed number per burr may be useful traits when selecting sub clover for seed yield.

Later studies by Collins *et al.* (1976) also found that prevention of burr burial reduced the yield of viable seed. This was due to a decline in total burr numbers, number of mature burrs, number of seeds/burr, individual seed weight and seed viability. As in the earlier studies of Yates (1958), they found that the ability of sub clover to set seed in unburied burrs depended on the cultivar. The later-maturing cultivars had the greatest capacity to produce seed in unburied burrs. Seed set in early cultivars such as Gingin and Shenton Park A was affected more by preventing burr burial than in the later cultivars such as Midland B, Dinninup and Daliak. The proportion of hard seed was lower in unburied burrs and the breakdown of hard-seededness was much faster, although there was significant variation between cultivars. Hard-seededness was found to depend largely on the temperature and moisture conditions at the time of seed production. As a result, all the strains studied, developed high proportions of hard seed in buried burrs.

The extent of burr burial has important implications on the persistence of sub clover-based pastures. Burial of burrs provides protection from grazing animals and also provides a viable source of seed in the soil. So any genotype which exhibits good burr burial ability should persist under heavy grazing pressure.

2.5.2 Density and seed yield

As discussed in Section 2.2, plant density can have strong influences on the herbage production of sub clover. Seed yield of sub clover has also been shown to be affected by plant density. Walton (1975) suggested that sward density was very important when considering experiments which evaluate sub clover genotypes for seed yield under defoliation.

Donald (1954) studied the effects of sowing density on seed yields of sub clover and Wimmera ryegrass. Sub clover was sown at densities of 12, 79, 269, 1931 and 18,510 plants/m^2. Seed yield was greatest at intermediate densities (269 and 1931 plants/m^2) and decreased at the highest density. Decreases in seed yield per plant were not compensated by having more plants at the higher densities. Widely spaced plants were found to have the greatest number of inflorescences per plant, but they had smaller seed and fewer seeds per inflorescence than plants in denser swards. The results indicate that intra-plant competition was occurring between inflorescences at the sparse densities where inter-plant competition would be at the lowest. Donald concluded that dense swards were the most useful for grazing but if seed multiplication was desired, intermediate densities gave the highest seed yields. However, the relationship of density to seed production will vary from season to season (i.e. variations to the break of the season, moisture conditions of the soil, etc.).

Rossiter (1959) conducted a series of one-year experiments in which a large number of sub clover cultivars were grown either as single-spaced plants or in swards. Plant density was shown to affect the relationship between the interval of sowing to flowering (maturity grading) and the pattern of seed production. Single plants and swards reacted differently. The total yield (tops + burrs) and the seed yield increased linearly for single plants as the maturity grading increased. Swards had a slight decrease in total yield as maturity grading increased but seed yield declined dramatically. To illustrate the response, the early cultivar Dwalganup was shown to have the lowest seed yield when grown as single plants, but had the highest seed yield under sward conditions. The reverse was true for the late cultivars Wenigup and Tallarook. Differences between spaced plants and swards in seed production were ascribed to available soil moisture. Under sward conditions soil moisture can be very low during spring. Dwalganup, grown as spaced plants, was found to flower one month later than plants grown in a sward. Hence spaced plants were exposed to harsher climatic conditions. Rossiter suggested that this may explain the poor seed yield of that cultivar under spaced plant conditions. Furthermore, Rossiter stressed that the scope of the data was not suitable for predicting long term adaptation since the experiments were only of one year duration. Similarly, Taylor and Rossiter (1967), using the cultivars Carnamah and Geraldton at 9, 36 and 144kg/ha showed that there was a significant decrease in seed yield at the highest sowing rate. Although senescence occured earlier in the high density swards there was no significant Cultivar x Sowing Rate interaction in terms of seed production.

Medicago species behave similarly to sub clover when sown at a range of densities. Cocks (1984) found sowing rate to be important because of its effect on seed survival of *M. truncatula*. Softer seeds were formed under less dense swards possibly because sparse swards offered less shading from the impact of the sun's heat. To examine the effect on seed yield a range of *Medicago* species were sown at two rates 10, and 200 kg/ha (Cocks 1987). There was a strong Species x Density interaction for the number of seeds per pod. Generally, at the highest density, the seed production was less but the number of seeds greater. Variation in seed yield at the higher density when compared to the lower density can be explained by flowering time. Flowering was earlier at the high density which may be a response to moisture stress. Later, in a similar experiment, Cocks (1987) reported that at a high sowing rate (256 kg/ha) flowers were more likely to set seed: however, flower production was highest at the sowing rates less than 30 kg/ha. Furthermore, early-produced flowers were more likely to give rise to mature pods compared to later-produced flowers.

Bolland (1986), also studied the effect of sowing rate (2 and 100/kg/ha) on the cultivars Clare, Mount Barker and Esperance. Attention was given to the relationship between interval from sowing to flowering. Seed yields increased with increasing sowing rate and declined as maturity grading increased. Declines in seed yield due to maturity grading were markedly decreased as sowing rate increased. These results support the earlier findings of Rossiter (1959) and Taylor and Rossiter (1967).

2.5.3 Effects of defoliation on seed yield

Timing of defoliation affects seed yield and could be more important than the number of defoliations (Rossiter 1961). This may help explain the differences between results from various researchers.

(i) Defoliation by mechanical methods: Increased production of seed by sub clover in response to one or more defoliations (by cutting or mowing) has been demonstrated (Rossiter 1961; Scott 1971; Collins 1978, 1981; Wolfe 1981 and Dunlop 1985). Increases in seed yield due to defoliation were partly attributed to increases in the inflorescence number and other yield parameters such as marked increases in burr burial (Collins 1978; Dunlop 1985). Marked increases in burr burial resulting from defoliation were also noted by Rossiter and Pack (1972), Walton (1975) and Collins (1981).

Poorly timed defoliations (i.e. during and after flowering) may depress seed production (Rossiter 1961, 1972; Collins and Aitken 1970; Collins *et al.* 1976 and Collins *et al.* 1983b). Low seed production may be due to delayed flowering resulting from defoliation (Collins and Aitken 1970; Rossiter 1972). Alternatively the removal of photosynthetic tissue during the reproductive phase may reduce the amount of assimilate available for subsequent seed growth and development resulting in reduced seed yield (Collins *et al.* 1976). The response to defoliation is further modified by the density of the sward. Cut swards of Dwalganup had increased flowers/unit area than uncut swards when severely defoliated at early flowering or after flower initiation (Rossiter 1972). Spaced plants defoliated at the same stages had larger reductions. Rossiter (1972) concluded that field implications from these results may suggest that grazing low density swards may greatly reduce seed yield.

Cultivars react differently if defoliation continues after the commencement of flowering. A Cultivar x Defoliation interaction was found for seed yield when cutting was continued after the commencement of flowering (Collins 1978). For example, the cultivars Yarloop and Midland B had a reduction in seed yield when cutting continued midway through flowering, when compared with treatments when cutting ceased before flowering. In contrast, Seaton Park suffered no reduction in seed yield from the same defoliation treatment. Practical implications are that frequent and severe grazing of pure sub clover swards prior to flowering will enhance seed production. Later Collins *et al.* (1983b) found the cultivar Midland B to be more sensitive to defoliation throughout the flowering period when compared with Seaton Park. It was postulated that Midland B may have set seed and senesced earlier than Seaton Park as a result of the severe defoliation treatment. This may have allowed Seaton Park to benefit from the resources which were previously utilized by Midland B. The influence of grazing during flowering on sub clover seed yield will depend on the cultivar and grazing intensity. Sub clover appears to be well adapted to severe defoliation, and this undoubtedly has contributed to its success under a range of conditions, such as continuous grazing at high stocking rates (Rossiter 1961; Carter 1966, 1968c, 1977). However, poor seed yield has resulted from high stocking rates (Sharkey *et al.* 1964). The reason for this may be due in part to the consumption of seed by livestock at high stocking rates (Carter and Lake 1985).

Hagon (1973b), Walton (1975) and later Collins (1983b), found no response of seed yield to pre-flowering defoliation. The lack of response of seed yield to pre-flowering defoliation (Walton 1975) contrasts with the results obtained earlier by Rossiter (1961, 1972). Walton (1975) explained that this was most probably due to the lower plant density used in his experiments compared to Rossiter (1961, 1972). As a result, leaf area would be low therefore allowing better light penetration than the denser swards used by Rossiter. Therefore, stem development resulting from defoliation, did not increase seed yield. Rossiter found that for dense, undefoliated swards, stem growth was limited due to supra-optimal leaf area: hence, the production of less flower nodes. Shading may be responsible for seed reductions under dense sward conditions. Collins *et al* .(1978) showed that the shading of sub clover reduced the number of inflorescences per unit area. Dunlop (1985) also found that shading at flowering for sub clover reduced seed yield.

(ii) Defoliation by grazing: Defoliation in most seed production experiments involved mechanical defoliation. The impact of grazing on seed production of sub clover needs attention.

The success or failure of a sub clover cultivar to persist under grazing was related to its ability to produce seed when grown in ungrazed pure swards (Rossiter 1966). Rossiter grew a range of cultivars i) under single sward conditions, ii) as single cultivar swards with an indicator cultivar grown in association and iii) as a mixture of several strains. Seed yield was found to vary for each of the three competitive situations. Success of a cultivar to persist was found to be related to seed yield and maturity grading. Data supported the proposal that the success or failure of a sub clover cultivar grown in a grazed mixture is closely related to the seed yield of that strain grown in pure swards. Furthermore, success was attributed to seed size, petiole length and hard-seededness, although petiole length is not expected to be of any advantage under heavy grazing.

In addition to his cutting experiments, Rossiter (1961) tested the cultivars Dwalganup, Yarloop and Bacchus Marsh under grazed conditions from June 17 to August 26 at 5 sheep/ha. At the stage when sheep were removed, Dwalganup had begun flowering but Yarloop and Bacchus Marsh had not. Although, the Cultivar x Grazing interaction was not significant, grazing increased seed production for all three cultivars. Seed production increased by 23% and seed number by 45 percent. However, the weight of individual seeds from both above- and below-ground burrs was decreased by grazing. Defoliation by cutting also caused a decline in seed size. In view of the results from the cutting experiment, grazing increased seed yield mainly because grazing was early and commenced in June and finished toward the end of August, at which time only Dwalganup had begun flowering. Marret (1960) recommended that first year stands of sub clover need to be grazed lightly during the flowering stage and this is standard practice for any new annual pasture sown at low rates. As a result, Dwalganup and Yarloop gave good seed production with a high percentage of hard seed.

Management practices which delay flowering may lower seed yield (Collins and Aitken 1970, 1971). It was suggested that if grazing occurs early in the growing season flowering may be postponed by 3 to 4 weeks. Seed yields of Mt Barker are known to be drastically reduced when stocking rates are high, so possibly a delay in flowering may partly be the reason for reduction in seed yield (Collins and Aitken 1971).

Rossiter and Pack (1972) observed in the field that increased stocking rate increased both the seed production and hard-seededness of Geraldton when grown in a mixture with Woogenellup. Increased grazing pressure decreased shading caused by the taller cultivar Woogenellup leading to improved competitiveness of Geraldton during vegetative growth.

However, Carter (1966), Carter *et al.* (1982) and Carter and Lake (1985), described a grazing experiment in which the hard and total seed yield decreased progressively over a five year period on plots which were continuosly grazed at the highest stocking rate (22.2 sheep/ha). At the low stocking rate (7.4 sheep/ha) barley grass became dominant, botanical compostion fluctuated greatly and so did sub clover seed production. It was concluded that the mixture of cultivars used (Bacchus Marsh, Dwalganup and Yarloop) was able to withstand heavy grazing and sub clover set seed even in the fifth year of the experiment which was a drought year. Furthermore, sub clover seed samples were grown and identified and were found to decline progressively in the Cultivars Bacchus Marsh and Dwalganup while Yarloop was found to increase during five years of continuous grazing (Carter 1968c).

Recently, de Koning (1984) and de Koning and Carter (1987b) found that high grazing pressure applied in mid-season caused a decline in the seed yield of the cultivars Yarloop and Clare. However, this effect was primarily due to the high stature of both cultivars at the time of the first grazing which caused excessive mortality of many Yarloop and Clare plants.

2.5.4 Hard-seededness

Hard-seededness is an important attribute for pasture legumes, particularly for persistence in a pasture-ley in a crop rotation. Hard seed (i.e. impermeable to water), will not germinate on the first rainy occasion. In dry regions this is of particular importance because soft seeded cultivars can lose a high percentage of their seed through early germination resulting from a false break to the season. For this reason, softer-seeded cultivars are better suited to higher rainfall regions where the rainfall is more reliable.

The level of hard-seededness found depends on many factors such as cultivar, the degree of burr burial, defoliation and the environmental conditions (eg.humidity and temperature). As discussed earlier, defoliation can increase the number of burrs buried. Buried burrs have higher levels of hard-seededness than unburied burrs. There are however, many interactions involved even though some cultivars are known to have inherently high levels of hard seed. Cultivars have been shown to display inherent differences in their ability to bury burrs and their response to defoliation (see 2.5.3). Hagon (1974) showed that later-maturing cultivars generally had higher levels of soft seed compared to the earlier-maturing cultivars. There was a negative correlation (r = -0.61***) between seed yield and maturity grading (i.e. Later-maturing cultivars had less seed yield). The correlation was just significant when number of seeds/unit area was related to maturity grading. However, Hagon stressed that if the percentage residual hard seed level was very high in any year, there would be a limited amount of readily-germinable (i.e. soft) seed for emergence in autumn. This problem is observed to occur for many of the medics when high levels of regeneration are sought. High levels of hard-seededness in medics is common and often limits the density of regenerating pasture (e.g. Dear and Jenkins 1987).

Collins (1981) demonstrated that the level of hard-seededness in the cultivar Midland B was affected by defoliation, whereas Seaton Park was not. In the earlier study by Collins (1978), both Yarloop and Seaton Park increased hard seed levels due to defoliation. This was because cutting significantly increased the proportion of buried burrs which have higher levels of hard-seededness.

The level of hard seed may also be influenced by the number of seeds per burr. This assumption was tested by Salisbury and Hallaron (1979a) using the cultivars Merino, Tallarook and Dwalganup. Seed from 2, 3 and 4-seeded burrs from each of the cultivars was germinated at diurnal temperatures 15^{o}C/60^{o}C. Comparisons could be made within cultivars but not between. Generally, 4-seeded burrs had the highest percentage of hard seed. It was suggested that if differences were significant, the differences between cultivars need to be looked at more closely, as it may explain some of the variations in hard-seededness between cultivars. Salisbury and Hallaron (1979b) also found that seed set in the latest flowers was most likely the first seed to show softening of hard seed. Quite often the largest seed was found in the last flower. Usually hard-seededness in the largest seed, or the seed with the highest moisture content breaks down first, however, the stage of flower development seems to be more important. Salisbury and Hallaron proposed that the pre-determination of hard seed breakdown was due to either a promoter or an inhibitor which is distributed disproportionally to the flowers in the inflorescence. Earlier, Grant *et al.* (1964) had shown that the large seeds were less hard than the small seeds. They determined this by separating the seed from three genotypes (Portugal CPI 19465, Burnerang, Mount Barker) into seed size classes. The large- and small-seed were sub divided into hard- and soft-seed categories. The proportion of hard seed varied between cultivars and from year to year. The data also supported those results obtained by Yates (1957, 1958) which showed that relatively cool conditions favoured the formation of larger seed. Varietal differences in hard-seededness were most likely due to the differing times of flowering, hence the differing conditions for seed maturation experienced by each of the cultivars.

Differences in the pattern of seed softening of various cultivars were shown to be significant (Bolland 1987). Five cultivars (Woogenellup, Seaton Park, Daliak, Esperance and Trikkala) were only allowed to set seed in the year of sowing. Levels of soft seed were measured in the field each May for the regeneration years. Development of soft seed was recorded in a diurnal alternating temperature oven (15°/60°C). Residual seed collected at the end of the two regeneration years had a significantly greater number of soft seeds than the seed collected at the end of the sowing year. Both Trikkala and Woogenellup were considered the softest, while Daliak was the hardest.

In the Tamworth region of New South Wales, the sub clover cultivars which produced the most seed had the greatest number of seedlings in the following autumn (Hagon 1973a). When rainfall was reliable the dense swards produced more dry matter in early winter. Reed *et al* . (1985) showed that the hard-seeded early cultivar Daliak and the hard-seeded, early to mid season cultivars Seaton Park and Esperance were the most successful with regard to plant density in early winter. The results from Hagon (1973a) and Reed *et al.* (1985) indicate that high seed yield combined with hard-seededness are essential for good levels of regeneration. However, a common field observation is that soft-seeded cultivars re-establish at higher densities in second-year pastures.

In addition to the role that hard-seededness plays in the persistence of sub clover, physiological seed dormancy may also be important. The work of Gladstones (1987) supported the contention of Taylor (1984) that physiological seed dormancy plays a significant part in the control of the pattern of sub clover germination in field conditions. Gladstones (1987) observed that genotypes which exhibited high dormancy in petri dish tests were also found to be slower by a few days in their emergence when sown under field conditions in Perth, Western Australia.

Taylor (1984, 1985) and Taylor and Ewing (1988), showed that burrs from a range of sub clover cultivars had a decreased rate of seed softening with increased depth of burial in soil. Burrs were left on the soil surface or buried 2, 6, and 10cm deep in the soil. For the hardest seeded cultivar, Nungarin, there was no significant decline in the proportion of hard seed following four years burial at 10cm (Taylor and Ewing 1988). After three years, less than 20% of Nungarin seed on the soil surface remained hard. On the other hand, the cultivar Geraldton had only 5% hard seed remaining after only one year on the surface. Seventy five percent of Geraldton seed remained hard at the depth of 10 cm. While the seed buried at 10cm depth is not expected to emerge, it is hoped that in a crop-pasture rotation sufficient seed can be brought to the surface by tillage prior to the pasture phase. However, it should be remembered that normally there is no tillage after a cropping phase before natural regeneration of sub clover. Burial to a depth of 2 cm was sufficient to reduce the rate of seed softening when compared to surface seed (Taylor 1984). It is also the 2 cm depth at which most burr will be buried during the pasture phase if the soil and weather conditions are favourable. Furthermore, Taylor (1984) found evidence of some microbial decomposition of hard seed in the field. Previously, it was thought that hard seeds were fairly resistant to such microbial attacks. Certainly, at the Waite Institute in Adelaide, there has been substantial loss of both sub clover and medic seeds buried by scarifier in a red brown earth (Carter *et al*. 1987)

Conclusions: Differences in seed yield between sub clover cultivars and the ability of sub clover to bury burrs has been established (e.g. Yates 1961; Barley and England 1970; and Collins 1978). Burr burial and hard-seededness are both important factors which are influenced by environment and genotype. Both ensure the long-term survival of sub clover-based pastures. Burr burial is also important for the protection of seed from grazing animals. Therefore, the ideal sub clover cultivar would bury enough seed to ensure long-term persistence but also yield sufficient seed above-ground to contribute to the summer nutrition of grazing livestock. The influence of grazing on seed production and seed survival is little understood in sub clover-based pastures and requires further examination. Some research on these aspects is addressed in Chapter 4 and 5 of this thesis.

2.6 Seed survival following ingestion by animals

2.6.1 The grazing of dry pasture residues during summer-autumn

The quantity and quality of annual pastures declines markedly during summer when the sward matures and dries off. Increasingly, sheep become dependent on the nutritional value of dry burrs/pods which allow them to maintain body weight (e.g. Wilson and Hindley 1968; Hall 1984). Often sheep are under nourished over the summer/autumn period because of the limitation imposed by the availability and quality of dry pasture residues, although Donald and Allden (1959) found no adverse long-term effects of nutritional stress over summer in young sheep.

The greater dependence of sheep on burrs and seeds over summer means that varietal differences in the production of seeds and their nutritional value can be important. Research has shown that the seed is the most useful nutritional component of dry pasture residues during summer (Franklin and Powning 1942; Vercoe and Pearce 1960; Franklin *et al.*1964; Wilson and Hindley 1968 and Denney *et al.* 1978). Large differences in crude protein and chemical composition exist in the pods of medic species and burrs of sub clover (Franklin and Powning 1942; Hume *et al.* 1968) and liveweight gains of sheep can be affected by the pod/ sand/or burrs ingested from the specified cultivars of legume pastures grazed. Large differences in the crude protein content were found between the *Medicago* species used by Franklin and Powning (1942). *Medicago orbicularis* was found to have a crude protein level for the whole pod of between 27.85% and 31.55%, compared to *M. laciniata* (48.85% and 49.96%). Subterranean clover was much lower with values between 18.21% to 22.55% crude protein in the whole burr.

Nutritionally, small hard seeds ingested by livestock were considered to be less digestible than large seeds (Franklin and Powning 1942). It was found that 57% of the *Trifolium glomeratum* seeds fed were passed intact in the faeces. In conclusion, sheep were unable to digest small seeds in the unground state. However, many pasture researchers (Carter 1980, 1981; Carter and Lake 1985, Carter 1987 and Carter *et al.* 1989) have found that the survival of small hard seed to be beneficial in terms of pasture persistence. The return of some seed via the faeces to grazing systems is an important component of regeneration and is a method of dispersal of both desirable and undesirable species. (See section 2.6.3)

In Australia, much of the research on summer grazing has focused on the nutritional aspects of the consumption of dry pasture residues and seeds. Very little data is available on the fate of seed once ingested by grazing livestock. Wilson and Hindley (1968) took into account the seed component and fed dry tops, seed and the burr of subterranean clover with dry ryegrass to penned sheep. The burr content of the diet was varied and the seed throughput in the faeces measured. On average, 5% of the seed eaten by sheep was passed as whole seed in the faeces. Germination of this seed was found to be 51% which was the same as that of the seed on offer (52%). A field experiment was also undertaken to assess the proportion of clover burrs eaten by oesophageal-fistulated sheep while they grazed dry pasture. Four different types of dry pasture were grazed, viz. i) pure Wimmera ryegrass, ii) pure subterranean clover, iii) a mixture of both ryegrass and subterranean clover, and iv) the mixture of ryegrass and subterranean clover after flowering of subterranean clover was prevented. The nitrogen content (crude protein) of the differrent pasture types was measured. Those pastures containing subterranean clover had more nitrogen content in the diet than grass only. On the mixed ryegrass/sub clover pasture burrs comprised 10.3 percent of the total dietary intake by sheep. Wilson and Hindley (1968) concluded that the pods of pasture legumes can be important as a protein supplement in summer and that dry clover tops can be just as important as the pods as a protein source. However, this would depend on the severity of grazing.

In a study by Squires (1978) the liveweight changes of sheep were related to estimated intake of clover seed over a 60-day period on irrigated pastures at Deniliquin, NSW Sheep lost weight over the period of the experiment: however, the least weight loss was found for intakes of 750g/day clover seed. Sheep which were only fed burr had the slowest decline in liveweight, while sheep fed burr-free residues showed wide fluctuations in weight. In contrast, sheep fed tops and burrs were found to gain weight. The percentage of sub clover burr in the diet of grazing sheep was also studied by Hall (1984) at Wagga Wagga, NSW. The highest percentage of burrs in the diet was found during drought in mid-July and the digestability of the burr was between 45-55%. Energy content rather than nitrogen content is likely to limit animal production when the burr constitutes most of the dietary intake (Hall 1984).

2.6.2 The dissemination of weed seeds via defaecation

Much of the early research on seed survival following ingestion by animals was concerned with weed seeds. Researchers at the beginning of the 20th century recognized the problem of weed seeds in livestock feeds and the viability of those seeds. Much of the research on weed seed survival has provided a valuable insight into the survival of seed from useful pasture species. Hills and Jones (1907) found viable weed seeds in many commercial feed stuffs and expressed concern that the digestive systems of horses and cows were not able to destroy them as well as sheep and poultry. Weed seeds in feed stuffs were seen as a potent source of weed dispersal (Beach 1908). Emphasis of early research was therefore focused on weed seeds and the role of various farm animals in dispersing those seeds (Atkeson *et al* . 1934; Harmon and Keim 1934 and Dore and Raymond 1942).

Harmon and Keim (1934) studied the through-put and the percentage survival of seed from seven different weeds: velvet weed (*Abutilon abutilon L.*) 22.8%, field bindweed (*Convolvulus arvensis L*) 23.1%, white sweet clover (*Melitlotus alba Desv.*) 15.0%, smooth leaf dock (*Rumex acetocella*) 6.2%, annual smartweed (*Polygonum pennsylvanicum L.*) 12.8%, wild rose (*Rosa arkansana*)10.1% and perennial peppergrass (*Lepidium draba*) 9.4%. They were fed to a variety of farm animals, viz:

yearling calves, geldings, wethers, four month old hogs and ten month old cockerels. One thousand seeds of each weed species was fed to the different farm animals and the percentage of seed recovered varied widely according to the different classes of animals. The average (overall mean for weed species) percentage of uninjured seeds recovered from the faeces of various animals was 24.1% (for hogs), 23.1% (calves), 12.9% (horse), 10.7% (sheep) and 0.3% (chickens). It was concluded that the percentage recovery of seed was correlated to the thoroughness of mastication and/or digestion by the different classes of animals. Viability of the the uninjured seed was tested and the overall average was 6.7% from each 1,000 seeds fed to the animals. Survival of seed in the manure of cows and the horse was further examined. After one month burial, only velvet weed, field bindweed, white sweet clover, and pepper grass seeds were viable. The rest of the series of weed species were partially decomposed.

Further studies have examined the survival of weed seeds when stored in manure. Atkeson *et al.* (1934) determined whether or not the spreading of manure over fields caused weed infestations, particularily when feeds contained large amounts of weed seeds. A range of weed seeds, which varied in their size, structure and type of seed coat were fed to cows. Fourty-two hours was required before any substantial amount of seed was passed through, but then seed continued to come through for up to four days following feeding. The main findings were that the soft (permeable) seed had reduced vitality (i.e.viability) following passage through the cows, which was attributed to the penetration of digestive juices into soft seed. It was concluded that in many instances the seed would die when the manure is spread directly on the land. Alfalfa (*Medicago sativa*), one of the species fed, had only a 7% reduction in germination following passage through the digestive tract and storage in manure compared to the original germination test before feeding. Heady (1954) recommended that animals suspected of carrying weed seeds should be held on a weed-free diets for at least 72 hours. From the results of his experiments, Heady concluded that sheep and deer had aided the spread of both desirable and undesirable plants onto the rangelands of California. Ozer (1979) also found that seed from 10 different species had varying levels of survival immediately after defaecation and after three months storage in sheep dung heaps. The species *Vicia sativa*, *Hordeum nodosum* and *Onybrychis sativa* were totally destroyed. The germination potential of the other seven species was as follows: *Coronilla varia* (6.8%), *Lotus corniculatus* (6.1%), *Trifolium repens* (5.1%), *Phleum pratense* (4.9%), *Medicago sativa* (4.6%), *Agrostis alba* (3.2%) and *Stipa viridula* (1.1%).

The spread of noxious weeds, especially the small-seeded weed species, via livestock is of concern in Australia. The dispersal of *Echium plantagineum* by sheep was studied extensively (Piggin 1978). Seed of this species were placed directly in the rumen of fistulated sheep and 50% survived. Approximately 120 seeds/sheep/day passed through the sheep most seed being defaecated in 30 days. Germination of the seed when defaecated within 24 hours of ingestion had similar levels to that of seed before feeding (40%). However, if the seed took longer than 24 hours to be defaecated the germination percentage dropped rapidly to 10%. This was attributed to high temperatures rather than digestion in the alimentary tract. Clearly enough of the weed seed survived passage through sheep and was deposited in the faecal pellets to contribute to its widespread occurrence in Australia.

Variability between sheep was also noted by Piggin (1978). The number of seeds passed varied considerably between sheep (41 - 275 seeds/day) and between days for any one sheep. This is probably due to sheep size; large sheep tended to eat more fodder and seed, and therefore pass more faeces and seed than small sheep. Other research has found that large differences exist between animals in experiments of this kind (Suckling 1950,1952; Powell and Mapes 1955; Carter 1980, 1981; and Leonard 1986).

The passage of seed through grazing sheep was also studied by Piggin (1978). Germination was found to be much lower when compared to the fistulated sheep (1 to 2% from an initial level of 30% prior to feeding). Nevertheless, it is clear that the movement of stock contaminated with the weed seed should be controlled both within and between farm districts, since most germinable seed is passed within three days of ingestion. Holding yards which can be carefully watched could restrict the spread of *E. plantagineum.* and many other weeds.

2.6.3 The dissemination of seed from pasture plants via defaecation

The benefits of dispersal of seed from pasture species defaecated by grazing livestock has been recognized as important for the persistence of pasture species (Suckling 1950,1952; Powell and Mapes 1955 and Vercoe and Pearce 1960). Cattle especially have been used in the dispersal of pasture seeds. Dore and Raymond (1942) found that a single cow could defaecate approximately 900,000 seeds of *Trifolium repens* in a grazing season. The reason given for the high levels of seed survival of *T. repens* is the high levels of hard seed, coupled with small seed size. Seeds were able to avoid or escape injury during mastication and pass through the digestive tract of the cows.

Suckling (1950,1952) studied in detail the ingestion of white clover (*Trifolium repens*) seed by sheep and the impact of this on the persistence of that species in New Zealand. Unscarified seed fed to sheep while grazing a pure grass sward was found to pass through sheep better than scarified seed (29% and 3.7% recovered seed respectively), which confirms the earlier work of Atkeson *et al* . (1934). Suckling (1952) fed seed to sheep using gelatine capsules with the aim to minimize chewing damage. A large percentage of hard seed was destroyed: of the 90% (impermeable) seed fed only 29% hard seed survived. However, the survival rate of hard seed is much greater than that of soft (permeable) seed. Scarified seed containing 98% soft seed prior to feeding, was all destroyed on passage through sheep. Three of the four sheep had no trace of seed in their dung after six days following ingestion. One sheep was killed (this sheep had traces of seed at six days) and the digestive tract dissected to see whether seed still remained within the digestive tract. Considerable amounts of hard seed was found in the folds of the omasum. Thus, he concluded that some seed can be excreted with the faeces for a long time following ingestion.

The fate of white clover seed when grazed *in situ* was also considered by Suckling (1950, 1952). Two sheep grazed white clover pasture with predetermined availabilities of both mature and immature flowering heads. From the first sheep only 4.3% of the available seed was recovered (3.3% hard, 1% swollen and discoloured). From the second sheep, 0.76% of the seed available in the feed was recovered (0.65% hard, 0.11% swollen and discoloured). Germination and seedling appearance from faecal samples in the field was also monitored. Suckling (1950, 1952) concluded that (i) it may be possible to graze white clover pasture with high quantities of ripe flowering heads with a large flock of sheep and to introduce the flock onto areas in the hill country of New Zealand to increase the population of white clover and (ii) the hard (impermeable) seed which is passed through the animal and has staggered germination over a long period, may be important for upgrading established sown pastures where it is an advantage for seed to germinate over an extended period rather than on the first occasion when temperature and moisture conditions appear to be favourable.

Powell and Mapes (1955), also investigated the survival of seeds from various pasture plants with the objective of finding appropiate species for disseminating seed via defaecating livestock. Sub clover (*Trifolium subterraneum*), rose clover (*Trifolium. hirtum*), crimson clover (*T. incarnatum*), burr medic (*Medicago polymorpha*), tall fescue (*Festuca arundinacea*), harding grass (*Phalaris tuberosa* var. stenoptera), veldt grass (*Ehrharta spp.*) and smilo (*Oryzopsis miliacea*) were fed to 4 steers. Percentage recovery of viable seed was 12.5%, 25.0%, 17.7%, 1.0%, 1.5%, 0.6% and 72.0% respectively. High quantities of hard seed were found in faeces for rose and crimsom clovers and it was concluded that viable hard seed could pass through the animal. For the purpose of the dissemination of seed via livestock, both smilo and rose clover were considered the only economical species due to seed costs and high survival following ingestion by steers. Furthermore, seed dispersed via livestock in this manner should only be considered if the land is not suitable for the use of machinery and aerial sowing by plane is too costly.

The survival of a variety of different seeds fed to dairy cows was studied by Yamada and Kawaguchi (1972). They fed seeds from ladino clover (*Trifolium repens*), sub clover, Italian ryegrass (*Lolium italicum*), orchard grass (*Dactylis glomerata*) and Bahiagrass (*Paspalum notatum*) to two Holstein heifers. The highest percentage recovery of seed was found for Bahiagrass, followed by Italian ryegrass and sub clover. Orchardgrass and Ladino clover had the lowest percentage recovery. Furthermore, the number of seedlings emerging from faeces was also examined. Italian ryegrass had the highest number of seedlings to emerge from 1kg of faeces; sub clover, orchardgrass and bahiagrass were the lowest, while Ladino was intermediate. Yamada and Kawaguchi concluded that Italian ryegrass and Ladino clover could be disseminated by dairy cows.

For seed to pass intact through the digestive tract of animals, it has to survive the initial mastication which physically breaks down seeds. In the case of ruminants, this may also include regurgitation and further mastication. Hence, large seeds are more prone to crushing damage by chewing. The large seeds from both snail medic (*Medicago scutellata*) and the gama medic (*M. rugosa*) cv. Paragosa had the lowest survival of seed following passage through sheep, compared to the smaller-seeded species Jemalong (*M. truncatula*), Harbinger (*M. littoralis*) and Tornafield (*M. tornata*) (Jenkins 1978). In general the survival of medic species was low, ranging from 1.7% (snail medic) to 6.3% for Tornafield. Any seed which survives the first stage of mastication, has to undergo further influences from the digestive tract, such as chemical breakdown and enzymic activity, all of which, if the seed coat is weakened, predisposes it to heat damage. Once the seed is passed out in the faeces, survival of seed will depend on how well it can resist fermentation in the manure.

The importance of the survival of seed from useful pasture species following ingestion by grazing livestock, and the influences this may have on the regeneration capacity of pastures, was not given much attention in Australia until recent times (Carter 1976, 1980, 1981; Carter and Lake 1985; Jones and Simao Neto 1987 and Simao Neto and Jones 1987).

An intensive experiment was undertaken at the Waite Agricultural Research Institute, South Australia on hard-setting red brown earth by Carter (1981), to quantify and qualify the influence of sheep grazing *Medicago truncatula* pasture during the summer-autumn months. Highly significant linear decreases were found to occur for the total pasture (r = -0.999), medic pods (r = -0.992) and medic herbage (r = -0.997) during the 56 days of grazing. Extraction of medic seed from faeces showed a dramatic decline in the seed throughput (6,155 - 3,251 viable seeds/sheep/day). Not only was there a progressive decrease in the number of viable seeds left on the soil surface (23,715/m^2 on day 0 to 2,652/m^2 on day 56) but the sheep selected the largest pods first which contained the most seed and the heaviest seeds, leaving progressively smaller pods and smaller seeds. These surviving small seeds may be regarded as ecologically-less-fit in a crop pasture rotation (Carter *et al.* 1988). The experiment showed that sheep were very efficient at harvesting medic pods on hard-setting soils and thereby seriously depleting the seed reserves of medic pastures during summer and autumn. Depletion of seed reserves results in poor seedling density at the break of the season. In addition, low seed reserves are insufficient for regeneration following a cropping sequence.

The impact of seed size and degree of hard-seededness on seed survival has been studied by Carter (1977, 1980) and Carter *et al.* (1988, 1989). Recent studies conducted by ICARDA in Aleppo, Syria (Thomson *et al.* 1987) compared the harder-seeded ICARDA medic lines with the Australian cultivars. The annual clovers *Trifolium campestre* and *T. tomentosum* were fed to Awassi sheep. The objective was to identify medics with good survival following ingestion by sheep, in order to reduce the impact of overgrazing. Seed size accounted for 80% of the survival of seed (i.e. smaller seeds survived better): however, smaller seeds increase the difficulties associated with establishment in prepared seed beds (Carter and Challis 1987). In addition, the sheep may be used as a means for seed dispersal seed onto marginal lands and into cereal stubbles. More recently, Cocks (1988) reported an experiment in which ewes grazed dry medic residues over the summer in Syria. Sheep were grazed at three stocking densities (5.3, 10.7, and 16.0 sheep/ha). These sheep were found to gain weight from grazing dry medic residues, although there was no further liveweight increase for sheep grazed at the highest level. Furthermore, the day on which pods ceased to disappear also coincided with the day liveweights began to fall. Sheep were found to gain weight as long as the pod availability exceeded 10 kg/ha. However, the level of pod needed for the persistence of pasture is considerably higher than 10kg/ha and cannot be related to the condition of the ewes.

Survival of the seed from pasture legume species following ingestion by animals was beginning to emerge as highly important in Australia following the research by

Carter (1980, 1981). The need to test important tropical legume and grass species had finally gained recognition (Simao Neto *et al* 1987; Jones and Simao Neto 1987). Some new cultivars of legumes such as *Medicago murex* were found to have very poor survival (in some cases 0%) while *Trifolium balansae* cv. Paradana had approximately 40% survival following ingestion by sheep (Leonard 1986; Carter 1987; Carter *et al.* 1988; Carter *et al.*1989). The high survival of *T. balansae* was attributed to it having small, hard seeds. Similarly, short seed length was found to be a factor influencing the high recovery of seed from tropical pasture species (Simao Neto *et al.* 1987) Simao Neto and Jones (1987) tested a range of grasses and legumes (Simao Neto *et al.* 1987) that were divided into three categories according to the amount of hard seed present: a mixture of hard and soft seed, 100% soft seed, and 100% hard seed. To avoid the effects of mastication, the seeds were suspended in nylon bags in the rumen of cattle (*in sacco*) or subjected to *in vitro* tests. All soft legume seed were destroyed. The percentage hard seed in the seed sample before feeding was the best indicator of the level of survival from ingested seed.

Jones and Simao Neto (1987) also examined the relationship between the amount of seed in the diet and the quality of the diet and the subsequent effects on seed recovery from sheep. Basal diets of three different qualities, low (45%), medium (60%) and high digestibility (70%) were fed to penned sheep. Both the percentage seed recovery and viability of seed recovered was unaffected by the amount of seed fed. In contrast, Thomson *et al.* (1987) found that feeding equal seed number compared to equal pod mass, always gave higher seed survival. However, quality of the diet was found to affect the percentage recovery of seed (Jones and Simao Neto 1987). The low quality diet had the lowest survival of seed found in faeces (10% of the total seed ingested) whereas there was 28% recovery of ingested seed found for the medium and high quality diets. In conclusion, Jones and Simao Neto (1987) suggested that if animals are to be used for the dissemination of pasture seed it is important to have a high quality diet and a high proportion of small, hard legume seed.

Although, it is desirable for weed seeds to be destroyed by fermentation in faeces, it is important for useful pasture species to be able to survive in faeces for extended periods. Suckling (1950) made the assumption that only the hard seed would be able to withstand fermentation of faeces and retain its viability. Most of the seed in the faeces remained in the soil in a viable but dormant state long after the faeces had decomposed. Furthermore, most of the permeable seed is destroyed by mastication and digestion and the soft seed that is found in the faeces doesn't appear to survive the period of fermentation or it is desiccated. Similarly, Simao Neto and Jones (1986) found that hard-seeded tropical pasture legume seeds were resistant to storage in cattle faeces and there was good emergence of legume seedlings from faeces (Simao Neto *et al.* 1987).

Conclusions: Few studies have attempted to examine the impact of grazing sheep on the survival of sub clover seed once ingested although many studies have been conducted in pen feeding facilities. Furthermore, the survival of sub clover seed within faecal pellets has not been examined in the Mediterranean-type environment of southern Australia. Although the emergence of medic from faecal pellets has been studied during the period 1976 - 1989 (Carter 1976 *et seq.*). Some studies which considered survival of seed in faecal pellets have been conducted in favourable well watered conditions using white clover or tropical species (eg. Suckling 1950; Simao Neto and Jones 1986). However, the likelihood that sub clover seed deposited in faecal pellets is a significant source of seed for regeneration has received scant attention in Australia. Because sub clover can bury some seed in the soil surface the impact of summer-autumn grazing on seed survival is frequently less severe than with *Medicago* species which do not bury seed. These matters will be discussed further in Chapter 5 of this thesis.

3

SMALL-PLOT EXPERIMENT 1985

The effects of sowing rate and time of sowing on the growth and seed production of four cultivars of sub clover.

3. SMALL-PLOT EXPERIMENT 1985 - The effects of sowing rate and time of sowing on the growth and seed production of four cultivars of sub clover

3.0 Introduction

Herbage production in winter and seed yield of a pasture can influence the year-round livestock carrying capacity of a sub clover-based pasture. Therefore the main objectives of this experiment were: (i) To examine the early productivity and competitiveness of new and old cultivars in response to density and sowing time. The decision was made to neither defoliate nor control weeds, thus giving the opportunity to examine early productivity and ability of cultivars to control weeds. (ii) To examine the interrelations of sowing rate and resultant plant density on early productivity (i.e. looking for optimum densities to ensure maximum early production). (iii) To examine seed production and natural regeneration in 1986.

Early winter production is dependent on plant density (Donald 1954; Black 1957; Hagon 1973a; Wolfe 1981). It has been suggested that seed size can effect early growth (Black 1957), but Lawson and Rossiter (1958) came to the general conclusion that seed size had no effect on growth rate of a sub clover sward provided that sowing rate was held constant and was based on pure germinating seed.

Time of sowing is important because it can affect the herbage and seed yield of cultivars of differing maturities (Morley 1961; Rossiter 1966). More recently Dear and Loveland (1984) found differences between cultivars that were sown in early autumn but no differences at later sowing times. Also seedling growth at different densities is little understood when sown at different times (Silsbury and Fukai 1977). Time of sowing is only important in the year of establishment.

There has been some controversy over observed differences in the winter production of sub clover cultivars (Rossiter and Collins 1980; Wolfe 1982).

Nevertheless, since the early 1950's farmers and research workers have observed that the early growth of some cultivars of sub clover is more vigorous, especially during the winter months (Carter 1953; 1954; Anon. 1955). For example, the winter vigour and erect growth habit of both cv. Yarloop and cv. Clare have been recommended for controlling weeds such as *Oxalis pes-caprae* (Higgs 1958). More recently, de Koning (1984) and de Koning and Carter (1987 a,b) have shown the superior winter production of Clare and Yarloop sub clover in comparison to the cultivars Mt. Barker, Trikkala and Larisa.

It is important that the ecology of cultivars be examined as well as their potential productivity assessed because high herbage production may not necessarily be an advantage in terms of seed production. The two may be antagonistic because excessive shading has been shown to reduce seed yield (Collins *et al* 1978; Dunlop 1985).

3.1 Materials and methods

Location and preparation of site: The experiment was conducted at the Waite Agricultural Research Institute (hereafter W.A.R.I.) Adelaide, South Australia. The average annual rainfall is 625mm and the soil type a hard-setting, red-brown earth (Urrbrae loam). The site was cultivated with a rotary hoe April 29, 1985 and sprayed with Sprayseed® (Paraquat 175g/l + diquat 75g/l) May 17, 1985. Prior to sowing the area was harrowed, to give a fine seed bed.

Treatments and experimental design: Four cultivars (Clare, Esperance, Trikkala and Yarloop) were selected to give a range of characteristics such as maturity grading, growth habit, reputed winter growth (General Introduction, Table 1.1). These cultivars are suited to the environment at the W.A.R.I. Each cultivar was sown at 1, 4, 16, 64, 256, and 1024 kg/ha (based on pure germinating seed). This range represents the widely varying levels of seed found in field situations. The two highest sowing rates are representative of soft seed levels which can occur in good stands of subterranean clover.

To heighten any contrast in the winter growth between cultivars, two sowing times were used viz: May 17 = (Early) and June 7 = (Late). The experiment was of split-plot design for sowing time with sowing rate and cultivar randomized within each sowing time. A summary of the experimental design is as follows:

Cultivars (4) x Sowing Rates kg/ha (6) x Sowing Times (2) x Blocks (3) = 144 plots.

Each block (see diagram 3.1) was split into an Early- and a Late-sown half. The four cultivars at six sowing rates (i.e. = 24 treatments) were randomized within the areas allocated to each sowing date (See Diag. 3.2). Each plot measured 2.5 x 5.0 metres. Seed was weighed out for each cultivar (1.25, 5, 20, 80, 320 and 1,280 g pure germinating seed/plot respectively) which represented the range of sowing rates 1, 4, 16, 64, 256, and 1024 kg/ha respectively.

The weighed seed was wet-inoculated with Rhizobium type C in a peat slurry and allowed to dry. At sowing time the appropiate seed was placed in a large screw-top glass jar with slightly moistened sand. Single superphosphate equivalent to a rate of 100kg/ha (120g per plot) was added last to the jar. The seed, sand and superphosphate were then mixed thoroughly. The plots were lightly raked prior to hand-broadcasting with the mixture, and again following sowing to ensure good coverage of the seed.

DATA COLLECTION

Emergence counts of sub clover (plants/m^2) were made for the early-sown treatments from May 29 to May 31, counting one block per day. Two quadrats (25 x 40 cm) per plot were used to count plant numbers. Plant numbers were counted for the late-sown treatments on July 4.

Harvests: The plots were sampled six times throughout the growing season: Harvest 1 on June 12; Harvest 2 on July 3; Harvest 3 on July 31; Harvest 4 on August 28; Harvest 5 on September 25; and Harvest 6 on October 24, 1985. Only early-sown plots were harvested at Harvest 1, since late-sown plots had not emerged at this stage.

Quadrats were placed on plots shortly after the emergence of early-sown treatments. Sixteen galvanised wire quadrats (25 x 40 cm) were arranged on each treatment plot. The plots were divided into east and west sections (ie. 8 quadrats per half), and harvests were randomized among the eight quadrats (six of these quadrats were used for the herbage harvests). Harvest 1, corresponded with quadrat position 1 and so on. Quadrat position 7 was used for the seed harvest and quadrat 8 was used for the regeneration counts in the following year (1986). In brief, on each harvest occasion two quadrats were taken per plot, one from the eastern half and one from the western half of the plots.

Measurements: Each sub clover plant was cut to just below ground level so that plants could be counted. For the two highest densities a subsample of 50 plants was removed from the centre of the quadrat and this was used to calculate total plant numbers. All herbage samples were dried at 85^{o}C for 24 hours in a forced-draught dehydrator.

Other measurements made at each harvest occasion included total herbage yield of sub clover and yield of the weeds.

<u>Seed harvest:</u> A seed harvest was made on January 8 and 9, 1986 using an infiltrometer ring (28cm diam. i.e. 15.35/m^2) to define the sample area. An east and a west sample were taken on each plot. The above- and below-ground (3cm deep) soil/seed samples were bagged separately. A stiff, fibre hand broom was used to collect the above-ground samples and a rabbiting hoe was used to dig up the below-ground sample. The infiltrometer rings were placed in the randomised position of the seventh quadrat. The samples were oven dried at 40^{o}C in a forced-draught dehydrator for 24 hours. Below-ground samples were then wet-sieved through a square-holed, 1mm sieve to retrieve intact burrs and any loose seed: these samples were then returned to the dehydrator for drying at 40^{o}C for 24 hours. Surface samples were processed by carefully removing the burrs by hand from the dry pasture residues. In addition, thirty infiltrometer ring samples were taken in the pathways of the experiment to assess the amount of contamination from other sub clover cultivars, the seed of which was present as hard seed in the below-ground samples.

Yield components measured from the seed harvest were: individual burr weight (mg/burr), % hard seed, % soft seed (permeable, readily germinable), % dormant seed (permeable, swollen seed but no germination), total seed weight (kg/ha), and mean seed weight (mg/seed).

Regeneration of the sub clover cultivars on this field site was examined in autumn 1986. Sub clover seedlings were counted by using the eighth random quadrat position (east and west) in each of the plots. Pathway counts (30 quadrats each, 40 x 25 cm) were also made to measure the contamination of previously resident sub clover on the experiment site.

<u>Germination tests of seed in burrs:</u> Burr germination tests were conducted on intact burrs. Burrs were taken at random from Block 1 samples (statistical analysis showed no significant differences between Blocks for all parameters). Twenty five burrs were placed in Petri dishes with three pieces of filter paper (Whatman ® qualitative no.1) on the bottom and one piece on the top of the burrs. Each treatment was replicated 4 times

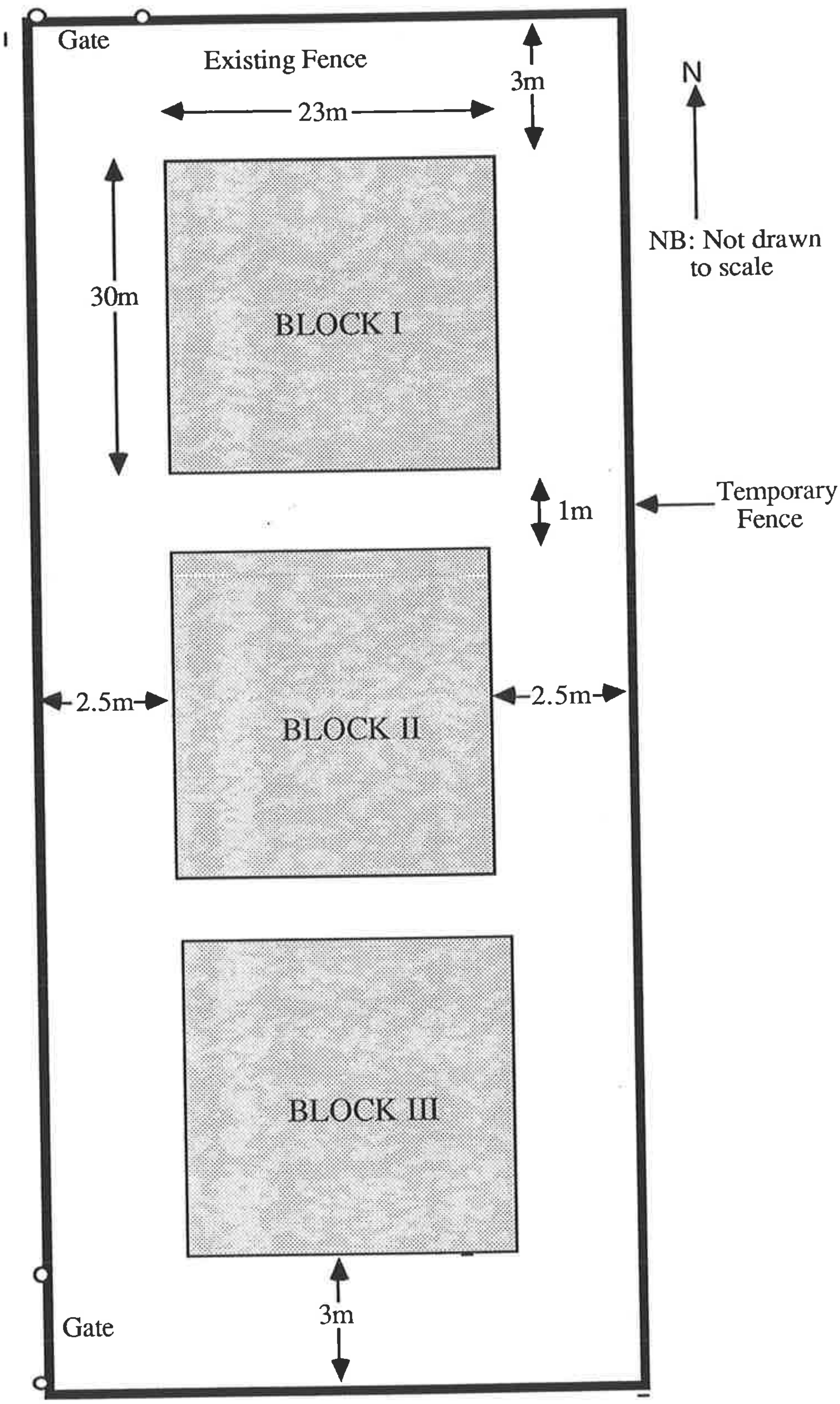
except with the lowest sowing rate, when only 2 replicates were possible. Ten ml of distilled water containing 1.6g/litre of the fungicide Thiram was added to each dish. Germination tests were of 14 days duration in a humidified incubator at 19^oC. The burrs were dissected to determine the proportion of hard and dormant seed after 14 days, oven-dried at 40^oC and the hard seed threshed out and counted. It was found that dormant seed was crushed by threshing, therefore, the proportion of dormant seed content was determined by the amount of seed unaccounted for after the germinated and hard seed were counted. The total number of seeds per Petri dish was known from prior dissections of intact burrs.

Data Analysis

Analyses of variance (Genstat IV format) were conducted on all data for the parameters sub clover numbers (plants/m^2), sub clover yield (kgDM/ha) and weed yield (kgDM/ha). Natural logarithm transformations were made where the data was not homogeneous. An overall analysis was made at each harvest occasion so that Sowing Rate and Sowing Rate x Cultivar interactions could be detected. Each sowing rate was analysed separately so that cultivar differences within a sowing rate could be detected.

Analyses of variance were made on log-transformed data for seed yield. In addition, because of missing values (missing samples were those removed for burr germination tests) the remaining seed samples were not analysed separately for each sowing rate. Analyses were made using the GLIM statistics programe. GLIM can handle uneven replicates and missing values. The other yield parameters, seed number/m^2 and individual seed weight were not analysed separately for each sowing rate for the same reason. Hence least significant differences were not calculated for each sowing rate but Cultivar x Sowing Rate interactions could be found. Germination data from seeds in burr were arcsine-transformed and GLIM was used for the analyses of variance.

Diagram 3.1: Block orientation and size within the allocated field site.



Total area = 28 x 98m

Diagram 3.2: The random allocation of treatments to the blocks.

1.	Yarloop	1 kg/ha	13.	Esperance	1 kg/ha
2.	"	4 "	14.	"	4 "
3.	"	16 "	15.	"	16 "
4.	"	64 "	16.	"	64 "
5.	"	256 "	17.	"	256 "
6.	"	1024 "	18.	"	1024 "
7.	Trikkala	1 kg/ha	19.	Clare	1 kg/ha
8.	"	4 "	20.	"	4 "
9.	"	16 "	21.	"	16 "
10.	"	64 "	22.	"	64 "
11.	"	256 "	23.	"	256 "
12.	"	1024 "	24.	"	1024 "

N

BLOCK I

Late Sown

8	22
21	3
18	5
2	9
17	6
16	23
10	1
11	24
14	4
20	15
7	12
13	19

Early Sown

19	5
9	8
23	15
2	18
14	1
16	10
7	4
24	21
20	3
22	6
13	12
17	11

BLOCK II

Early Sown

7	19
17	22
15	3
6	24
11	21
9	20
23	13
14	12
16	1
8	2
5	4
18	10

Late Sown

24	1
22	21
5	12
13	9
2	7
17	6
14	4
18	23
15	11
19	20
10	3
8	16

BLOCK III

Late Sown

5	9
1	12
24	6
16	15
3	20
13	18
21	17
10	2
23	19
8	4
11	22
14	7

Early Sown

15	2
4	19
13	1
5	21
8	11
24	22
17	20
16	12
23	9
14	3
7	6
18	10

3.2 HERBAGE HARVEST RESULTS 1985

Descriptions of the results summarise the main effects such as Sowing Time, Sowing Rate and Cultivar. First order interactions such as Sowing Time x Cultivar are described if they are significant. Tables in Appendix A contain the actual values which have been used for the figures. There is an appendix table for each parameter for the herbage harvests and seed harvest. Mean monthly minimum and maximum temperatures also rainfall are presented in Table 1a for the 1985 growing season.

Table 3.0: Maximum and minimum air temperatures, and rainfall during the period of the 1985 field experiment at the Waite Agricultural Research Institute.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Air Temperatures												
Max. °C	28.1	27.9	27.0	22.4	18.1	14.8	14.8	15.0	16.6	20.7	23.0	23.3
Min. °C	16.1	16.6	17.0	13.8	11.1	9.0	8.9	9.0	8.9	12.1	13.6	13.9
Rainfall (mm)	1.6	3.2	49.4	55.6	100.2	65.2	58.6	94.0	71.6	37.8	27.4	59.6

3.2.1 Sub clover plant population

The number of sub clover plants (#/m^2) varied according to the sowing rate and cultivar. The mean seed weights of Yarloop, Trikkala and Clare were 9.3, 8.2, and 11.1 mg respectively, hence plant numbers were similar for these cultivars. However, Esperance had considerably smaller seed (4.5mg), thus on the basis of equal weight of pure germinable seed many more seeds were sown resulting in higher populations of seedlings than the other cultivars.

Sowing Time: For each harvest occasion, the effect of time of sowing on plants/m^2 was mostly found to be non significant (Table 3.1). The only Sowing Time x Cultivar and Sowing Time x Cultivar x Sowing Rate interactions found to be significant were at Harvest 2.(Table 3.1, Appendix A Table A.1). These interactions are not considered important because they only ocurred at Harvest 2 and the main effect Sowing Time was not significant.

Table 3.1: Summary of Analyses of Variance for sub clover plant number. (Based on natural logarithms).

Harvests	H1	H2	H3	H4	H5
Treatments					
Sowing Time (ST)	-	n.s.	n.s.	n.s.	n.s.
Cultivar (Cv)	P<0.05	P<0.001	P<0.001	P<0.001	P<0.01
Sowing Rate (SoR)	P<0.001	P<0.001	P<0.001	P<0.001	P<0.001
ST x Cv	-	P<0.01	n.s.	n.s.	n.s.
ST x SoR	-	n.s.	n.s.	n.s.	n.s.
Cv x SoR	n.s.	n.s.	P<0.01	P<0.01	P<0.01
ST x Cv x SoR	-	P<0.01	n.s.	n.s.	n.s.
Coeff. of Var.%	12.8	18.3	16.5	19.3	16.1

Cultivar and Sowing rate effects: Analysis was made on each sowing rate separately so that cultivar differences at each sowing rate could be clearly seen. Differences between cultivars are summarised in Figure 3.1. and in the Appendix Tables A.2 and A.3. Table A.2 shows the actual values used for Figure 3.1. Differences between cultivars were significant throughout the growing season (Table 3.1). The significant cultivar effect was due to the cultivar Esperance which had the greatest number of plants at most harvests, but also had the greatest reduction in plant numbers as time progressed, particularly at the higher sowing rates.

Sowing Rate was highly significant throughout the growing season and from Harvest 3 to Harvest 5 Sowing Rate x Cultivar was significant (Table 3.2, Appendix A.4). Esperance and Clare always had the greatest plant numbers at the lowest sowing rate. Differences between cultivars were not so great at 1024 kg/ha and this can probably be attributed to plant losses due to intense competition at the highest sowing rate. At low sowing rates there is an increase in plant number toward the end of the season (Fig. 3.1). At intermediate rates there was little change. Increases seen at the low sowing rates could be due to delayed emergence of sub clover or merely variability of sampling.

Figure 3.1: The sub clover plant densities of four cultivars sown at six sowing rates.

Legend:
- ⊡ Yarloop
- ◆ Trikkala
- ◘ Esperance
- o Clare

Vertical bars show LSD (5%)

+ See Appendix A, Table A.3

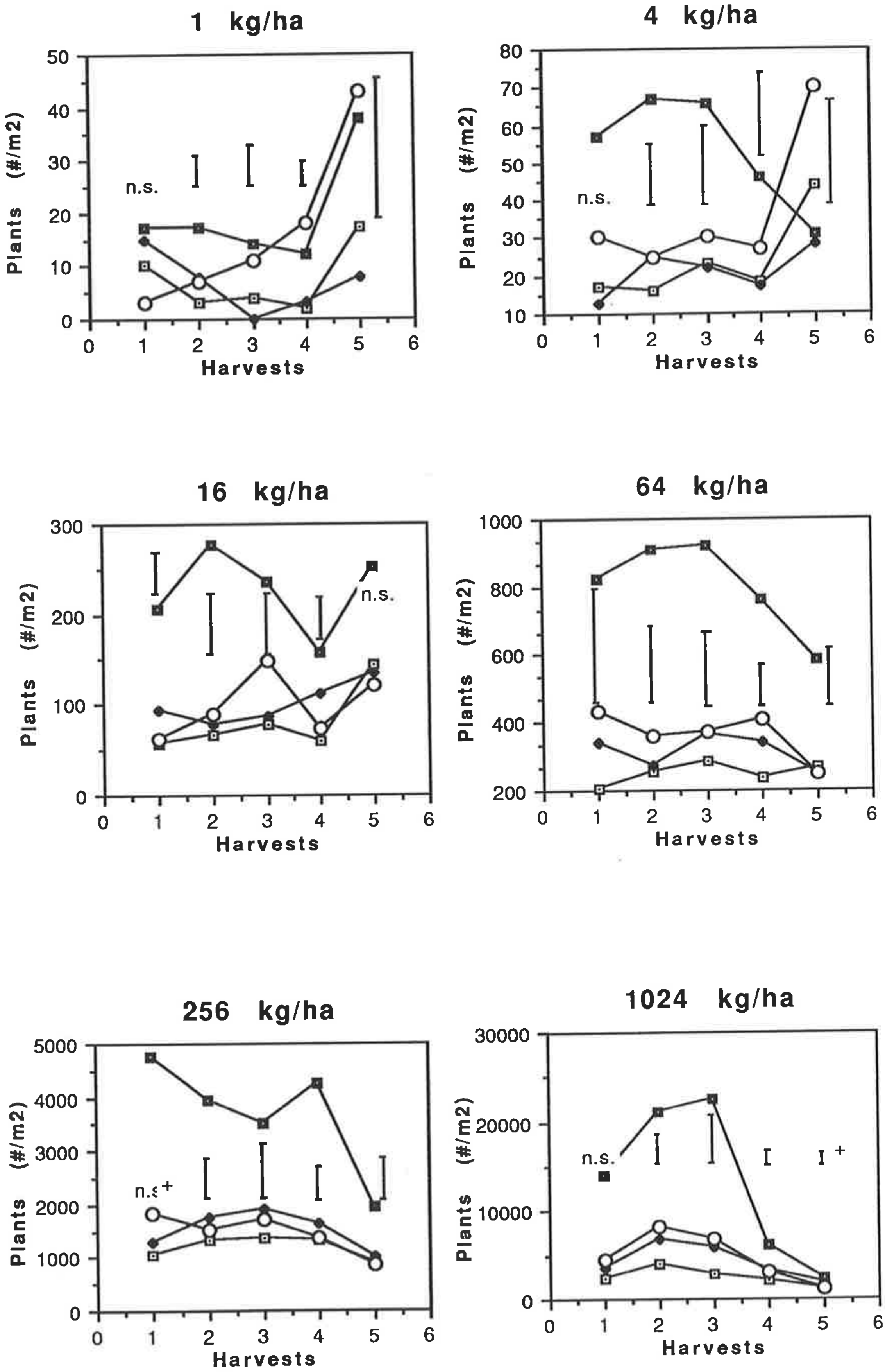

1 kg/ha
Plants (#/m2)
Harvests
n.s.
4 kg/ha
Plants (#/m2)
Harvests
n.s.
16 kg/ha
Plants (#/m2)
Harvests
n.s.
64 kg/ha
Plants (#/m2)
Harvests
256 kg/ha
Plants (#/m2)
Harvests
n.s.+
1024 kg/ha
Plants (#/m2)
Harvests
n.s.
+

Table 3.2: The relationship between plant number (y) and sowing rate (x) for the four cultivars at Harvests 1, 3 and 6. ($Y = a + bx + cx^2$)

	a	b	c	r	Probability
Harvest 1					
Yarloop	119.0	-304.5	87.0	0.995	P<0.01
Trikkala	226.0	-523.9	139.2	0.988	P<0.05
Esperance	909.2	-2199.5	568.9	0.988	P<0.01
Clare	243.4	-635.1	176.7	0.993	P<0.01
Harvest 3					
Yarloop	131.1	-360.9	107.6	0.995	P<0.01
Trikkala	385.5	-935.5	241.0	0.987	P<0.05
Esperance	1947.8	-4198.3	974.1	0.967	P<0.05
Clare	519.8	-1155.8	284.4	0.979	P<0.05
Harvest 6					
Yarloop	15.1	-34.6	29.9	0.989	P<0.01
Trikkala	64.5	-170.3	60.8	0.996	P<0.01
Esperance	10.9	-82.7	65.7	0.990	P<0.01
Clare	61.1	-77.9	35.7	0.993	P<0.01

3.2.2 Herbage production

a) Sub clover

Sowing time: The effect of time of sowing was significant for Harvest 2 only (Table 3.3). The Sowing Time x Cultivar and Sowing Time x Cultivar x Sowing Rate interactions at Harvest 2 were also significant for some sowing rates (Appendix Table A.5). Late-sown treatments generally showed a marked reduction in yield, but Yarloop and Trikkala were the least affected by late sowing whereas the herbage production of Esperance and Clare was significantly reduced. When sown late, there were very few differences between cultivars. In most situations when Sowing Time x Cultivar was significant this was due to Clare having the highest yield when sown early.

Table 3.3: Summary of Analyses of Variance for the yield parameter Sub clover herbage.

Harvests	H1	H2	H3	H4	H5	H6
Treatments						
Sowing Time (ST)	-	P<0.05	n.s.	n.s.	n.s.	n.s.
Cultivar (Cv)	P<0.05	P<0.001	P<0.001	P<0.01	P<0.001	P<0.05
Sowing Rate (SoR)	P<0.001	P<0.001	P<0.001	P<0.001	P<0.001	P<0.001
ST x Cv	-	P<0.05	n.s.	n.s.	n.s.	n.s.
ST x SoR	-	n.s.	n.s.	n.s.	n.s.	n.s.
Cv x SoR	n.s.	n.s.	P<0.01	P<0.05	P<0.001	n.s.
ST x Cv x SoR	-	P<0.05	n.s.	n.s.	n.s.	n.s.
Coeff. of Var. %	20.1	19.0	20.5	24.9	15.9	13.3

Cultivar and sowing rate effects: Sowing Rate was highly significant at each harvest (Table 3.3). The sub clover production at the highest sowing rate had a linear increase for all cultivars except Esperance (Fig. 3.2). The lowest sowing rates never obtained the same level of production as the highest sowing rate. Sowing Rate x Cultivar interactions were evident for Harvests 3 to 5 (Appendix Table A.7). At Harvest 3, the sowing rate 1024 kg/ha was superior in yield to the other sowing rates but only for the cultivars Esperance and Clare. At Harvest 5 there was very little difference between the sowing rates 64 to 1024 kg/ha for all the cultivars. Esperance would account for much of the Cultivar x Sowing Rate interaction.

Table 3.4 shows the relationship between plant density and sub clover production at Harvests 1, 3 and 6. At harvest 1 and 3 the cultivars Yarloop, Trikkala and Clare required less seedlings to achieve similar production to that of Esperance which had the most seedlings. Also at harvest 1 and 3 there was no optimum seedling density. By Harvest 5 optimal plant densities were reached for the cultivars Trikkala, Esperance and Clare (1,500 - 2,000 plants/m^2 for Esperance and Trikkala and approximately 1,200 for Clare). Yarloop had not reached an optimum plant density.

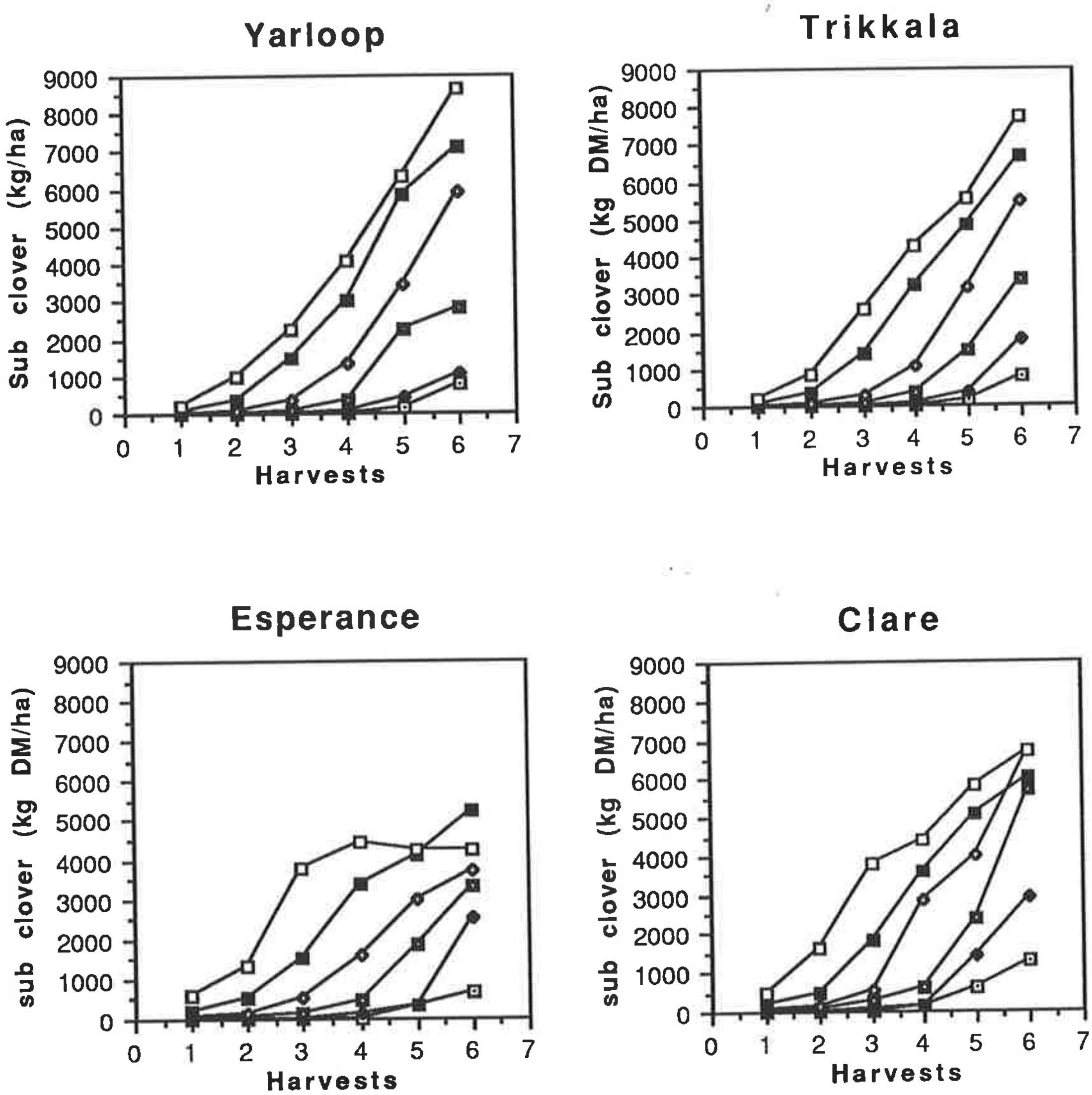


Figure 3.2: Yields of sub clover cultivars at six sowing rates in the small-plot experiment, 1985 (Mean of two sowing times).

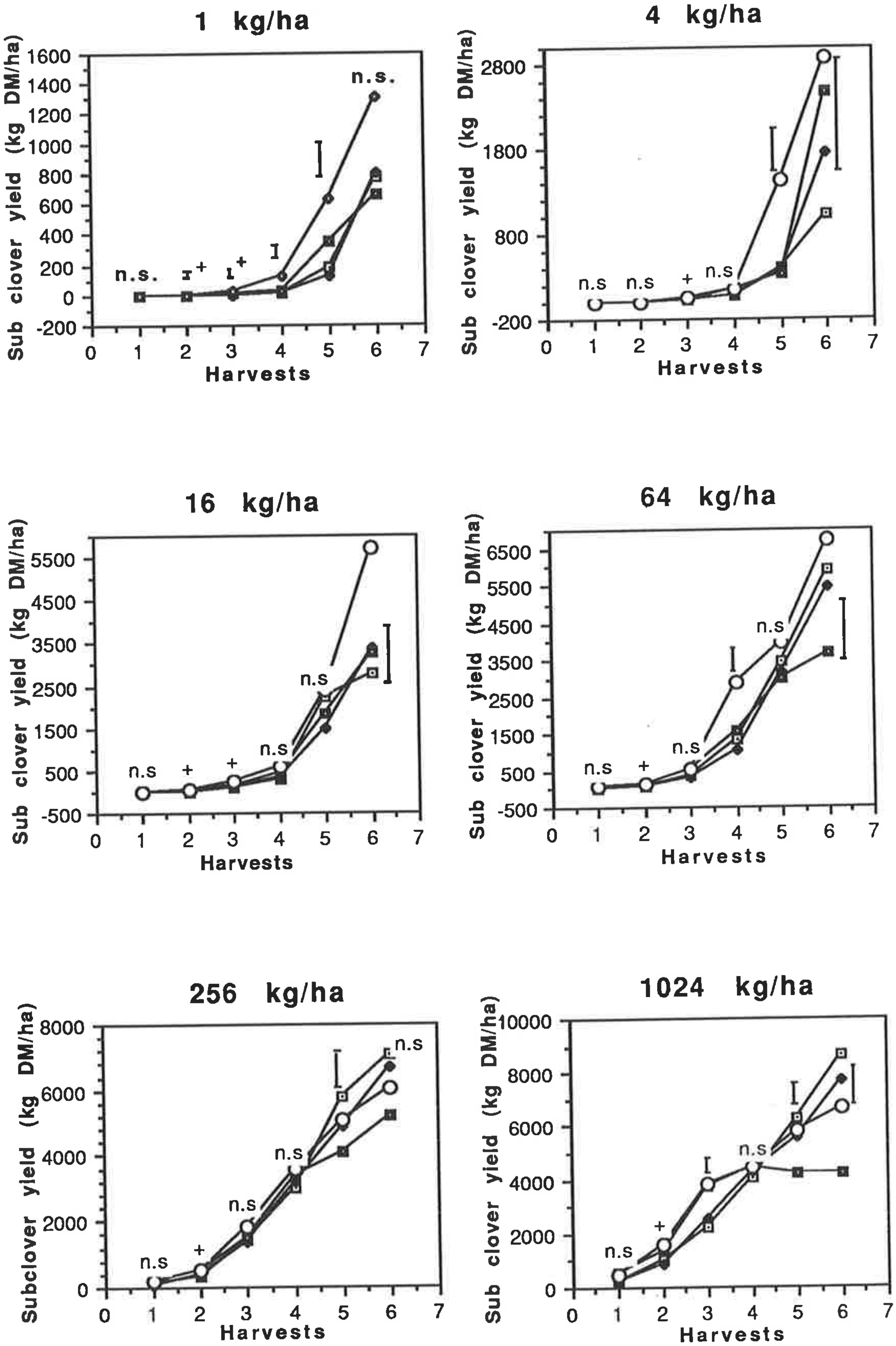
Legend:
- ⊡ 1 kg/ha
- ◆ 4 "
- ◘ 16 "
- ◇ 64 "
- ■ 256 "
- □ 1024 "

Figure 3.3: Yields of four sub clover cultivars at six sowing rates (Mean of two sowing times).

Legend:
- ⊡ Yarloop
- ◆ Trikkala
- ◘ Esperance
- ○ Clare

Vertical bars show LSD (5%)

+ See Appendix A, Table A.9



1 kg/ha
Sub clover yield (kg DM/ha)
Harvests
n.s.
+
+
n.s.
4 kg/ha
Sub clover yield (kg DM/ha)
Harvests
n.s
n.s
+
n.s
16 kg/ha
Sub clover yield (kg DM/ha)
Harvests
n.s
+
+
n.s
n.s
64 kg/ha
Sub clover yield (kg DM/ha)
Harvests
n.s
+
n.s
n.s
256 kg/ha
Subclover yield (kg DM/ha)
Harvests
n.s
+
n.s
n.s
n.s
1024 kg/ha
Sub clover yield (kg DM/ha)
Harvests
n.s
+
n.s

Table 3.4: The relationship between sub clover herbage production (y) and plant density (x) at Harvests 1, 3 and 6. ($Y = a + bx + cx^2$)

	a	b	c	r	Probability
<u>Harvest 1</u>					
Yarloop	0.06	0.009	-	0.999	P<0.001
Trikkala	0.34	0.007	-	0.997	P<0.001
Esperance	0.65	0.004	-	0.999	P<0.001
Clare	0.62	0.01	-	0.996	P<0.001
<u>Harvest 3</u>					
Yarloop	7.7	0.08	-	0.987	P<0.001
Trikkala	11.7	0.04	-	0.979	P<0.001
Esperance	26.5	0.01	-	0.971	P<0.01
Clare	26.2	0.05	-	0.973	P<0.01
<u>Harvest 5</u>					
Yarloop	89.4	0.51	-	0.952	P<0.01
Trikkala	48.8	0.73	0.0002	0.970	P<0.05
Esperance	38.8	0.48	0.0001	0.981	P<0.01
Clare	86.6	1.03	0.0005	0.954	P<0.05

Cultivar effects are summarised in Figure 3.3 (Also see Appendix A, Tables A.6 and A.7). No significant differences between cultivars were found very early in the season (Harvest 1) but highly significant differences between cultivars were evident from Harvest 2 to Harvest 6. However, this also depended on the sowing rate (Fig.3.2 and Appendix Table A.8). Early in the season both Clare and Esperance were the highest yielding cultivars at the sowing rates 1, 16, 64, 256 and 1024kg/ha (Fig. 3.3). Late in the season Yarloop and Trikkala had the highest yield at 256 and 1024 kg/ha (Fig 3.3). All cultivars had marked increases in yield as time progressed except Esperance sown at the highest density. Esperance had no further increase in yield beyond Harvest 4.

b) Weeds

A range of broadleaf and grass weeds became established in the treatment plots. Early in the season the main broadleaf weed was sour sob (*Oxalis pes caprae*), but other broadleaf weeds such as wire weed (*Polygonum aviculare*) and fumitory (*Fumaria officinalis*) had begun to grow. Wire weed became more prominant later in the season after the soursob had senesced and matured. The grass weeds included annual ryegrass (*Lolium rigidum*) which became more dominant as the season progressed. There were also volunteer cereal plants. The weed component of the experimental areas was examined to assess the effects of the weeds on the different cultivars at the various sowing rates and at both times of sowing.

Table 3.5: Summary of Analyses of Variance for yield of weeds. (Based on natural logarithms).

Harvests	H1	H2	H3	H4	H5	H6
<u>Treatments</u>						
Sowing Time (ST)	-	n.s.	n.s.	n.s.	n.s.	n.s.
Cultivar (Cv)	n.s.	n.s.	n.s.	n.s.	$P<0.001$	$P<0.001$
Sowing Rate (SoR)	$P<0.05$	$P<0.001$	$P<0.001$	$P<0.001$	$P<0.001$	$P<0.001$
ST x Cv	-	n.s.	n.s.	n.s.	$P<0.05$	n.s.
ST x SoR	-	n.s.	$P<0.05$	n.s.	n.s.	n.s.
Cv x SoR	$P<0.05$	n.s.	$P<0.05$	n.s.	n.s.	$P<0.01$
ST x Cv x SoR	-	n.s.	n.s.	n.s.	n.s.	n.s.
Coeff. of Var. %	47.8	20.6	13.1	10.4	9.2	8.7

<u>Sowing Time:</u> No significant differences were found between early and late sown treatments for the amount of weeds present (Table 3.5). Only one significant Sowing Time x Cultivar interaction was found at Harvest 5 (Appendix A.6), and a Sowing Time x Sowing Rate interaction at Harvest 3 in relation to weed invasion (Table 3.5). Both these interactions are not considered very important because they only occurred on one harvest occasion.

<u>Cultivar and sowing rate effects:</u> Sowing rate was highly significant at all harvest occasions except Harvest 1 ($P<0.05$, Table 3.5). Therefore, the ability to suppress weeds is primarily due to sub clover plant numbers. Sowing Rate x Cultivar was significant for Harvests 1, 3 and 6. Generally Clare, Yarloop and Trikkala gave the best weed control particularly at the highest sowing rate at Harvest 6 (Appendix A.10). Esperance showed a

limited ability to compete with weeds even at the highest sowing rate this was probably due to great losses of plants (Fig. 3.4).

There were no significant differences in the ability of any one cultivar to suppress weed growth early in the season (Harvest 1 to Harvest 4) for each of the sowing rates. Cultivar differences in the ability to suppress weeds did not occur until late in the season (Harvests 5 and 6) and only at sowing rates 16 to 1024 kg/ha (Fig. 3.5, Appendix A.11, A.12).

The results also indicate that herbage production of a cultivar governs its ability to suppress weeds. Sub clover herbage production was plotted against weed DM at H1, H3 and H6 (Table 3.6). At Harvest 1 no cultivar showed any ability to suppress weeds. However, at Harvest 3 all cultivars showed the ability to suppress weeds as the sub clover herbage production increased. At Harvest 6 increases in sub clover herbage production significantly reduced weed production for all cultivars except Esperance. The smaller Esperance plants are probably not good competitors with weeds.

Table 3.6: The relationship between sub clover herbage production (x) and weed yield (y) at Harvests 1, 3 and 6. ($Y = a + bx + cx^2$)

	a	b	c	r	Probability
Harvest 1					
Yarloop	23.7	-0.12	-	-0.747	n.s.
Trikkala	13.6	-0.05	-	-0.486	n.s.
Esperance	8.3	-0.01	-	-0.399	n.s.
Clare	13.3	-0.03	-	-0.558	n.s.
Harvest 3					
Yarloop	709.0	-0.22	-	-0.925	P<0.01
Trikkala	725.0	-0.18	-	-0.879	P<0.05
Esperance	803.0	-0.14	-	-0.965	P<0.01
Clare	799.0	-0.15	-	-0.972	P<0.01
Harvest 6					
Yarloop	6926.0	-0.61	-	-0.938	P<0.01
Trikkala	7156.0	-0.69	-	-0.952	P<0.01
Esperance	6587.8	-0.52	-	-0.769	n.s.
Clare	7239.0	-0.77	-	-0.867	P<0.05

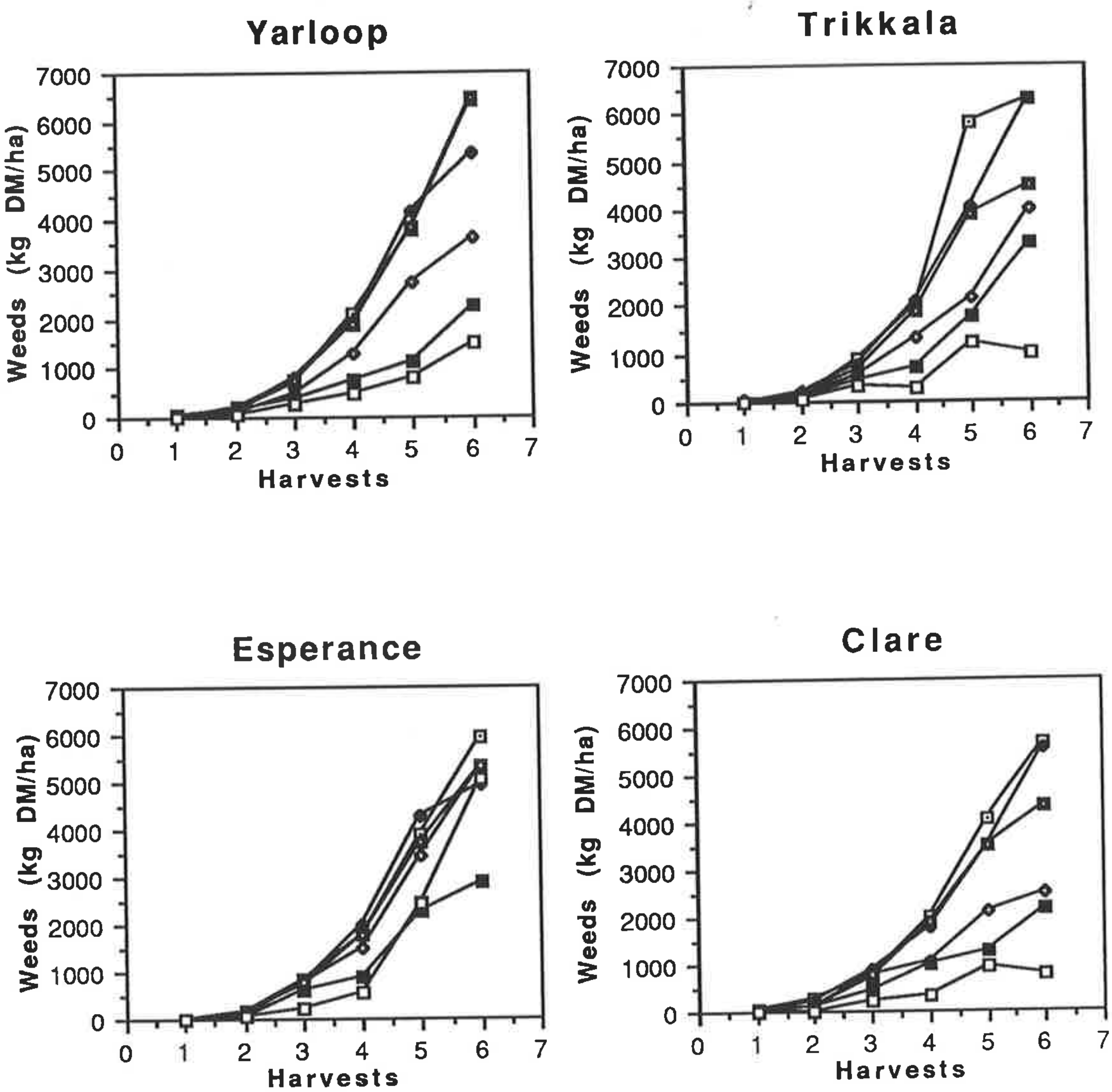


Figure 3.4: Yield of weeds growing with four cultivars of sub clover sown at six densities.

Legend:
- ⊡ 1 kg/ha
- ◆ 4 "
- ◘ 16 "
- ◇ 64 "
- ■ 256 "
- □ 1024 "

Figure 3.5: Yield of weeds growing with four cultivars of sub clover sown at six densities.

Legend:
- ⊡ Yarloop
- ◆ Trikkala
- ◘ Esperance
- ○ Clare

Vertical bars show LSD (5%)

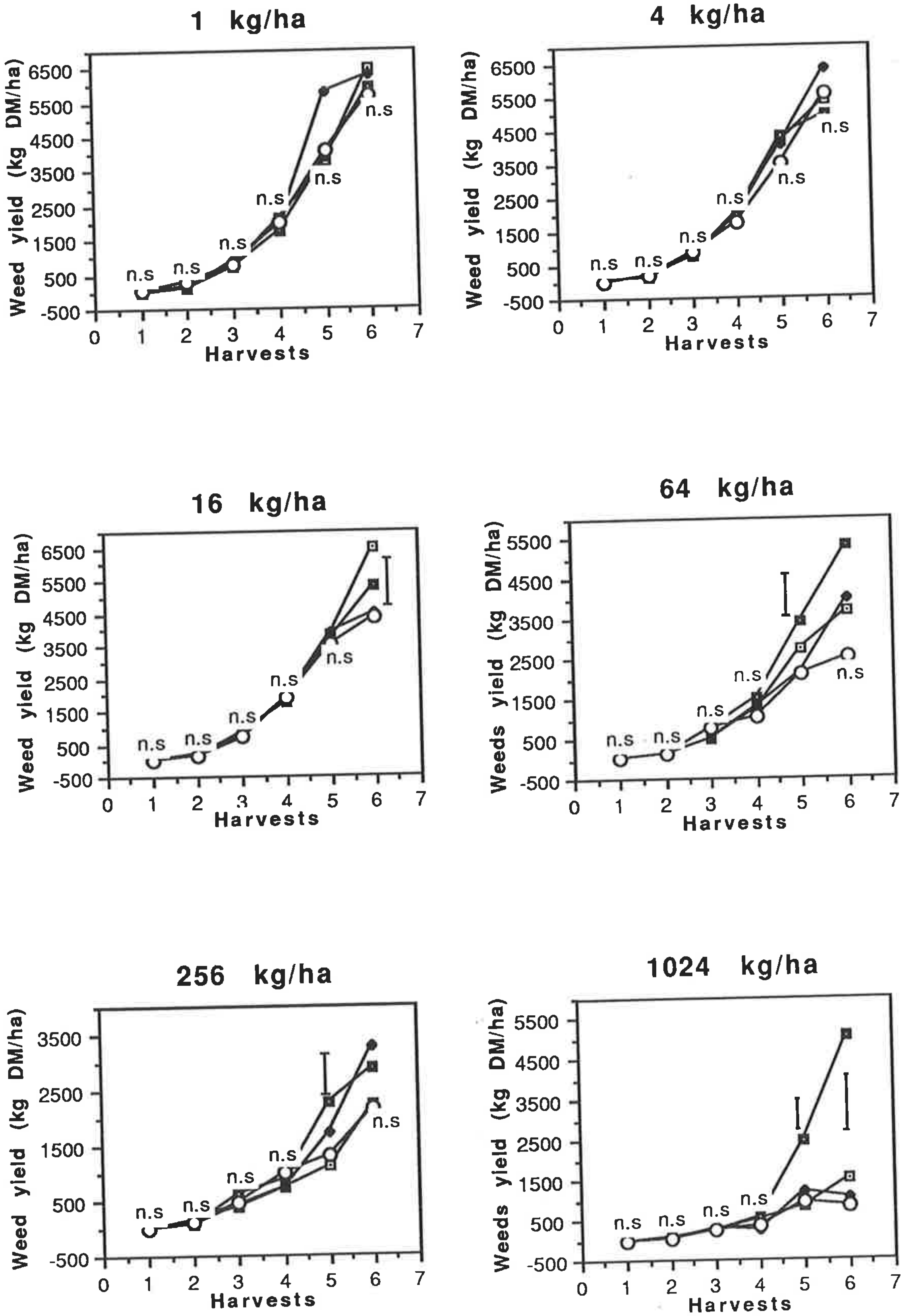

1 kg/ha
Weed yield (kg DM/ha)
6500
5500
4500
3500
2500
1500
500
-500
0 1 2 3 4 5 6 7
Harvests
n.s
4 kg/ha
Weed yield (kg DM/ha)
Harvests
16 kg/ha
Weed yield (kg DM/ha)
Harvests
64 kg/ha
Weeds yield (kg DM/ha)
Harvests
256 kg/ha
Weed yield (kg DM/ha)
Harvests
1024 kg/ha
Weeds yield (kg DM/ha)
Harvests

Figure 3.6, illustrates the proportions of sub clover and weeds. As sowing rate increased the proportion of sub clover in the sward increased, and the proportion of weeds decreased. Clare at the lower sowing rates (1 to 16 kg/ha) has the highest proportion of sub clover, especially at Harvest 6. Esperance lost its competitiveness at 1024 kg/ha as the season progressed presumably due to plant losses. Harvests 5 and 6 show a marked increase in the amount of weed present in Esperance plots (Also see Figure 3.4).

Figure 3.7 illustrates the relation of sub clover plant density and weed yield at Harvest 5. There was the potential for the cultivars Yarloop, Trikkala and Clare to increase their ability to suppress weeds if the plant density was higher than 1,200 for Clare and Yarloop and 1,850 for Trikkala. Esperance clearly showed the least ability to control weeds even though it had the highest plant density.

Figure 3.6: Yield and botanical composition of plots sown to four sub clover cultivars.

Legend: Y = Yarloop
T = Trikkala
E = Esperance
C = Clare

NB: Figure 3.6 continued next page

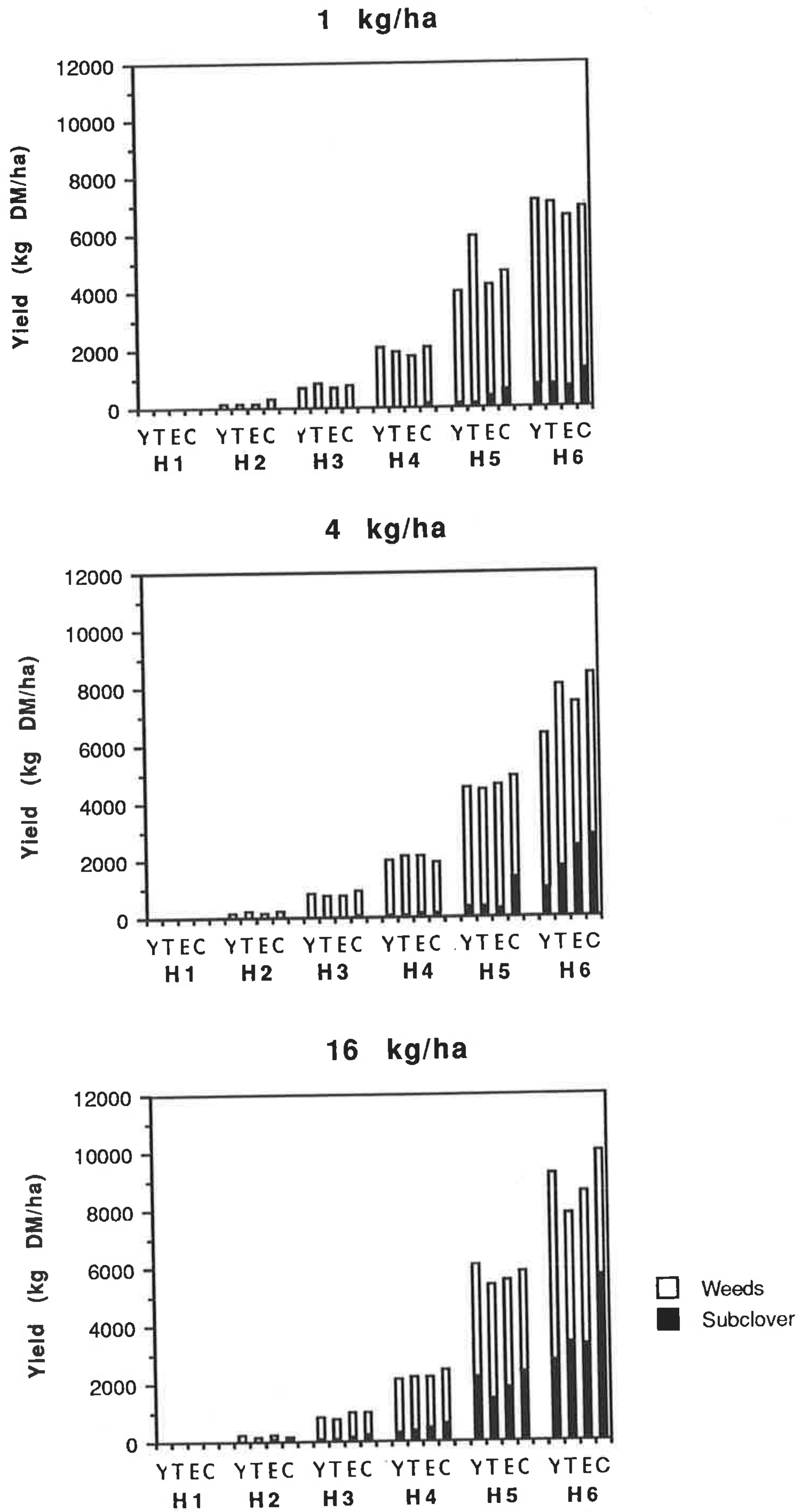
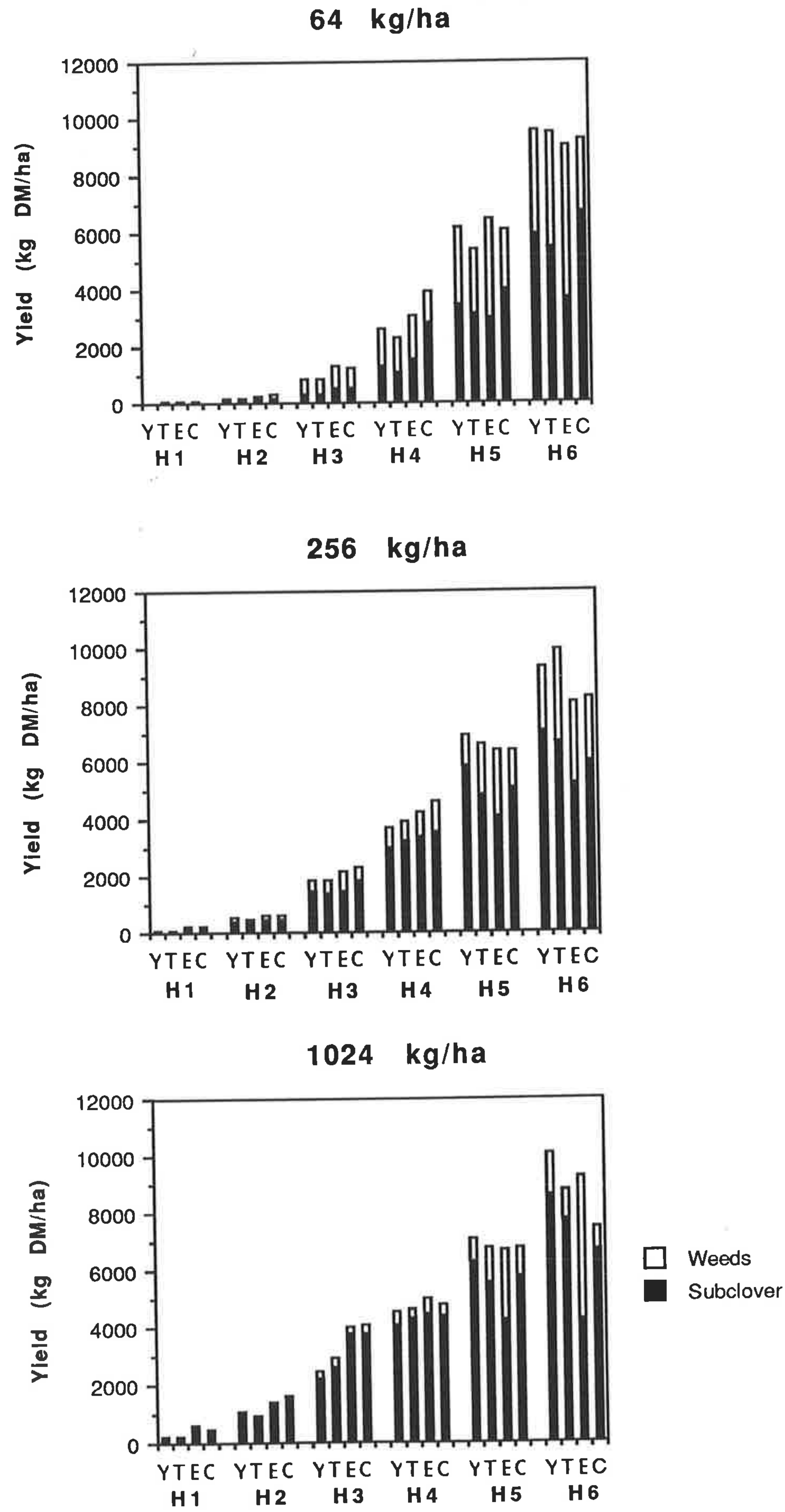

1 kg/ha
Yield (kg DM/ha)
12000
10000
8000
6000
4000
2000
0
YTEC YTEC YTEC YTEC YTEC YTEC
H1 H2 H3 H4 H5 H6
4 kg/ha
Yield (kg DM/ha)
12000
10000
8000
6000
4000
2000
0
YTEC YTEC YTEC YTEC YTEC YTEC
H1 H2 H3 H4 H5 H6
16 kg/ha
Yield (kg DM/ha)
12000
10000
8000
6000
4000
2000
0
YTEC YTEC YTEC YTEC YTEC YTEC
H1 H2 H3 H4 H5 H6
Weeds
Subclover

Figure 3.6: Yield and botanical composition of plots sown to four sub clover cultivars.

Legend:

Y = Yarloop
T = Trikkala
E = Esperance
C = Clare


64 kg/ha
Yield (kg DM/ha)
12000
10000
8000
6000
4000
2000
0
YTEC H1
YTEC H2
YTEC H3
YTEC H4
YTEC H5
YTEC H6
256 kg/ha
Yield (kg DM/ha)
12000
10000
8000
6000
4000
2000
0
YTEC H1
YTEC H2
YTEC H3
YTEC H4
YTEC H5
YTEC H6
1024 kg/ha
Yield (kg DM/ha)
12000
10000
8000
6000
4000
2000
0
YTEC H1
YTEC H2
YTEC H3
YTEC H4
YTEC H5
YTEC H6
Weeds
Subclover

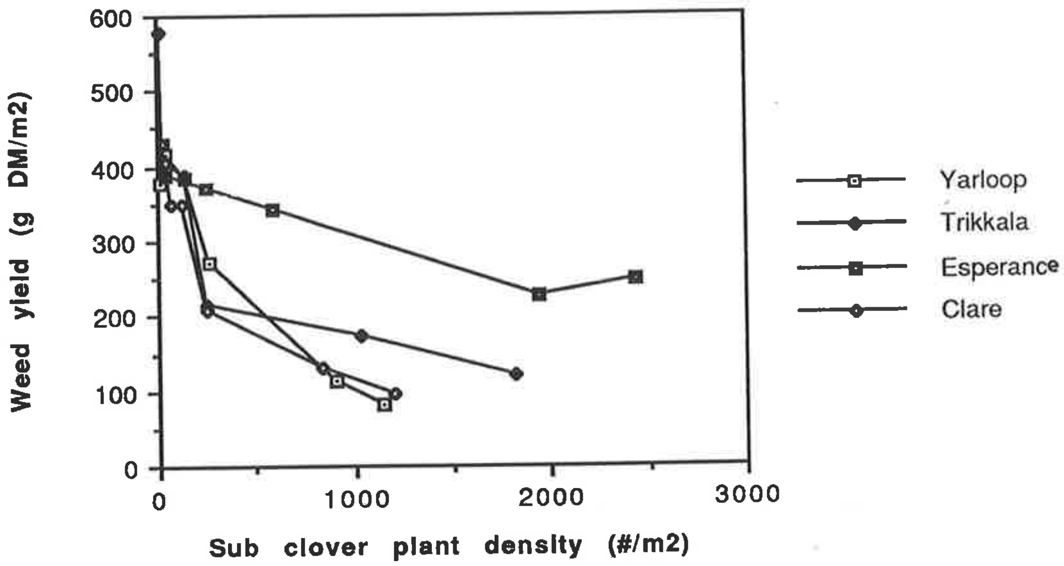


Figure 3.7: Harvest 5, relationship between sub clover plant number and weed yield.

3.3 SEED HARVEST RESULTS 1985

3.3.1 Seed Yield

Table 3.7: Summary of the Analysis of Variance on the parameters seed yield, seed number, mean seed weight and regeneration in 1986.

	Seed yield		Seed number		Mean seed wt.		
	Above/g	Below/g	Above/g	Below/g	Above/g	Below/g	Regeneration
Sowing Time	n.s	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Cultivar	P<0.05	P<0.001	n.s.	P<0.001	P<0.001	P<0.001	P<0.001
Sowing Rate	P<0.001	P<0.001	P<0.001	P<0.001	P<0.001	P<0.001	n.s.
ST x Cv	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
ST x SoR	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s
Cv x SoR	P<0.05	P<0.001	P<0.05	P<0.001	P<0.01	P<0.01	P<0.01
ST x Cv x SoR	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

Sowing Time: Time of sowing did not affect the above- or below-ground seed yield (Table 3.7).

Cultivar and sowing rate effects: Clare and Yarloop had the highest above-ground seed yield for most sowing rates (Table 3.8). Below-ground seed yields showed a highly significant cultivar effect (P<0.001). Sowing Rate x Cultivar interaction was also highly significant for below-ground seed yield (P<0.001), with Clare having higher seed yields at most of the sowing rates, particularly the lowest rate (Table 3.8). Highest seed yield was obtained at different sowing rates for each of the cultivars. Yarloop and Trikkala had the maximum seed yield when the initial sowing rate was 64 kg/ha, Esperance at 16 kg/ha and Clare at 4 kg/ha.

Table 3.8: Seed yields of subterranean clover at six sowing rates (Above-ground (AG), Below-ground (BG) and Total (T) seed yield , all in kg/ha).

Sowing Rates (kg/ha)		1	4	16	64	256	1024
Yarloop	AG	14	52	196	428	622	534
	BG	3	28	63	112	45	61
	T	17	80	259	540	667	595
Trikkala	AG	15	46	187	364	396	450
	BG	12	31	54	126	61	123
	T	27	77	241	490	457	573
Esperance	AG	11	60	298	355	270	246
	BG	21	32	101	46	46	55
	T	32	92	399	401	316	301
Clare	AG	81	187	200	496	527	576
	BG	140	195	127	103	117	144
	T	221	382	327	599	644	720

Table 3.9 shows the relationship of sub clover seed yield to herbage production. All cultivars had increased seed yield when herbage production increased for the above-ground and total seed yield components. However, Clare showed the smallest increase. Below-ground seed patterns were clearly different: Trikkala was the only cultivar which showed a significant increase in below-ground seed yield as the sub clover herbage increased.

Table 3.9: Subclover seed yield (y) [above-, below-ground and total] in relation herbage production (x). (Y = a + bx)

	a	b	r	Probability
Above-ground				
Yarloop	-20.0	0.1	1.000	$P<0.01$
Trikkala	-44.3	0.1	1.000	$P<0.001$
Esperance	-19.3	0.1	0.800	n.s.
Clare	-49.1	0.1	0.900	$P<0.05$
Below-ground				
Yarloop	23.8	0.006	0.600	n.s.
Trikkala	7.1	0.01	0.800	$P<0.05$
Esperance	27.3	0.007	0.400	n.s.
Clare	177.6	-0.008	0.600	n.s.
Total seed yield				
Yarloop	3.9	0.1	1.000	$P<0.01$
Trikkala	-37.2	0.1	1.000	$P<0.001$
Esperance	8.0	0.1	0.800	n.s.
Clare	128.5	0.1	0.800	$P<0.05$

Figure 3.8 shows the relationship between sowing rate and the percentage of seed buried. Most cultivars show a decrease in burr burial as sowing rate increased.

The plant density required maximise total seed yield is shown in Figure 3.9. Both Trikkala and Clare show the potential to increase seed yield beyond the plant densities of 1,800/m^2 and 1,200/m^2 respectively. Yarloop had reached an optimum total seed yield of approximately 650 kg/ha at the plant density 950 plants/m^2. Esperance showed no further increase in total seed yield beyond the plant density 600plants/m^2. All cultivars show rapid increases in seed yield at relatively low plant densities (i.e. 200 plants/m^2, Harvest 5) beyond which further seed yield increases are limited.

Seed yield was also plotted against seed number (Table 3.10). All cultivars showed clear increases in seed yield as seed number increased. However, these results also indicate that the seed size of Esperance is limiting seed yield.

Table 3.10: Interrelations of Seed yield (y) and seed number (x) for above-, below-ground and total seed components. (Y = a + bx)

	a	b	r	Probability
Above-ground				
Yarloop	0.4	0.008	1.000	P<0.001
Trikkala	0.9	0.007	1.000	P<0.001
Esperance	0.1	0.005	1.000	P<0.001
Clare	-1.0	0.009	1.000	P<0.001
Below-ground				
Yarloop	-0.6	0.01	0.979	P<0.001
Trikkala	0.3	0.008	0.982	P<0.001
Esperance	0.8	0.005	0.958	P<0.01
Clare	-4.0	0.1	0.987	P<0.001
Total seed yield				
Yarloop	0.5	0.008	0.993	P<0.001
Trikkala	1.5	0.007	0.996	P<0.001
Esperance	1.0	0.005	0.985	P<0.001
Clare	1.0	0.009	0.992	P<0.001

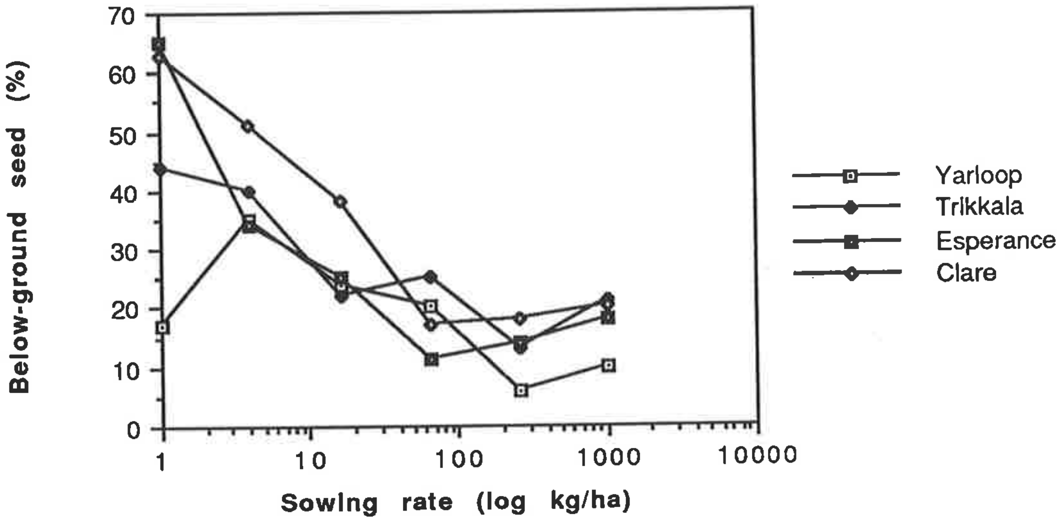


Figure 3.8: The relationship between the percentage seed yield found below-ground and sowing rate.

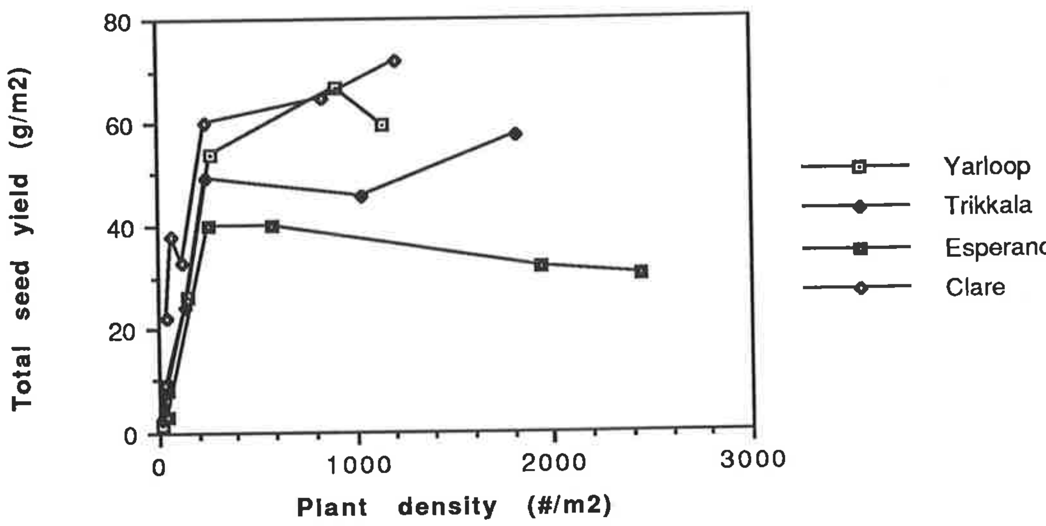


Figure 3.9: Relationship between total seed yield of sub clover and plant density at Harvest 5.

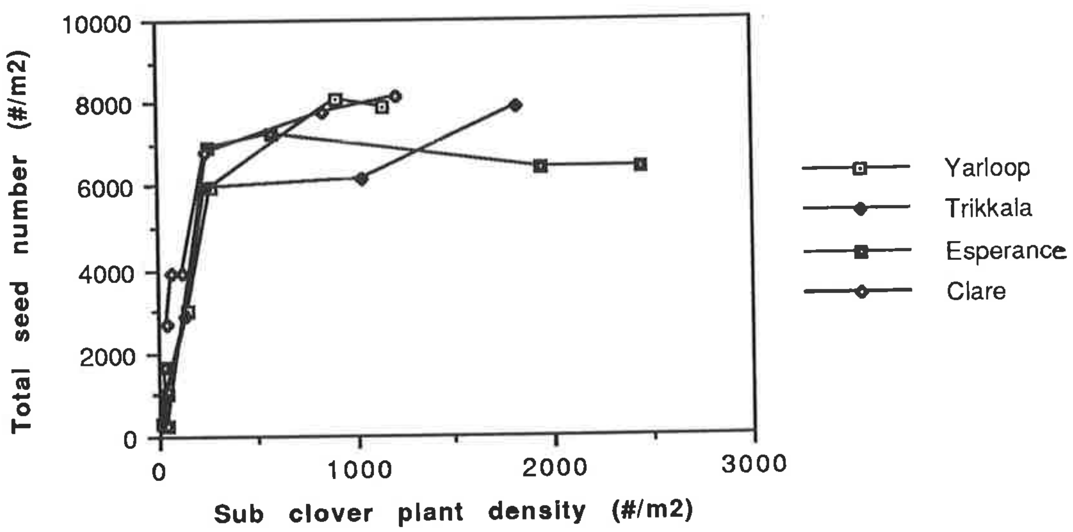


Figure 3.10: Sub clover total seed number in relation to sub clover plant density at Harvest 5.

3.3.2 Seed number

Similar trends were found for seed number as for seed yield.

Sowing Time: As found for seed yield, time of sowing did not effect the number of seed formed above- or below-ground (Table 3.7).

Cultivar and sowing rate effects: A significant Sowing Rate x Cultivar interaction for above-ground seed numbers was found (Table 3.7). The cultivars Trikkala and Clare had the highest number of above-ground seeds at the sowing rate 1024 kg/ha, Yarloop at 256 kg/ha and Esperance had the maximum seed number at 64 kg/ha (Table 3.11).

The main effects of Cultivar and Sowing Rate were highly significant for below-ground seed numbers ($P<0.001$, Table 3.7). The first order interaction Sowing Rate x Cultivar was highly significant ($P<0.001$). Clare had the most seed at the lower initial sowing rates.

Table 3.11: Seed production of subterranean clover at six sowing rates (Above-ground (AG), Below-ground (BG) and Total (T) seed number/m^2).

Sowing Rate		1	4	16	64	256	1024
Yarloop	AG	236	665	2364	4791	7512	7070
	BG	80	335	651	1158	559	837
	T	316	1000	3015	5949	8071	7907
Trikkala	AG	200	537	2296	4519	5247	6224
	BG	146	344	614	1449	909	1692
	T	346	881	2910	5968	6156	7916
Esperance	AG	202	1038	5064	6338	5468	5213
	BG	66	632	1837	936	957	1197
	T	268	1670	6901	7274	6425	6410
Clare	AG	1015	2222	2450	5477	6277	6607
	BG	1664	2104	1458	1292	1457	1738
	T	2679	3886	3908	6769	7734	8145

Total seed number (Figure 3.10) followed a similar pattern to that of total seed yield (Figure 3.9) in relation to sub clover density.

3.3.3 Individual seed weight

Individual seed weights were derived from the raw data seed weights (g/infiltrometer ring) divided by the number of seeds/infiltrometer ring. Analyses of Variance was not conducted on each sowing rate separately.

Sowing time: Time of sowing was not statistically significant for above- and below-ground individual seed weights. A slight reduction of approximately 0.5 mg/seed resulted from late sowing.

Cultivar and sowing rate effects: The main effect of Cultivar was highly significant for both above- and below-ground seed ($P<0.001$). Clare, Yarloop and Trikkala had the heaviest seeds for above-ground seed while Esperance was the lightest (Table 3.12, Appendix A, Table A.13). Similarly, below-ground seed was heaviest for Yarloop, Clare and Trikkala, with Esperance having the lowest individual seed weight. Below-ground seed was generally heavier than above-ground seed.

Table 3.12: Mean seed weight (y) in relation to sowing rate (x) for above- and below-ground burrs. (Seed weight in mg) ($Y = a + bx + cx^2$)

	a	b	c	r	Probability
Above-ground					
Yarloop	7.2	0.8	-0.1	0.939	P<0.05
Trikkala	8.3	-0.2	-	-0.908	P<0.05
Esperance	6.0	-0.2	-	-0.819	P<0.05
Clare	7.8	0.1	-	0.608	n.s.
Below-ground					
Yarloop	8.0	1.3	-0.2	0.862	n.s.
Trikkala	7.9	0.6	-.1	0.828	n.s.
Esperance	5.6	-0.1	-	-0.826	P<0.05
Clare	8.8	-0.2	-	-0.754	n.s.

Differences were found between cultivars in their responses to increasing sowing rate for both above- and below-ground seed ($P<0.01$) (Table 3.12). Despite these differences, the mean seed weight is relatively stable over a wide range of sowing rates. Above-ground mean seed weight decreased with increasing sowing rate for the cultivars Trikkala and

Esperance (Table 3.12). Clare maintained similar seed weight over the range of sowing rates while Yarloop had the greatest weight at 64 kg/ha. For the below-ground component, Esperance was the only cultivar to have a significant decrease in mean seed weight as sowing rate increased.

3.3.4 Germination tests of seeds in burrs

Table 3.13: Summary of analyses of variance for the percentage soft, hard and dormant seed at each sowing time. (Analyses made on arcsine-transformed data).

	% Soft		% Hard		% Dormant	
	Above/g	Below/g	Above/g	Below/g	Above/g	Below/g
Early Sown						
Cultivar	P<0.001	P<0.001	P<0.05	P<0.05	P<0.001	P<0.05
Sowing Rate	P<0.001	P<0.05	P<0.001	P<0.01	P<0.001	P<0.01
Cv x SoR	P<0.001	P<0.01	P<0.001	P<0.05	P<0.001	P<0.05
Late Sown						
Cultivar	P<0.001	P<0.001	P<0.01	n.s.	P<0.001	P<0.01
Sowing Rate	P<0.01	P<0.05	P<0.01	n.s.	n.s.	P<0.01
Cv x SoR	P<0.01	P<0.001	P<0.001	n.s.	P<0.001	P<0.05

3.3.4.1 Percentage soft seed

Sowing time was not tested statistically as a main effect. Seed from early-sown burrs was germinated at a different time than seed from late-sown burrs. There was a slight increase in percentage soft seed in above-ground burrs from late-sown treatments. Increases were four to five percent greater for all cultivars late-sown compared to early-sown treatments. Below-ground burrs did not appear to be influenced to the same extent as the above-ground burrs. Yarloop and Esperance were the only cultivars which had increased in soft seed from late-sown treatments (increase of 7% for both cultivars).

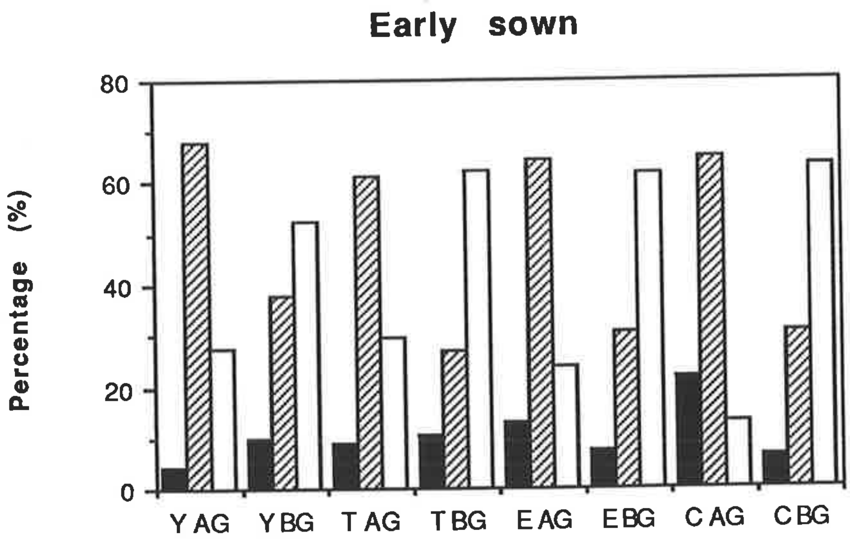
The soft seed consisted of those seeds which germinated readily from burrs within 14 days. Data is presented in Appendix A tables 14 - 17 for all germination test results includes hard (impermeable) and dormant seed (imbibed but did not germinate). All germination percentage results were transformed to arcsine for analyses of variance. However, all data in the text, and tables in the Appendices have the natural values presented.

Sowing time: Both above- and below-ground data on germination of seed in burrs were analysed separately for each sowing time. Above-ground burrs from late-sown treatments had a higher soft seed percentage. For early-sown treatments the order of lowest soft seed to highest soft seed was as follows, Yarloop (4.2), Trikkala (8.8), Esperance (12.6) and Clare (21.8). This order remained the same for the late-sown treatments (8.8, 15.4, 18.3 and 27.6 respectively) (Appendix A, Table A.17). Figure 3.11 illustrates the relationship between soft seed, hard seed and dormant seed. For early- or late-sown treatments it can be seen that there are relatively more dormant seed below-ground. Conversely there was much less hard seed below-ground.

In contrast, below-ground samples were not as strongly influenced by sowing time as the above-ground samples. There were very few increases in soft seed with burrs from late-sown treatments. For both Yarloop and Esperance there was an increase in soft seed with late-sown treatments.

Cultivar and sowing rate effects: As mentioned earlier, Clare had the highest overall soft seed from the above-ground burrs ($P<0.001$) (AppendixA, Table A.14). This is in complete contrast to below-ground burrs, when Clare had one of the lowest soft seed percentages. Also in complete contrast Yarloop seed from burrs were more readily germinable if they were from below-ground samples.

Sowing Rate x Cultivar interactions were mostly highly significant ($P<0.001$). Despite the variation in the results (Appendix A.14), it does show that cultivars have a slight decrease in soft seed percentage with increasing sowing rate for above-ground samples. Below-ground results were also variable. For early-sown treatments there is a gradual decrease in soft seed percentage as sowing rate increases for most cultivars.



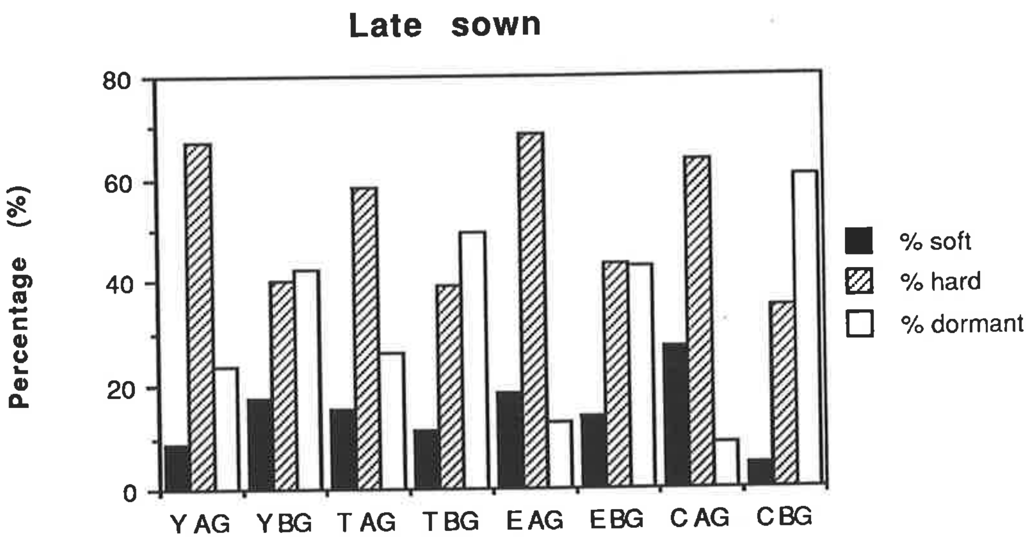


Figure 3.11: The percentage soft, hard and dormant seed of sub clover produced on early- and late-sown treatments.

Legend: Y = Yarloop
T = Trikkala
E = Esperance
C = Clare

AG = Above-ground
BG = Below-ground

3.3.4.2 Percentage hard seed

The hard seed was defined as seed which did not imbibe water within 14 days during the germination test.

Sowing time: Time of sowing did not affect the percentage hard seed found in above-ground burrs. The results for above-ground burrs from early-sown treatments were not consistent. However, below-ground burrs were influenced by the time of sowing, in particular the cultivars Trikkala and Esperance. Both cultivars had a greater percentage of hard seed below-ground with later-sowing (Figure 3.11).

Cultivar and sowing rate effects: Differences between cultivars were not great for early-sown treatments above-ground ($P<0.05$) (Figure 3.11). Late-sown treatments exhibited more pronounced differences between cultivars ($P<0.01$) (Figure 3.11). Generally, Yarloop had the highest percentages of hard seed for above-ground burrs.

Differences between cultivars were only evident on early-sown plots for below-ground burrs (Fig 3.11). Yarloop had the highest level of hard seed. Interestingly the overall percentage hard seed in below-ground burrs was approximately 20% less than those for the above-ground burrs. This appears to be related to the level of dormant seed (See next section 3.3.4.3).

The Cultivar x Sowing Rate interaction for percentage hard-seed was highly significant at both sowing times for above-ground burrs ($P<0.001$) (Appendix A.15). Results show that Yarloop and Trikkala behaved similarly. Below-ground interactions for Cultivar x Sowing Rate were only significant for early-sown treatments ($P<0.05$). Clare was the only cultivar which had decreased hard seed percentage as sowing rate increased.

3.3.4.3 Percentage dormant seed

Dormant seeds were defined as those seeds which imbibed water but failed to germinate within 14 days. Below-ground burrs tended to have a much higher proportion of dormant seed (approx. 54%) than above-ground burrs (approx. 20%).

Sowing time: There was a slight reduction in dormant seed in above-ground burrs with late sowing (Fig. 3.11) in Trikkala, Clare and Yarloop, but almost a 50% reduction in Esperance. A similar reduction in the proportion of dormant seed was found in below-ground burrs, with late-sown treatments.

Cultivar and sowing rate effects: Differences between cultivars were highly significant for above-ground burrs ($P<0.001$). Treatments at both sowing times showed Clare to have the least dormant seeds above-ground, while both Yarloop and Trikkala had the highest (Figure 3.11). Cultivar differences were not as pronounced for the below-ground samples ($P<0.05$ and $P<0.01$ for early- and late-sown treatments respectively). Yarloop has less dormant seed than the other cultivars for early sown plots. Clare had the highest proportion dormant seed for late sown plots, while both Yarloop and Esperance had the lowest proportion dormant seed.

No clear trends can be seen for the above-ground burrs in relation to the interaction Cultivar x Sowing Rate. Each cultivar behaved differently (Appendix A.16). No interaction was clear for the below-ground burrs.

3.3.5 Natural regeneration of sub clover on experiment site

Sowing Time: Time of sowing in 1985 had no effect on regeneration in 1986.

Cultivar and sowing rate effects: There was no significant effect of Cultivar on seedling regeneration at the sowing rate 1 kg/ha (Table 3.14). Differences between cultivars occurred at 4 kg/ha where Clare and Esperance had the most seedlings. Esperance had the highest population of seedlings at 16 kg/ha, but was statistically similar to Clare. The sowing rates

64, 256 and 1024 kg/ha of Esperance had clearly the highest number of seedlings. The interaction Cultivar x Sowing Rate was significant (P<0.01, Table 3.14). The cultivars Clare, Trikkala and Yarloop showed a tendancy toward slightly higher seedling numbers at the lowest rates, with an decrease in seedling number as sowing rate increased. Esperance had an increase in seedling number as sowing rate increased. Seedling numbers in 1986 was partly related to seed number and also to germination percentage of seed in burrs.

Table 3.14: Sub clover regeneration in 1986 on the 1985 experiment site (# seedlings/m^2) (Expected emergence based on percentage soft and % dormant seed are shown in brackets).

Sowing rate	Yarloop	Trikkala	Esperance	Clare	LSD (5%)
1	489 (161)	1191 (171)	1039 (131)	878 (1623)	n.s
4	810 (393)	292 (428)	915 (466)	1270 (2295)	415**
16	432 (1142)	487 (1166)	1565 (2716)	989 (2188)	870*
64	391 (1873)	596 (2631)	1159 (2755)	234 (2165)	521*
256	56 (5564)	405 (3089)	2099 (2669)	289 (1939)	893**
1024	74 (3522)	341 (3573)	1415 (2706)	249 (2794)	262***

n.s = not significant, * = P<0.05, ** = P<0.01, *** = P<0.001

It should be noted that there are more seedlings at the lower sowing rates (1 and 4 kg/ha) than at the expected emergence. This probably relates to contamination by seedlings derived from seed already present in the soil at the start of the experiment. Contamination seedlings are just as likely to be impeded by the excessive herbage cover as the sown cultivars and this is the likely reason why there was less contamination at the higher sowing rates.

In 1986 only two cultivars (Yarloop and Clare) were affected by residual sowing rate effects from 1985 (Table 3.15). Both cultivars had significantly reduced seedling numbers in 1986 in response to increased initial sowing rates. This was probably due to increased dry pasture residue causing the blanketing of seedlings. Both Yarloop and Clare had high herbage production in 1985.

Table 3.15: Seedling regeneration in 1986 (y) in relation to sowing rate in 1985 (x). (Y = a + bx)

	a	b	r	Probability
Yarloop	688.1	-90.2	-0.829	P<0.05
Trikkala	823.8	-78.4	-0.614	n.s.
Esperance	1006.1	103.6	0.622	n.s.
Clare	1140.4	-141.0	-0.812	P<0.05

However, sub clover herbage yield at the end of the 1985 season was plotted against seedling number and Yarloop was the only cultivar significantly affected by increased herbage production (Table 3.16).

Table 3.16: Seedling number at the beginning of 1986 (y) in relation to sub clover herbage yield at the end of 1985 (x). (Y = a + bx)

	a	b	r	Probability
Yarloop	701.8	-0.08	-0.875	P<0.05
Trikkala	835.6	-0.07	-0.552	n.s.
Esperance	678.1	0.2	0.765	n.s.
Clare	1359.5	-0.2	-0.725	n.s.

3.4 Discussion and conclusions

3.4.1 Herbage harvest results

Plant density: Esperance had clearly the highest plant numbers which were greatly reduced later in the season. No doubt there was a high level of intra-plant competition between the numerous but small plants of Esperance and dramatic self-thinning resulted. At high plant densities mutual shading is common and often results in self-thinning (Westoby and Howell 1982). Competition for light and moisture may have been strong. In comparison, the plant density of the cultivars Yarloop, Trikkala and Clare was not large enough to cause the same magnitude of reduction as found for Esperance at the higher sowing rates. Competition which results in dominance and suppression occur in all plant communities (Stern 1965): competition in high-density Esperance plots was high. Donald (1951) found that the higher the density the earlier the growth stage at which competition begins. This appears to have happened to Esperance. Yates (1961) also found that as density increased differences in herbage production between strains are reduced. To some extent this has occurred, especially at the high sowing rate of 1024 kg/ha late in the season. Esperance was no longer the cultivar with significantly more plants, Trikkala was also statistically similar. In some cases there was a rise in plant numbers beyond Harvest 1, this could be due to late emergence of seedlings increasing the plant density count, or the initial plant counts may have been inadequate. Another explanation could be delayed germination due to reduced dormancy and breakdown of hard-seededness.

Sub clover herbage yield: The two early-maturing cultivars (Yarloop and Trikkala) were the least affected by late sowing, while the late-maturing cultivars, (Esperance and Clare) were most affected as these require a longer growing period to reach their maximum productive potential. Therefore, late-sowing resulted in very few cultivar differences compared to early-sown treatments. For example, Clare had the highest yield for early-sown treatments but was not much higher in yield than the other cultivars when sown later. These results support those of Dear and Loveland (1984) who also found that cultivar differences were reduced with later sowing. In this experiment it appears that the three week interval between sowing times was sufficient to show this effect. However, late sowing did not limit the production of Esperance and Clare late in the season. This indicates that favourable seasonal conditions were of sufficient length for the later-maturing cultivars. The sowing dates used are typical of the environment and the seasonal conditions for that year.

The high yield of the cultivar Esperance early in the season can be attributed to many small plants. Early high yield of the cultivar Clare can be attributed to large plant size even though the density was lower than Esperance. However, Esperance was the only cultivar which had reached a plateau in herbage production at the high sowing rate. The plateau in yield for Esperance can be attributed to the great loss of plants. Individual plant weights of Esperance at that stage of growth were not sufficient to compensate for loss of plants. Overall, the highest sub clover production at the end of the season was 8628 kg DM/ha for the cultivar Yarloop sown at 1024 kg pure germinating seed/ha.

Lawson and Rossiter (1954) found no differences in yield of sub clover cultivars provided these were sown at equivalent weights of pure germinating seed per unit area. Similar results were obtained by de Koning (1984) and de Koning and Carter (1987a). However, the results from the 1985 experiment are at variance, possibly due to weed competition early in the season.

The lower densites of sub clover (1, 4, and 16 kg/ha) in the small-plot experiment 1985 never reached the same sub clover yields as the higher rates (64, 256 and 1024 kg/ha). No doubt this reflected the substantial weed invasion which suppressed the low-density sub clover. Under favourable (weed-free) conditions low plant densities can attain similar yield to higher plant densities (Davidson and Donald 1958, Adem 1977, Prioul and Silsbury 1977). However, the two highest rates of sub clover, reached similar yields at the end of the season.

Weed yield: Cultivars exhibited various levels of competitiveness with weeds, although this depended on the rate of sowing (i.e. sub clover plant density) and the stage in the growing season. No cultivar was able to suppress weed growth at the two lowest sowing rates. The ability to compete with weeds is affected by the growth habits of the cultivar and the weeds. For example, Scott (1971) found plots with tall cultivars (Clare and Yarloop) had significantly fewer weeds than more prostrate cultivars (Geraldton, Mt. Barker and Tallarook). In this 1985 experiment, the tall cultivars (yarloop, Trikkala and Clare) were the most successful competing with weeds. The more numerous and smaller prostrate plants of Esperance are not as competitive as the fewer, larger and taller plants of Yarloop, Trikkala and Clare. Taller and fewer plants are probably more effective in reducing the weed composition by shading some of the weeds. This situation is not dissimilar to that described by Burch and Andrews (1976) who found the fewer, taller Yarloop plants were able to compete successfully with the more numerous but prostrate plants of Larisa. However, weed numbers were not counted in the 1985 experiment, but the canopy height of the cultivars Trikkala, Clare and Yarloop were similar to or higher than the weeds in the plots, while Esperance was shorter.

All cultivars had fewer weeds as sowing rate increased. Greater sub clover plant populations and increased erectness of the swards contributed to the lessened level of weeds. Morphological changes to sub clover swards as with increased density (as described by Yates 1961) would contribute to some extent to weed control. Morphological changes such as sward height may have contributed to some weed control in Esperance plots at the higher sowing rates. However, when Esperance plants died at the highest rate, the gaps remaining were quickly utilized by weeds and the remaining Esperance plants were insufficient to compete with the weeds. Clare swards had become very tall at the highest sowing rates shading weeds effectively, therefore the ratio of weeds to clover was lowest. However, herbage production of a cultivar was also important for weed control. Reductions in herbage production of the cultivar Esperance was due to a loss of plants which probably resulted in greater weed invasion.

3.4.2 Seed harvest results

Seed yield: Some caution is required when interpreting results of above- and below-ground seed yields from only one season, because the extent of burr burial depends on the interaction between cultivar, environment and condition of the soil surface (Yates 1958). In addition, the density of sub clover plants has a very important influence on burr burial. Donald (1954) also stressed that the relationship between density and seed production depended on season.

The big loss of plants of Esperance at the high sowing rates has affected the above-ground seed yields. The other cultivars had higher seed yields as sowing rate increased, but this did not occur for Esperance which had no further increases beyond the sowing rate 64 kg/ha. Esperance had similar seed numbers to the other cultivars, but small seed size limited seed yield. However, below-ground seed yield was very unresponsive to sowing rate. Total seed yield did not greatly increase above the plant density 200 plants/m^2. Similarly, Donald (1954) found the intermediate rates of sowing sub clover to be the most productive for seed yield (densities 269 and 1931 plants/m^2). Donald's highest density (18,510 plants/m^2) was very similar to the level of Esperance plants at the two higher sowing rates in the 1985 experiment. However, seed yield was not related to sub clover herbage production for Donald's (1954) results. The cultivar used by Donald was Mt. Barker which belongs to the *subsp. subterraneum* group as does Esperance used in the 1985 experiment. Esperance was the only cultivar that did not show any significant relationship between total seed yield and herbage production. Possibly both cultivars behaved similarly because they belong to the same sub-species group. Other cultivars representing a range of maturities from the *subsp. subterraneum* would require further density studies to test this assumption.

Bolland (1986) found that the seed yields of sub clover increased with increased sowing rates, but declined as maturity grading of the cultivars increased. However, decreases due to maturity grading were not found in the small-plot experiment 1985.

Clare the latest-maturing cultivar used did not have decreased seed yield (Highest level of total seed production 720 kg/ha).

The stimulus for burr burial appears to have decreased as sowing rate increased and this affected all cultivars to some degree. These results are similar to those of Yates (1961) who showed increased plant cover decreased the stimulus for burr burial due to micro-environment changes to temperature and humidity. Nevertheless, one would expect the burr burial to be relatively low at the low sowing rates in this experiment due to the weed cover. However, weed-infested plots had a sparse canopy structure in comparison to the high-density sub clover plots with dense, compact canopies.

Individual seed weight: The mean seed weight was greater in below-ground burrs (7.58 mg) compared to above-ground burrs (7.36mg). This was true for all cultivars except Esperance, which had similar seed weights for above- and below-ground seed. Similarly, Yates (1957) found that the strain Red Leaf had the lighter seed above-ground. But the results from the 1985 Waite Institute experiment indicate that not all cultivars behave the same way and the effect may be modified by plant density.

Decreases in seed weight as initial sowing rate increased were more pronounced for above-ground seed. Esperance and Trikkala were the only cultivars to show this response. Competition between plants within the swards as sowing rate increased would account for part of this effect. Inter-plant competition may explain why Yarloop had depressed mean seed weight at the higher sowing rates, but a combination of weed competition and intra-plant competition may be the cause for low mean seed weights at the lowest sowing rate. Donald (1954) found intra-plant competition occurring at the lowest and sparsest plant densities (12 to 79 plants/m2). The cultivar may determine the extent of intra-plant competition effects on mean seed weight, since the other cultivars in this experiment (i.e. Trikkala, Esperance and Clare) did not show signs of reduced mean seed weight at the lower densities.

Germination of seed in burrs: Increases in seed germination in burrs from late-sown treatments may suggest that more readily-germinable seed was produced under the shortened growing season. However, hard seed percentage did not change in response to sowing time for above-ground burrs. Above- and below-ground, dormant seed content was reduced in late sown treatments.

Clare was the only cultivar which had substantial decreases in the percentage soft seed in below-ground burrs when compared to above-ground burrs, irrespective of sowing time. Conversely, Yarloop had an increase in soft seed in below-ground burrs. Germination results of Yarloop follow those found by Yates (1957) and Quinlivan and Francis (1971), whereby better germination and viability of seed was found below-ground compared to above-ground seed. However, Clare contrasts with these results: thus any differences between above- and below-ground germination percentages may also be dependant on the cultivar.

Commonly the hard seed percentage found below-ground was approximately half that for the above-ground burrs, irrespective of cultivar or sowing rate effects. This result conflicts with most research which has found that the highest proportion of hard seed is found in below-ground burrs (Quinlivan and Francis 1971, Collins *et al.* 1976). Possibly the heavy soil texture at the Waite Institute may have influenced the amount of dormant seed produced below-ground due to high moisture content. Such soil types would retain more moisture than sandy textured soil types used by Quinilivan and Francis (1971) and Collins *et al.* (1976). Only below-ground burrs from early-sown treatments had significant differences between cultivars ($P<0.05$). Yarloop had the highest percentage hard seed below-ground. Differences in hard seed percentages between cultivars was not great for above-ground burrs ($P<0.05$), most cultivars having between 60 - 68 % hard seed irrespective of sowing rate.

The amount of loose seed was high in some samples which were wet-sieved and this in part may account for reduced hard-seed levels in burrs. Another reason for a lower percentage of hard seed below-ground could possibility be due to a high level of microbial attack on seed produced below-ground (Taylor 1984). This may cause some reduction in percentage hard seed. A high level of microbial attack may have resulted from the wet December 1985 (Table 3.0) and the warm temperatures. The December rainfall was very similar to normal June and July rainfall. This would have created ideal conditions for soil-borne microbes, because the soil would remain relatively moist for a longer time compared to the surface burrs and sub clover residues. Wet-sieving of below-ground samples is not believed responsible, because samples were blotted thoroughly with absorbent paper after washing and dried to prevent the imbibition of seed. Checks were made on burrs in the oven to see if imbibition did occur, and showed no imbibition.

Irrespective of sowing rate, there was variation between cultivars in the percentage soft seed and dormant seed categories. For example, Clare had the highest soft seed from above-ground burrs, conversely Clare had the lowest percentage dormant seed, usually half that of the other cultivars. The situation was reversed for the below-ground burrs; Clare had the lowest percentage soft seed and one of the highest dormant seed contents. Cultivar differences in soft and dormant seed levels will influence subsequent regeneration. A cultivar with high soft and dormant seed percentages will have high levels of germinable seed at the break of the season. However, this could also mean much seed will germinate with a 'false break' to the season, resulting in the loss of seed resources.

Regeneration of sub clover in the field: The number of seedlings was dependant on both cultivar and the sowing rate, irrespective of sowing time. The highest level of regeneration was obtained by the cultivar Esperance (2099 plants/m^2 at the initial sowing rate 256 kg/ha). Reed *et al*. (1985) found Esperance to be successful with regard to plant density early in winter. The numerous but smaller seed of Esperance accounts for this effect. Yarloop, Trikkala and Clare progressively had fewer seedlings as initial sowing rate increased. This is contrary to the actual numbers of seed produced per unit area which showed an increase in seed number as sowing rate increased. The high sowing rate cultivar plots of Trikkala, Clare and Yarloop were observed to have a greater bulk of dry sub clover residue on the surface than Esperance plots, therefore blanketing of seedlings may have been more severe on those plots. The 'blanketing effect' can be a serious problem of high density and/ or under-utilized swards in physically constraining emergence of seedlings following summer rains or early-autumn rains (Carter 1954, 1987).

3.4.3 Conclusions: The results of this experiment have shown that the early-season herbage production of sub clover-based pasture is dependent on seed size and plant density. High plant density is essential for high early winter production. However, this is partly dependant on the cultivar, for example Clare had less seedlings than Esperance but still maintained good early production. Results clearly show that the weight of pure germinating seed is important for early herbage production.

Maintaining high sub clover density in a pasture improves the ability of that pasture to produce seed and to compete with weeds. Suppression of weeds depends on both the sub clover plant density and the growth habit of the sub clover cultivar. This is especially important when sub clover-based pastures are ungrazed. The results also indicate that a pasture based on a more prostrate cultivar (e.g. Esperance) would require greater plant numbers than a taller cultivar (e.g. Clare) in suppressing weeds under ungrazed conditions. In practical terms it is normally better to have a lower yield from a pasture with a high proportion of desirable sown species, rather than a higher total pasture yield with a large proportion of weeds. Livestock production may be reduced if pasture contains a high percentage of unpalatable weeds. Research has shown that even when feed is limited early in the season sheep will avoid the most abundant species if these are unpalatable weeds (Broom and Arnold 1986). However, the 1985 experiment was not grazed and the closest comparison which could be made to practical situations would be pasture spelling early in the season to protect establishment or late in the season for haymaking practices. Nevertheless, both practical situations require high quality pasture.

The results from this experiment also show the relationship between herbage production and seed yield. In general the cultivars which produced the most herbage also had the highest seed yield. This was the trend for all cultivars except Clare which produced the highest seed yield but had similar herbage production to some other cultivars. In addition, both sub clover herbage and seed production increased as sowing rate increased. A cultivar such as Esperance had no further increases in herbage production when the sowing rate was high, seed yield followed the same pattern.

Sowing time effects have the most relevance in the year of establishment. Late-maturity cultivars of sub clover should be sown as soon as practical so benefits of high production (herbage and seed) can be achieved. In years of natural regeneration a late start to the season will affect the later-maturing cultivars the most in terms of reduced herbage and seed production.

High density swards which have not been grazed and have a large mass of dry pasture residue usually suppress emergence of seedlings in the following season. Therefore, it is important that some of the dry herbage cover is removed during the summer months to ensure that seedlings can emerge freely. Results also indicate that the smothering of emerging seedlings is influenced by the amount of dry pasture.

Management of pastures should aim for high herbage yield and seed yield. During summer and autumn grazing it will be essential to remove some dry residue to avoid suppression of emergence of seedlings by blanketing: however, summer-autumn grazing must be carefully monitored to avoid excessive depletion of seed (See Chapter 5). High production of pure germinating seed is essential for high seedling regeneration, resulting in good early herbage production of sub clover-based pastures.

4

GRAZING EXPERIMENT 1986 - 1987

4. GRAZING EXPERIMENT 1986 - 1987

4.0 Introduction

Sub clover plant density and grazing pressure are important components involved in maximizing herbage and seed production and the potential performance of sub clover cultivars has to be assessed under defoliation by the grazing ruminant animal.. The soil-plant-animal interactions are numerous and very complex but this is no reason to avoid research into these important interactions. Very little is known about the response of various clover species and cultivars under realistic grazing conditions. The following quotation from Francis *et al.*(1976) sums up some of the problems. ".... a need for more study in grazing recovery in relation to cultivar differences....should be considered in conjunction with winter growth because the two may in fact be antagonistic....rapid growing types with leafy growth may not recover as well as other types and persist less well in mixed swards". Many researchers have made reference to the lack of understanding of population dynamics and ecology of pastures grazed by animals (Rossiter 1966, Carter 1968, Carter 1977, Watkin and Clements 1978, Williams 1978, Whalley 1980, Dunlop *et al.* 1984, Christian 1987, Obst 1987).

A small-scale grazing experiment was described in which the importance of pasture and/or grazing management was revealed (de Koning and Carter 1987b). It is possible to have a high-producing cultivar (e.g. Yarloop or Clare) but if mismanaged (e.g. under- or over-stocked) density and herbage productivity may be reduced, and the benefits of high herbage production may be nullified also seed production may also be reduced. The experiment described in Chapter 3 demonstrated how under-utilised pastures with a large bulk of dry pasture residues can reduce the subsequent regeneration. The reverse situation can also occur: low-producing cultivars if managed wisely can produce comparatively well (Brougham and Cosgrove 1985). Walton (1975) suggested that sward density was very important when considering experiments which evaluated sub clover genotypes for seed yield under defoliation. This lack of information on the overall impact of grazing on sub clover provided the impetus to initiate further research on the grazing management of the cultivars that were ungrazed in the 1985 small-plot experiment. This experiment described in Chapter 3 did show cultivar differences in herbage and seed production and these differences varied with plant density. Therefore it is important to establish whether these differences will occur under grazed conditions.

A field experiment was established in 1986 to quantify the effects of three grazing pressures and two plant densities on the herbage and seed production of five cultivars of sub clover and a mixture of these.

4.1 Materials and Methods

Location and preparation of site: The grazing experiment was established on red-brown earth soil on semi-improved old pasture (volunteer grasses-*Lolium spp.* and *Vulpia spp.* -with some Bacchus Marsh sub clover) at the Mortlock Experiment station (M.E.S.), Mintaro, South Australia, approximately 85 km north of Adelaide. A fine seed bed was prepared by scarification, then sprayed with non-selective herbicide (Roundup ®) before sowing.

Experimental design: Five cultivars were used, viz; Nungarin, Dalkeith, Trikkala, Junee and Clare in order of maturity. These cultivars represented a range suited to the Clare-Mintaro region. The mean seed weights of the cultivars were 6.0, 7.1, 9.6, 7.0, and 12.5 mg respectively and the germination percentages of the same commercial seed was 99, 99, 95, 86, and 91 respectively. A mixture of all five cultivars, (20% by weight of each) was also included, because complex mixtures comprising several cultivars are considered more stable in the long term over several seasons and have been advocated by pasture researchers (eg. Carter and Wigg 1963; Carter 1983). Thus, there were six different sub clover swards (i.e. 5 cultivars and a mixture of all five) each at two densities.

Two sowing rates, Low = 10kg/ha and High = 200 kg/ha were used. These two rates, although not exactly the same as used for the 1985 small-plot Waite Insititute experiment are still within the range of rates which showed contrasting effects and are representative of the amount of seed commonly found in the field. A low rate (10 kg/ha) typifies new-sown pastures while the high rate (200 kg/ha) is representative of many regenerating pastures.

The swards were continuously grazed with Merino wethers at three stocking rates, viz: Low = 7 sheep/ha; Medium = 11 sheep/ha; High = 15 sheep/ha. The experimental design was therefore a split plot design with Stocking Rate as the main plots and Sowing

Rate and Cultivar factorially arranged as the subplots. There were 2 replicates. Each sown plot measured 2.9 x 30 metres (see Diagram 4.1). Thus the experimental design was:

Swards (6) x Sowing rates (2) x Stocking rates (3) x Blocks (2) = 72 plots.

Sowing details: The plots were sown with a 16-row John Shearer tyned seed drill with trailing harrows on May 28, 1986. Depth of sowing was c.10mm. Prior to sowing, the drill was calibrated for each cultivar at each sowing rate. The low sowing rate was sown through the small seed box. The high sowing rate was sown through the coarse side of the large grain box.

The 12 treatments were allocated at random within the six groups of 12 plots (see Diagrams 4.1 and 4.2). Despite calibration of the drill for each cultivar and mixture at both sowing rates there were discrepancies in the actual rates sown. The treatments were designated as follows:

Nominal 200 kg/ha	Actual (kg/ha)	Nominal 10 kg/ha	Actual (kg/ha)
A: Nungarin	241	G: Nungarin	11.8
B: Dalkeith	218	H: Dalkeith	11.3
C: Trikkala	202	I: Trikkala	10.7
D Junee	240	J: Junee	11.4
E: Clare	212	K: Clare	10.4
F: Mixture	225	L: Mixture	10.7

The buffer zone was sown the following day using the same mixture of cultivars at the nominal rate of 20 kg/ha. The actual buffer zone sowing rate was 22.7 kg/ha. A mixture of single superphosphate and lime (50% : 50%) was applied at the rate of 100kg/ha through the fertilizer box at the time of sowing. Prior to sowing all seed was inoculated with type C Rhizobium bacteria.

Watering points, gates and subdivisional fences were installed shortly after sowing, but following spraying with selective herbicide and insecticide. Redlegged earth mite was sprayed with Perfekthion EC46 on 12June 1986. The whole area was sprayed with Fusilade ® 212 (active ingredient fluazifop-butyl) at 500ml/ha rate on 21 August 1986 to control grasses). Establishment counts were made on 8 July, 1986. Regeneration counts in subsequent years were made on the 20 May, 1987 and finally on the 26 May, 1988. Details of rainfall for the 1986 and 1987 season are outlined in Table 4.0.

Table 4.0: Rainfall (mm) and mean monthly temperature (1972 - 87 data) for each month at the Mortlock Experiment Station, Mintaro, South Australia for the year 1986 and 1987 and the long-term mean at Mintaro P.O.†

	Rainfall (mm) 1986	Rainfall (mm) 1987	Temp Max. °C	Temp Min. °C
Jan	4.8	38.8	28.7	14.3
Feb	4.8	23.0	28.8	14.8
Mar	0.4	11.6	25.4	12.7
Apr	46.7	16.4	20.9	10.1
May	33.6	92.0	16.7	8.2
Jun	43.0	61.6	13.5	6.0
July	122.2	84.0	13.0	5.8
Aug	113.4	60.8	14.2	6.5
Sept	82.4	36.0	16.3	7.0
Oct	76.0	51.2	19.3	8.3
Nov	49.8	7.6	23.7	10.7
Dec	26.4	29.8	27.0	12.9
Annual mean * Yearly total	*603.5	*512.8	20.6	9.8

† At a distance of c. 2 km from the experiment site.

<u>Sheep selection, allocation and management:</u> Thirty six sheep were selected from a flock of 109, 2 year old Merino wethers. Those sheep selected were the closest in liveweight to the flock mean. Six of the thirty six sheep were spares. The remaining thirty sheep were allocated at random to the six subdivided paddocks (i.e. Blocks (2) x Stocking rates (3) = 6 paddocks; see Diagram 4). Each of the paddocks was 0.45 ha, therefore the number of sheep allocated to the Low (L.S.R), Medium (M.S.R) and High stocking rates (H.S.R) were 3, 5, 7 respectively (i.e. 7, 11, and 15 sheep/ha

respectively). Sheep were introduced to the area 5 September, 1986. At this stage the pasture was well established. Sheep had access to all treatment plots within a stocking rate. The sheep grazed the area continuously until 11 November, 1987.

Greasy wool weights (Appendix B, Table 1) were measured 9 March, 1987 and autumn-winter liveweights recorded on 4 July, 1987 and finally on 12 November, 1987 (appendix B.1). The table also shows the liveweights of individual sheep before the experiment.

Because of very low pasture availability, cereal hay was fed from 4 July to 5 Oct., 1987 to sheep on the two high stocking rate areas. Half a bale of hay was fed three times a week in the buffer zone.

Herbage harvests: The first herbage harvest was taken on 4 September, 1986 the day before sheep were introduced to the area. This harvest indicated the levels of pasture availability at the time the sheep were introduced to the area. Two 25 x 40 cm quadrats per treatment plot were cut to ground level (i.e. one taken west and the other east on the drill strip). The 'open' and 'closed' quadrat method of Mc Intyre (1946) was adopted for the measurement of pasture availability and cumulative growth of the pasture.

The "open" cuts were made adjacent to the quadrat cage which was placed on a similar representative site. Two quadrat cages measuring 70cm square and 1m tall were placed in each plot. The 'closed' cuts were taken from within the cage. Harvest 2, was taken on 23 October, 1986 using 40 x 36 cm quadrats (2 quadrats 'open' cut , 2 quadrats 'closed' cut per plot). Larger quadrat size was used because of the increasing height of the pasture. Harvest 3, the final harvest for 1986, was taken on 27 November, 1986 using 40 x 40cm quadrats, the same number of cuts were taken per plot as for Harvest 2.

Only two herbage harvests were taken throughout the 1987 growing season, these were taken on 16 September and 25 November, 1987 (Harvests 1 and 2 respectively). The reason for this was that the difference between the outside and the inside of the cage was not great due to the slow pasture growth in 1987. This was partly because of lower annual rainfall in 1987 (513 mm) compared to 1986 (604 mm) [see table 4.1]. At Harvest 1 in 1987, two 'open' and two 'closed' cuts were taken per plot using 36 x 40 cm quadrats cut to ground level. Only two 'closed' samples per plot using a 25 cm x 25 cm cutting quadrat were taken at Harvest 2. The cutting quadrat was used because at that stage the herbage was still green, but very tangled. An electronic pasture probe was used to take both 'open' and 'closed' readings on the same day (two 'open' and two 'closed' per plot = 288 readings).

All 'open' cuts were hand-separated into sub clover and weeds in 1986 and in 1987 into sub clover, grass and weeds. Herbage samples were dried at 85^oC for 24 hrs in a forced-draught dehydrator. Between both harvests in 1987 a non-destructive estimate of botanical composition was made on grazed areas (6 paddocks) on the 19 October using the Levy Point Quadrat method. Four sets of readings were taken per plot (two from the eastern end and two from the western end).

Quadrat cage placement and movement: Each drill plot was divided into two 15m lengths and a quadrat cage was placed in each half plot. One quadrat cage was placed at the western end of the plot and the second cage was placed on the mid-line. On each harvest occasion quadrat cages were moved onto a new representative site after the cut was taken from the in-place cage. Cages were progressively moved eastward along the plots (see Diagram 4.3). The schematic movement of cages in this manner avoided previously-harvested sites.

Seed harvests: Seed harvests were taken at the end of each growing season, when the burrs had fully matured. The seed harvests for the 1986 growing season were taken on the 6 and 7 January, 1987 and for the 1987 growing season the seed harvest was taken in late December (hereafter called 1986 and 1987 seed harvests respectively). Samples were taken within the two cages per plot. In addition, two sets of galvanised mesh (apertures 75mm x 50mm) cut into pieces 40 x 35 cm were placed adjacent to the cages on the last harvest occasion of each year to provide extra sampling areas. Therefore, a total of 4 seed samples were taken per plot. This gave a measure of the maximum seed production before the influence of burr consumption by sheep in early summer. Samples were taken using infiltrometer rings as described in Chapter 3, Materials and Methods. Both above- and below-ground samples were processed in the same way as outlined in Chapter 3.1. Burr numbers/m^2, seed number/m^2 and seed yield (kg/ha) were determined.

Germination tests were made on above- and below-ground burrs from both the 1986 and 1987 seed harvests. Two groups of 25 burrs were removed at random from each plot (i.e. 25 burrs from an east sample and 25 burrs from a west sample). This gave a total of 144 petri dishes for both above-ground and below-ground samples. A total of 288 petri dishes included both above- and below-ground samples. Burrs were treated in the same manner as described in Chapter 3.1.

Samples of 20 burrs for dissection were taken at random from each treatment plot across both sowing rates and all stocking rates (72 samples). Burrs were carefully pulled apart using forceps, so that the exact number and weight of seed could be determined. The weight of burr bracts was also measured.

<u>Data Analysis</u>: Analysis of variance was made on data using Genstat IV. An overall analysis was conducted to assess possible Sowing Rate x Cultivar and Sowing Rate x Stocking Rate interactions. If Sowing Rate was significant as a main effect each sowing rate was analysed separately to examine more closely differences between cultivars within a sowing rate.

Diagram 4.1: The position and orientation of treatment plots

L.S.R. = Low Stocking Rate
M.S.R. = Medium Stocking Rate
H.S.R. = High Stocking Rate

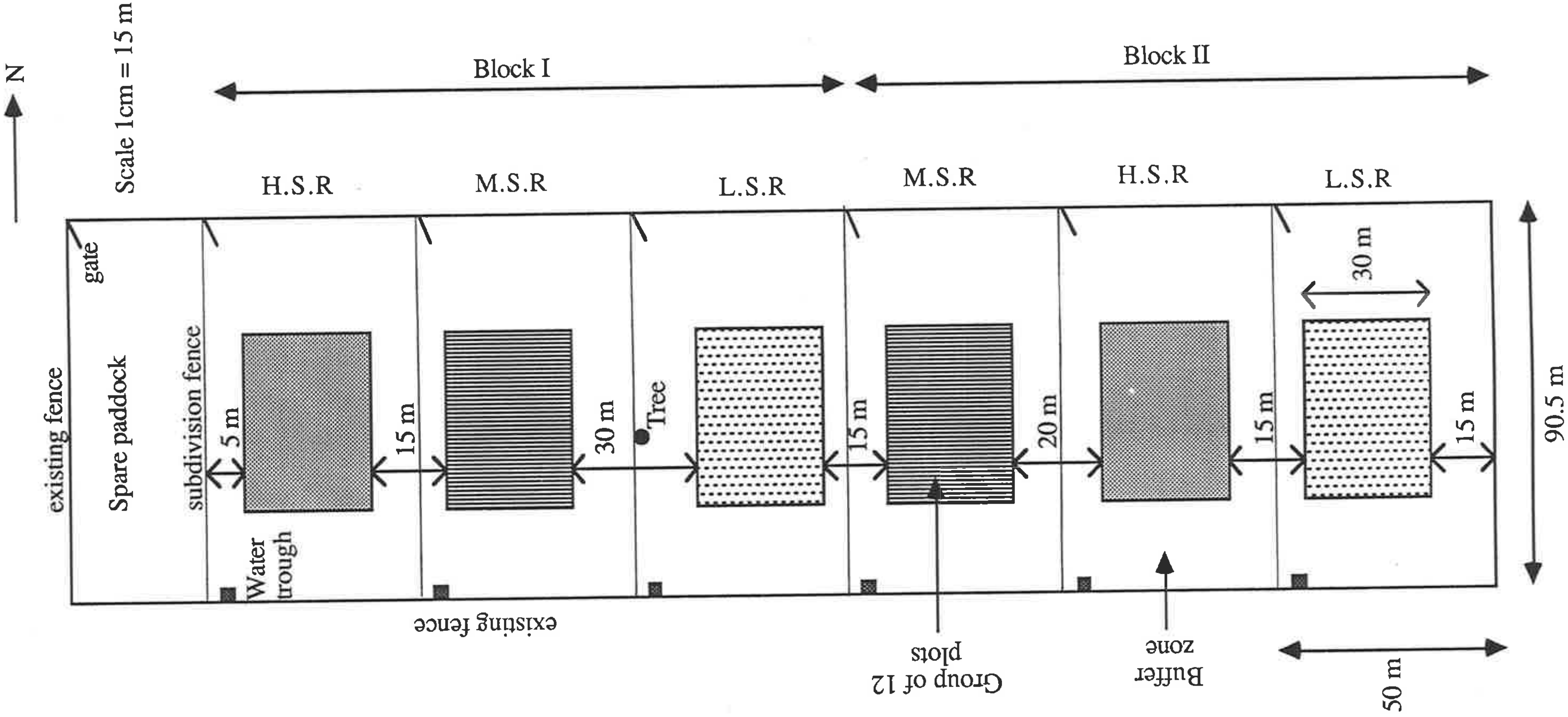
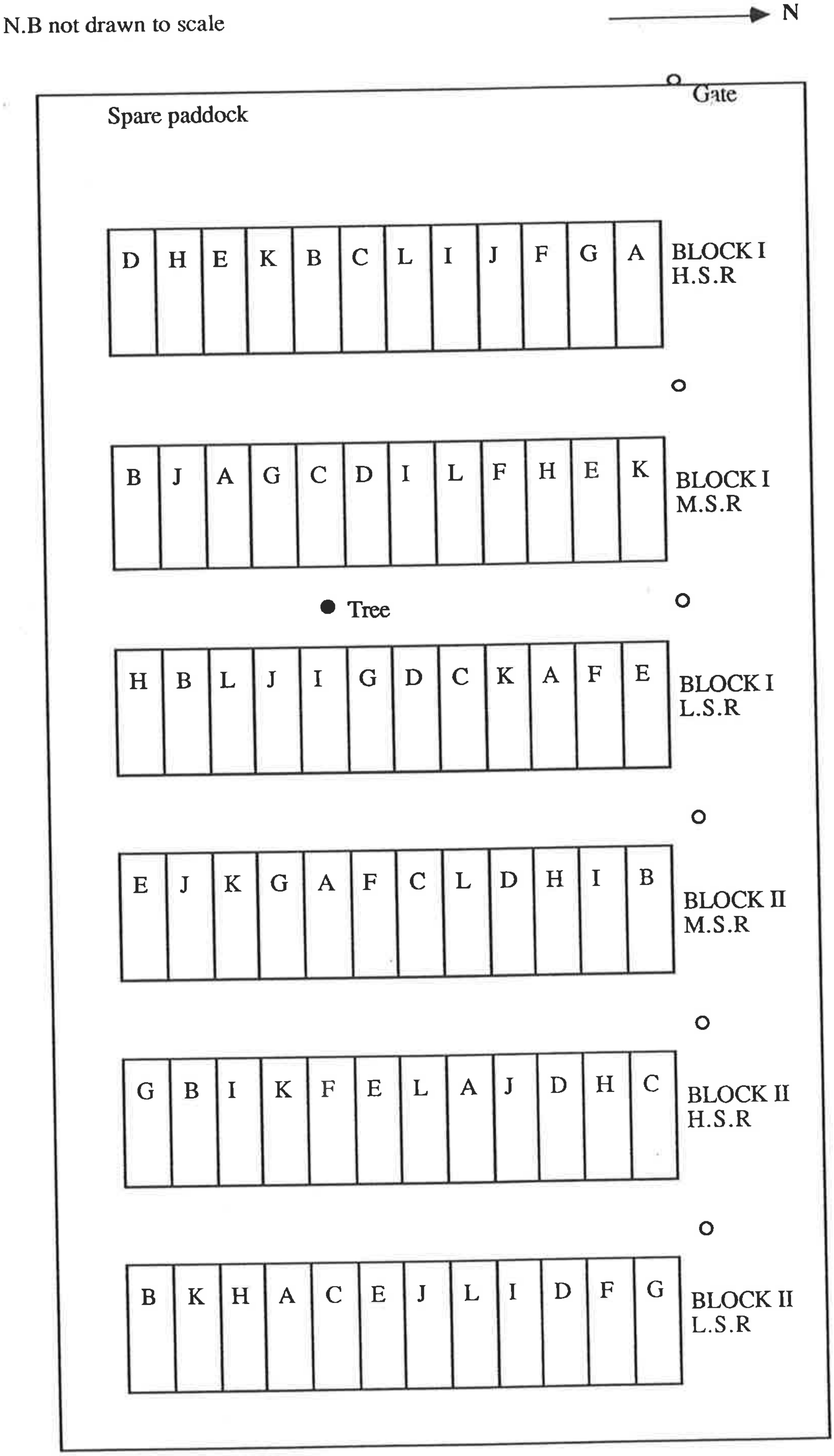

N
Scale 1cm = 15 m
Block I
Block II
H.S.R
M.S.R
L.S.R
M.S.R
H.S.R
L.S.R
gate
existing fence
Spare paddock
subdivision fence
5 m
15 m
30 m
Tree
15 m
20 m
15 m
15 m
30 m
90.5 m
Water trough
existing fence
Group of 12 plots
Buffer zone
50 m

Diagram 4.2: Randomization of treatments.

200 kg/ha	10 kg/ha
A: Nungarin	G: Nungarin
B: Dalkeith	H: Dalkeith
C: Trikkala	I: Trikkala
D: Junee	J: Junee
E: Clare	K: Clare
F: Mixture	L: Mixture


N.B not drawn to scale
N
Gate
Spare paddock
D H E K B C L I J F G A
BLOCK I H.S.R
B J A G C D I L F H E K
BLOCK I M.S.R
Tree
H B L J I G D C K A F E
BLOCK I L.S.R
E J K G A F C L D H I B
BLOCK II M.S.R
G B I K F E L A J D H C
BLOCK II H.S.R
B K H A C E J L I D F G
BLOCK II L.S.R

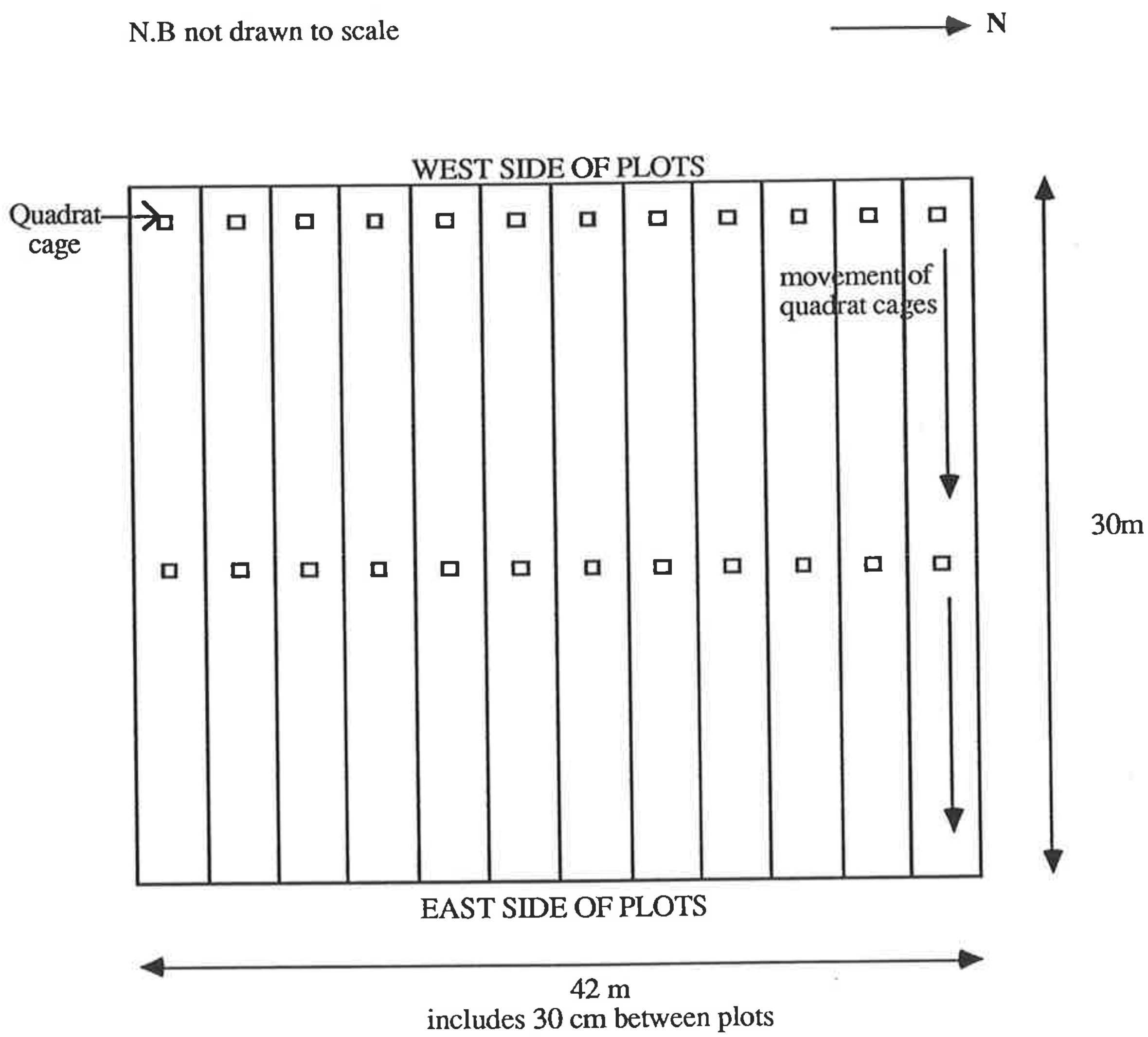


Diagram 4.3: The movement and position of quadrat cages.

Plate 4.1: General view of a low stocking rate area (7sheep/ha) at MES in 1986. High density plot in fore-ground.

Plate 4.2: View of a high stocking rate area (15 sheep/ha) at MES in 1986.
Left: high sowing rate plot.
Right: low sowing rate plot.

4.2 HERBAGE HARVEST RESULTS, MES 1986 - 1987

Detailed tables of the data are presented in Appendix B, Tables B.9 - B.29.

4.2.1 Sub clover establishment

Results in 1986

The actual number of seedlings to emerge was compared to the expected level of emergence (i.e. seed #/kg commercial seed x germination percentage = the number pure germinable seed/kgTable 4.1). The low sowing rate had a greater percentage emergence (78 - 96%) compared to the high sowing rate (61 - 78%). A possible cause for this difference may have been due to large numbers of seedlings germinating at the same time heaving up a surface crust on high sowing rate plots through which they could not emerge. Individual seedlings on the low sowing rates did not push up a soil crust. Both cultivars Nungarin and Dalkeith had more, but smaller seedlings emerging. Nevertheless, in terms of actual numbers of seedlings, differences were highly likely to occur between cultivars (Table 4.1).

In the year of sowing, (1986) establishment counts were made before sheep were introduced to the area. The data required natural log transformation. Counts were made along four transects across each of the six sets of treatment plots (288 counts made). The main effect, Sowing Rate was highly significant ($P<0.001$).

Table 4.1: Sub clover establishment counts at MES before sheep were introduced to the area (Plants/m^2, mean of four transects, 8 July 1986).

Sowing Rate	10 kg/ha			200 kg/ha		
	Expected	Actual	% Estab.	Expected	Actual	% Estab
Nungarin	177	142	80	3602	2183	61
Dalkeith	157	121	77	3045	1772	58
Trikkala	96	76	79	1818	1353	74
Junee	112	107	96	2355	1826	78
Clare	73	66	90	1484	1125	76
Mixture	117	94	80	2463	1626	66
Sowing Rate Mean		101			1649	

4.2.2 Pasture yield and botanical composition

Sub clover availability and weed yield was determined from 'open' cuts.

1986, Harvest 1 (4 Sept., 1986)

(i) Sub clover availability: Sowing rate had a highly significant effect (P<0.001, transformed data) on herbage production of sub clover. The mean yield for high and low sowing rate plots were 1931 and 194 kg DM/ha respectively.

Analyses were carried out on each sowing rate separately. Nungarin, Dalkeith, Junee, Clare and the mixture had very similar yields when sown at 200 kg/ha. Trikkala was the only cultivar which had a significantly lower yield (P<0.001, Table 4.2). Cultivars were not significantly different from one another when sown at 10 kg/ha.

(ii) Weed yield: Weed yield was determined from hand-separated samples. The 1986 season had only one category of weeds because of grassy weeds were eliminated by spraying with Fusilade ® early in the season. Surviving weeds comprised mainly broadleaf weeds such as poppy (*Papaver hybridum*), capeweed (*Arctotheca calendula*), and *Erodium spp*.

Sowing rate was the only factor which significantly influenced yield of weeds (P<0.05). More weeds were found on low sowing rate plots (151 and 344 kgDM/ha for high and low respectively). Sub clover cultivars did not influence the amount of weed present (Table 4.2).

Table 4.2: Available pasture: sub clover, weeds and total (kg DM/ha) at the sowing rates 10 and 200 kg/ha on 4 Sept., 1986 at MES, prior to grazing by sheep.

	Nungarin	Dalkeith	Trikkala	Junee	Clare	Mixture	Mean
10 kg/ha							
Sub clover	249	187	179	161	218	173	195
Weeds	304	388	385	399	343	244	344
Total	553	575	564	560	561	417	538
200 kg/ha							
Sub clover	2137	2030	1325	2019	2001	2073	1931
Weeds	125	143	230	148	129	131	151
Total	2262	2173	1555	2167	2130	2204	2082

Cultivar x Sowing Rate interaction for Sub clover, LSD(5%) = 204

1986, Harvest 2 (23 Oct., 1986)

(i) Sub clover availability: Sowing rate was highly significant ($P<0.001$, Table 4.3). Overall analysis showed no statistically-significant stocking rate effect. This could be the result of having only two replicates with which to test the effect of stocking rate. Another probable reason for the lack of difference is the high availability of pasture which is often the situation with first year experiments of this type.

(ii) Weed yield: Sowing rate was the only significant effect on weed yield ($P<0.001$). As found for Harvest 1, there were significantly more weeds on low sowing rate plots compared to high sowing rate plots (223 and 27 kg DM/ha respectively, also data needed logx + 1 transformation).

Table 4.3: Available pasture: sub clover, weeds and total (kg DM/ha) on 23 Oct., 1986 at MES.

	Nungarin	Dalkeith	Trikkala	Junee	Clare	Mixture
10 kg/ha						
Sub clover	2990	2242	2295	2651	1751	2513
Weeds	192	253	239	211	185	257
Total	3182	2495	2534	2862	1936	2770
200 kg/ha						
Sub clover	4662	4758	4936	5232	3688	4604
Weeds	15	18	33	53	4	39
Total	4677	4776	4969	5285	3692	4643

1986, Harvest 3 (27 Nov., 1986)

(i) Sub clover availability: Sowing rate was significant (6525 and 4559 for high and low sowing rates respectively, P<0.001, Table 4.4). Analysis of each sowing rate separately showed cultivar differences at the low sowing rate only (P<0.001). The cultivars Nungarin, Dalkeith and Clare had the lowest availability, while Trikkala, Junee and the mixture had the highest availabilities of sub clover (Table 4.4). The Stocking Rate x Cultivar interaction was also significant at the low sowing rate (P<0.05, see Appendix B, Table 12). All cultivars except Clare and the mixture, showed a decline in availability as stocking rate increased.

(ii) Weed yield: Sowing rate was highly significant (P<0.001, log transformed data). More weeds were found on low-sowing-rate plots compared to high-sowing-rate plots (486 and 25 kg DM/ha respectively, P<0.001, Table 4.4).

Table 4.4: Available pasture: sub clover, weeds and total (kgDM/ha) on 27 Nov., 1986 at MES.

	Nungarin	Dalkeith	Trikkala	Junee	Clare	Mixture
10 kg/ha						
Sub clover	3731	3491	5175	5624	3919	5415
Weeds	685	430	768	304	238	490
Total	4416	3921	5943	5928	4157	5905
At 10 kg/ha: Cultivar LSD (5%) = 851						
200 kg/ha						
Sub clover	5778	5412	7264	7505	6279	6913
Weeds	14	31	18	60	19	8
Total	5792	5443	7282	7565	6298	6921

1987, Harvest 1 (16 Sept., 1987)

(i) Sub clover availability: Dry Matter production was not significantly affected by the 1986 sowing rate (average of 1683kg DM/ha and 1836 kg DM/ha for high and low sowing rates respectively). The best overall availability was for Nungarin > Dalkeith =

Trikkala = Mixture >Junee = Clare (Table 4.5). The Stocking Rate effect was not significant for treatments sown at 200 kg/ha, but stocking rate effects were significant for treatments sown originally at 10 kg/ha (P<0.05, see Appendix B, Table13). All stocking rates varied significantly from one another, the high stocking rate had the lowest availability.

(ii) Weed yield: In 1987 there were clearly two categories of weeds, hence the division of "grasses" and "broadleaf". The category "broadleaf" consisted mostly of capeweed, *Erodium spp.*, cluster clover (*Trifolium glomeratum*) and woolly clover (*T. tomentosum*). More grasses were found on plots sown originally at the low rate (393 kgDM/ha) than on plots sown originally at the high rate (145 kgDM/ha). All data needed natural logarithmn transformation. No differences were found between high and low sowing rate treatments in the amount of "broadleaf" weeds (268 and 253 kgDM/ha respectively). Statistically there were no significant differences between stocking rates or cultivars: however, biologically differences may be significant. Reasons for this will be discussed later.

Table 4.5: Available pasture: sub clover, weeds and total (kg DM/ha) on 16 Sept., 1987 at MES.

	Nungarin	Dalkeith	Trikkala	Junee	Clare	Mixture
Sown at 10 kg/ha in 1986						
Sub clover	2538	1774	1717	1712	1203	2074
Grass	378	574	244	505	212	444
Broadleaf	232	309	232	209	392	147
Total	3148	2657	2193	2426	1807	2665
Sown at 200 kg/ha in 1986						
Sub clover	2768	1903	1508	1088	1076	1753
Grass	165	236	131	169	94	74
Broadleaf	151	89	335	416	454	162
Total	3084	2228	1974	1673	1624	1989
Overall cultivar mean (both sowing rates) LSD(5%) = 629	2653	1839	1613	1400	1140	1913

1987, Harvest 2 (final harvest - 25 Nov., 1987)

Pasture availability on 25 Nov., 1987 is summarised in Table 4.6. Electronic pasture probe readings were taken outside the quadrat cages to measure pasture availability on representative sites (high probe readings indicate high dry matter present). The low sowing rate had significantly more herbage than the high sowing rate (4614 kg DM/ha and 4348 kg DM/ha respectively, $P<0.05$). At the initial sowing rate of 200 kg/ha, Junee and Clare had the highest reading, hence the highest dry matter (Table 4.6). Clare plots also produced most herbage when sown initially at 10 kg/ha in 1986. It should also be noted that the probe readings included the green weed component but this was small. Stocking Rate had no effect on herbage on offer.

Estimates of pasture yield were obtained by plotting the inside cage probe readings vs. the actual dry matter yield cut from the same quadrat (Appendix B, Figure 1). Electronic pasture probe readings inside the cages varied widely enough to cover the range of readings found outside the cages. A regression was fitted and the values could be estimated from the equation: $y = 3568 + 524.1\ x$, ($r = 0.678^{***}$, $n = 144$).

Table 4.6: Pasture availability data (kg DM/ha) derived from Electronic pasture probe readings on the last harvest occasion on 25 November, 1987 at MES.

	Nungarin	Dalkeith	Trikkala	Junee	Clare	Mixture
Sown at 10 kg/ha in 1986	4202^{a}	4538^{ab}	4438^{ab}	4611^{abc}	5104^{c}	4790^{bc}
Sown at 200 kg/ha in 1986	4082^{a}	4129^{a}	4140^{a}	4700^{b}	4737^{b}	4297^{a}

Differing superscript letters indicate significant differences based on probe readings (within a sowing rate only)

1987, Levy Point Data:

A non-destructive assessment of botanical composition was made on 19 Oct., 1987. The Levy point quadrat method (Tiver and Crocker 1951) was used to quantify available pasture at that time. By using this method it was possible to also measure the percentage bare-ground exposed in the pasture which is very important in grazed pastures. Four categories of botanical composition were quantified, viz; sub clover %, other legume %, grass %, and broad-leaf weeds %. "Other legumes" consisted mostly of cluster clover and woolly clover.

No statistically-significant differences were found for the main effects of Stocking Rate, Sowing Rate and Cultivar for the category bare-ground. However, there was a trend for the percentage bare-ground to increase as stocking rate increased (See Appendix B, Table B.2).

The percentage sub clover was not significantly affected by any factor.

For the component of other legumes Stocking Rate x Sowing Rate was significant ($P<0.05$, see Table 4.8). At the high stocking rate there was a significant increase in other legumes on plots sown initially at 10 kg/ha compared to the high sowing rate (200 kg/ha).

No statistically significant differences were found for percentage grass. The level of broadleaf weeds was minimal: on average they comprised only 2 percent of the total herbage. Therefore, it was not surprising that no significant effects were found.

Table 4.7: Botanical composition: percentage overlapping cover of sub clover, grass, other legumes and broadleaf weeds (Levy point quadrat data) grazing experiment at MES on 19.10.87. (Analysis based on arcsine transformed data, natural percentages are presented here).

	Nungarin	Dalkeith	Trikkala	Junee	Clare	Mixture
Sub clover	59.9	56.2	73.5	59.5	71.0	69.7
Grass	15.7	23.6	6.1	17.1	9.8	11.8
Other legume	21.4	18.9	17.9	22.3	16.0	17.0
Broadleaf	3.0	1.3	2.5	1.1	3.2	1.5

Table 4.8: The interrelations between Stocking Rate and Sowing Rate for the percentage overlapping cover of other legumes (Levy point quadrat data) grazing experiment at MES on 19.10.87. (Analysis based on arcsine transformed data, natural percentages are presented here).

	Sowing rate in 1986	
	10 kg/ha	200 kg/ha
Stocking rate		
LSR	1.1	5.0
MSR	19.8	22.1
HSR	40.0	25.5
LSD (5%) = 16.5		

4.2.3 Pasture production

Pasture production is the amount of pasture growth between harvest occasions. This includes the weeds.

<u>1986, Harvest 1 to Harvest 2; (H1 - H2)</u>

Analysis of variance showed that Sowing Rate was the only factor that significantly affected pasture production ($P<0.001$, Table 4.9). The high sowing rate had the greater production (4582 kgDM/ha) compared to the low sowing rate (3165 kgDM/ha).

<u>1986, Harvest 2 to Harvest 3; (H2 - H3)</u>

In contrast to the previous growth period (H1 - H2), the high sowing rate had the lower pasture production (3046 c.f. 4394 kgDM/ha). There were significant differences in pasture production between cultivars at the higher sowing rate (Table 4.9). Clare and Junee, irrespective of stocking rate, had the greatest production while Dalkeith had the least. The effect of stocking rate was only significant at the low sowing rate ($P<0.05$). The pastures grazed at high (4479 kg DM/ha) and medium (5054 kg DM/ha) stocking rates had significantly more production than the pasture grazed at the low stocking rate (3649 kg DM/ha).

The high sowing rate plots produced more than low sowing rate plots (9793 and 8116 kg DM/ha respectively). Analysis of each sowing rate separately showed a significant effect of cultivar at the high sowing rate (P<0.01, Table 4.9), but no effect at the low sowing rate. Clare then Junee, Trikkala and the mixture had the highest pasture yields at the high sowing rate. Nungarin and Dalkeith were not significantly different.

Table 4.9: Pasture production between Harvests 1 and 2 (H1-H2; 50 days), Harvests 2 and 3 (H2-H3; 35 days), and Total Production (kg DM/ha) at MES in 1986.

	Nungarin	Dalkeith	Trikkala	Junee	Clare	Mixture
10 kg/ha						
H1 - H2	3340	3446	3056	2873	2900	3380
H2 - H3	3589	3133	4964	4897	4815	4967
Total *	7482	7272	8583	8330	8265	8763

Cultivar effect at 10 kg/ha: n.s.H1 - H2; n.s.H2 - H3; n.s.Total

* All total production figures include the first pasture availability cut before the the experiment was grazed by sheep.

	Nungarin	Dalkeith	Trikkala	Junee	Clare	Mixture
200 kg/ha						
H1 - H2	4347	4817	4655	4306	4692	4675
H2 - H3	2116	1703	3539	3783	4148	2986
Total *	8726	8694	9748	10256	11470	9865

Cultivar effect at 200 kg/ha: n.s.H1 - H2; LSD (5%) H2 - H3 =1659; Total =1358

1987, Cumulative winter production (emergence to Harvest 1)

Cumulative winter production of the pasture was determined from the first "closed" cut on 16 Sept., 1987 (Table 4.10). The plots sown initially at 10 kg/ha in 1986 had the highest production (5956 kgDM/ha) compared to plots sown initially at 200 kg/ha (5151 kg DM/ha, P<0.001). Cultivar differences were only found on plots sown originally at the high sowing rate. Nungarin had the highest production, while Trikkala, Junee and Clare the lowest. Dalkeith and the mixture were intermediate (Table 4.10).

1987, Harvest 1 to Harvest 2

The plots sown originally at 10 kg/ha were least productive (3147 kg DM/ha, P<0.01) compared to the plots sown originally at 200 kg/ha (3977 kg DM/ha). Cultivar differences in pasture productivity were found on plots originally sown at the high rate (P<0.01, Table 4.10). Trikkala, Junee and Clare plots had significantly greater pasture production between Harvests 1 and 2 while Dalkeith plots produced the least. This result contrasts with the earlier half of the season. At the lower sowing rate, Clare, Junee and Trikkala plots were the most productive whereas Nungarin plots were the least.

Total seasonal production is summarised in Table 4.10. Differences between the initial sowing rates was minimal at the end of the 1987 season (9128 and 8974 kgDM/ha for high and low sowing rates respectively, not significant).

Table 4.10: Pasture production: cumulative winter growth (emergence to Harvest 1, E-H1), Harvest 1 to Harvest 2 (H1-H2) and total production at MES in 1987.
(All data in kg DM/ha)

	Nungarin	Dalkeith	Trikkala	Junee	Clare	Mixture
Sown at 10 kg/ha in 1986						
E - H1	6253	6297	6114	5682	5285	6106
H1 - H2	1371	2869	3518	3611	4315	3200
Total	7624	9166	9632	9293	8825	9306
Cultivar effect at 10 kg/ha: n.s E - H1; LSD (5%) H1 - H2 = 964; n.s.Total						
Sown at 200 kg/ha in 1986						
E - H1	6294	5831	4503	4708	4512	5058
H1 - H2	2545	2395	4732	4530	5691	3971
Total	8839	8226	9235	9238	10203	9029
Cultivar effect at 200 kg/ha: LSD (5%) E - H1 = 970; H1 - H2 = 1506; n.s. Total						

4.3 SEED HARVEST RESULTS, 1986 - 1987

Seed yield samples were taken from 'closed' quadrats and from under the mesh placed adjacent to quadrat cages. Total seed yield comprised two components, above- and below-ground, and data from both components were analysed separately and together. The number of seeds/m^2, seeds/burr, mean seed weight and germination tests of seeds in burrs were analysed statistically. Seed yield was determined from the burr dissection data (see Methods and Materials). Firstly, the number and weight of seed from twenty random burrs was measured, also the number of burrs per m^2 was calculated (see Appendix B, Tables B.3- B.8). Thus, the number and weight of seed per m^2 could be estimated. Any loose seed was added for the final calculation.

4.3.1 Seed harvest 1986

4.3.1.1..Seed number/burr in 1986

(i) Above-ground: Seed number/burr for above-ground burrs is summarised in Table 4.11.

(ii) Below-ground: Dalkeith had significantly more seeds/burr than all the other cultivars except Nungarin at the sowing rate 200 kg/ha ($P<0.001$). The Cultivar x Stocking Rate interaction and Sowing Rate x Cultivar interaction was significant ($P<0.001$). Junee showed a significant decrease in the number of seeds/burr from the high stocking rate to the low stocking rate. The other cultivars did not change significantly between stocking rates (See Appendix B, Table B.20).

Table 4.11: Number of seeds/burr for above- (AG) and below-ground (BG) burrs and the mean for Total (T) at two sowing rates and three stocking rates for the year 1986 at MES (Data based on dissection of 20 burrs).

	Nungarin	Dalkeith	Trikkala	Junee	Clare	Mixture
10 kg/ha						
AG	2.53	2.45	2.49	3.00	2.46	2.34
BG	2.46	2.34	2.10	2.31	2.55	2.62
T	2.48	2.39	2.40	2.79	2.49	2.45
200 kg/ha						
AG	2.53	2.45	2.49	3.00	2.46	2.30
BG	2.39	2.78	2.17	1.80	2.08	1.79
T	2.46	2.65	2.43	2.83	2.32	2.15

Cultivar x Sowing Rate: LSD (5%) BG = 0.41

4.3.1.2 Mean seed weight in 1986

(i) Above-ground: Sowing rate had no effect on mean seed weight (6.87 and 6.85 mg for high and low sowing rates respectively). Clare and Trikkala had the heaviest seeds, whereas Nungarin and Junee had the lightest seeds. Stocking rate significantly affected mean seed weight ($P<0.01$). Seeds from the high stocking rate were significantly lighter (6.06 mg) than seeds from the medium and low stocking rate areas (7.34 and 7.19 mg respectively).

(ii) Below-ground: Seeds from the low sowing rate plots were significantly heavier than seeds from the high sowing rate plots (8.44 and 7.88 mg respectively). Clare had the heaviest seeds from below-ground burrs for the high sowing rate 200 kg/ha (Table 4.12). Clare also had the heaviest seeds at 10 kg/ha. Similarly, Nungarin and Junee were the lightest. Above-ground mean seed weights was 6.86 mg, compared to 8.16 mg for below-ground seed. Seed from high stocking rate areas was significantly lighter (7.49 mg, $P<0.05$) than seed from medium and low stocking rate areas (8.52 and 8.47 mg respectively).

Table 4.12: The mean seed weight (mg) from the above-ground and below-ground burrs also total burrs at two sowing rates and three stocking rates for the year 1986 at MES.

	Nungarin	Dalkeith	Trikkala	Junee	Clare	Mixture
10 kg/ha						
AG	4.97	6.90	7.83	4.88	10.05	6.48
BG	7.50	7.92	10.03	6.46	10.40	8.33
T	6.71	7.50	8.45	5.34	10.20	7.30
Cultivar effect at 10 kg/ha: LSD (5%) AG = 1.44; BG = 1.08						
200 kg/ha						
AG	4.85	6.87	8.05	5.37	9.05	7.05
BG	6.25	8.29	8.89	5.83	10.58	7.45
T	5.53	7.79	8.23	5.42	9.63	7.17
Cultivar effect at 200 kg/ha: LSD (5%) AG = 1.05; BG = 1.58						

4.3.1.3 Seed Number in 1986

Above-ground, below-ground and total seed number is summarised in Table 4.13.

(i) Above-ground: The Sowing Rate x Cultivar interaction for above-ground seed number was significant ($P<0.01$). Nungarin, Trikkala and Junee had significantly fewer seeds at the low sowing rate compared to the high sowing rate.

(ii) Below-ground: The interaction Cultivar x Sowing Rate was highly significant ($P<0.001$). Nungarin and Dalkeith had significant decreases in seed number for the low sowing rate. Conversely, Junee and the mixture had an increase in seed number from high to low sowing rates.

(iii) Total seed number: Cultivar x Sowing Rate was highly significant ($P<0.001$, Table 4.13). A Similar decrease in seed number with low sowing rate occurred for both above- and below-ground components. Nungarin, Dalkeith, Trikkala and Junee had significant decreases in seed number for the low sowing rate. Stocking rate had no significant effect on seed number at either sowing rate.

Table 4.13: Seed number/m^2: above-ground (AG), below-ground (BG) and total (T) seed number at two sowing rates and three stocking rates for the year 1986 at MES.

	Nungarin	Dalkeith	Trikkala	Junee	Clare	Mixture
10 kg/ha						
AG	4497	5029	12059	11815	4561	10483
BG	10631	7294	4337	4864	3664	8311
T	15236	12323	16313	16679	8225	18793
Cultivar effect at 10 kg/ha: LSD (5%) AG =3257; BG =1925; T =3861						
200 kg/ha						
AG	15098	8026	16528	20028	6635	10489
BG	14157	14809	4588	2349	4015	4630
T	29255	22836	21116	22377	10649	15119

Cultivar effect at 200 kg/ha: LSD (5%) AG = 3455; BG = 2471; T = 3938

Cultivar x Sowing Rate, Above-ground: LSD (5%) =3443
" " " , Below-ground: LSD (5%) =2244
" " " , Total: LSD (5%) =4345

4.3.1.4 Seed yield in 1986

(i) Above-ground: A Cultivar x Sowing Rate interaction was found (P<0.05, Table 4.14), due largely to the cultivars Nungarin, Dalkeith and Junee having significantly lower above-ground seed yields when sown at 10 kg/ha compared to 200 kg/ha.

(ii) Below-ground: Sowing Rate x Cultivar was significant (P<0.001). Dalkeith had a decrease in seed yield at the low sowing rate, whereas Junee and the mixture had increased yield at the low sowing rate.

(iii) Total seed yield: Cultivar x Sowing Rate was significant for total seed yield (P<0.05). Nungarin, Dalkeith and Trikkala had significantly less total seed yield on low sowing rate plots (Table 4.14).

The points used to plot Figures 4.1 to 4.6 were taken from Appendix B tables, each point representing a stocking rate. Total seed yield in 1986 was related to the seed number (Figure 4.1). Nungarin, Dalkeith and Trikkala clearly had the greatest seed yield and seed numbers were highly related. The results were more variable for the cultivars Junee, Clare and the mixture. Seedling number in 1987 was examined in relation to total seed yield in 1986 (Fig. 4.2). Nungarin, Trikkala, the Mixture and Dalkeith required less seed yield at 10 kg/ha sowing rate to establish the same or more seedlings compared to the 200 kg/ha sowing rate. Dalkeith actually showed a negative correlation between total seed yield and seedling number when sown at 200 kg/ha in 1986. This indicates that the seed yield was not limiting but some other factor, possibly a 'blanketing effect' was reducing the number of seedlings which emerged. Junee and Clare showed that seed yield in 1986 had no influence on seedling number in 1987.

Total seed yield in 1986 was clearly a determinant of to early herbage production in 1987 for the cultivars Nungarin and Dalkeith at both initial sowing rates (Fig. 4.3). Both cultivars had greater early production on less seed yield at the initial sowing rate of 10 kg/ha compared to 200 kg/ha. Dalkeith, Trikkala and Clare clearly showed a positive realtionship between increased seed yield resulting in higher herbage production at 200 kg/ha. No such relationship existed for 10 kg/ha: however, generally the early herbage production of Dalkeith, Trikkala and Clare was higher at 10 kg/ha compared to 200 kg/ha. Blanketing of seedlings is seen as a possible cause for reduced early herbage production in 1987 when the initial (1986) sowing rate was 200 kg/ha even though the seed yield was similar, or comparitively higher, than 10 kg/ha treatments. The mixture showed no response at either sowing rate.

Figure 4.1: The relationship between seed number and seed yield for each cultivar at MES in 1986.

Legend: ⊡ 10 kg/ha
◆ 200 kg/ha

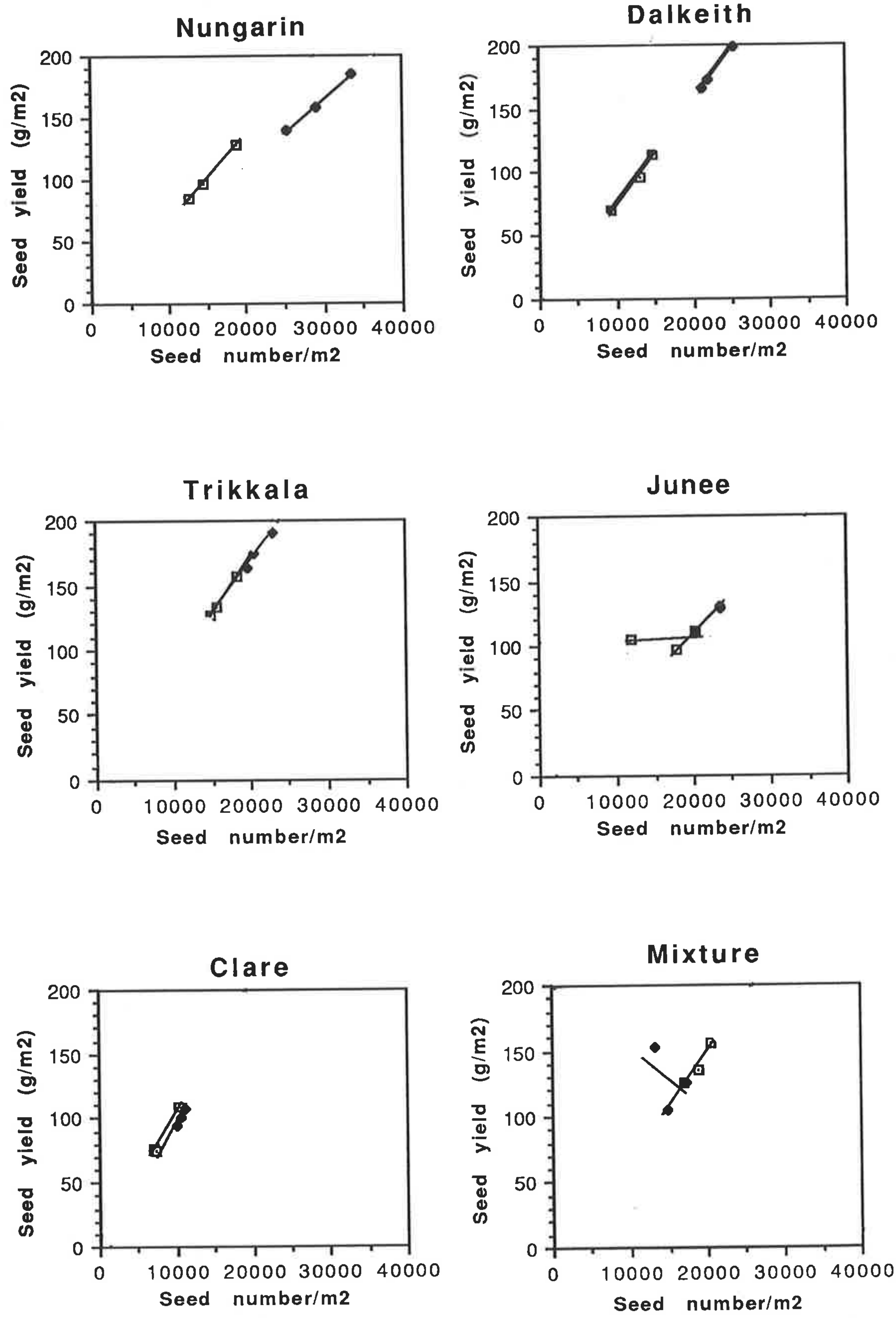
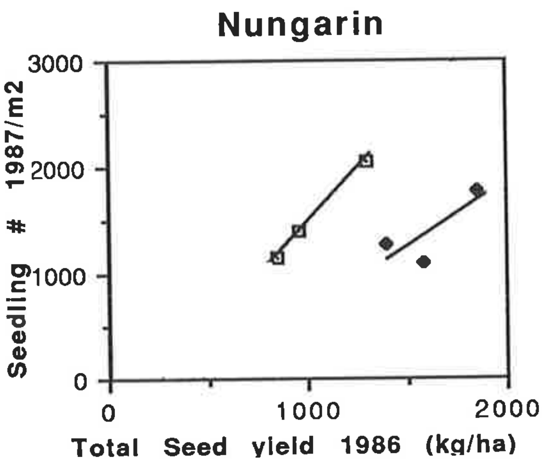
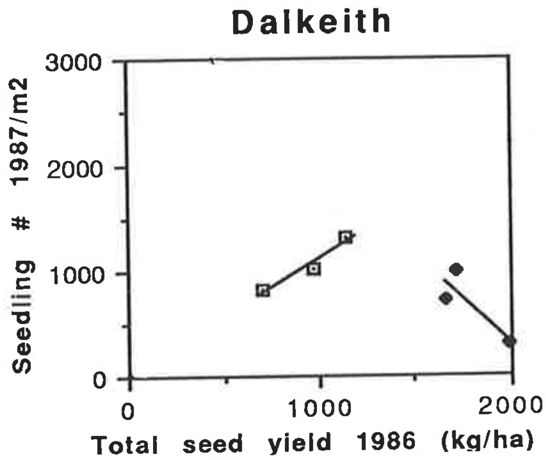
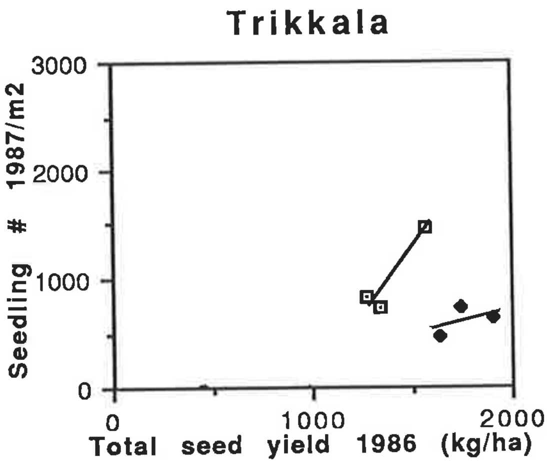

Nungarin
Dalkeith
Trikkala
Junee
Clare
Mixture
Seed yield (g/m2)
Seed number/m2
0
50
100
150
200
0
10000
20000
30000
40000

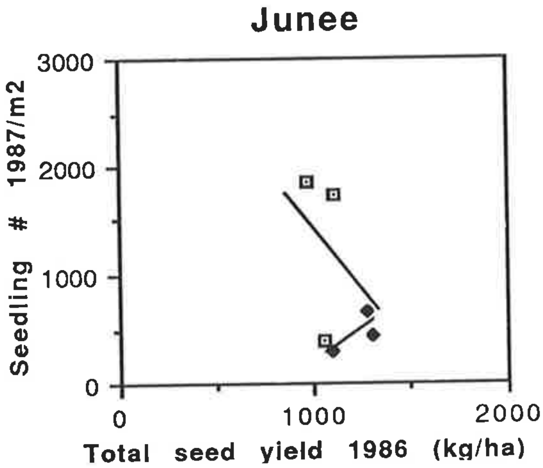
Figure 4.2: The relationship between seedling number in 1987 and total seed yield in 1986.

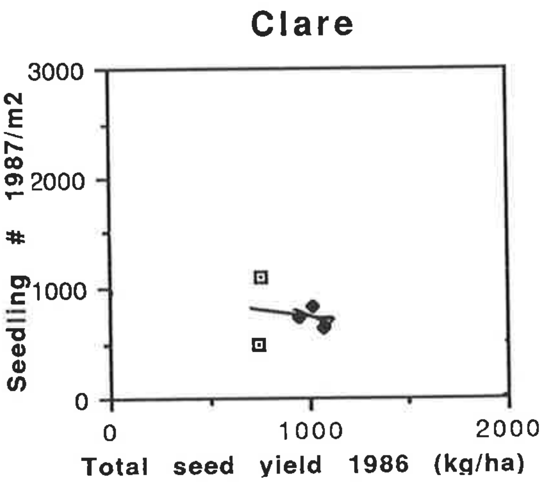
Legend: ⊡ 10 kg/ha
◆ 200 kg/ha


Nungarin
3000
2000
1000
0
Seedling # 1987/m2
0
1000
2000
Total Seed yield 1986 (kg/ha)


Dalkeith
3000
2000
1000
0
Seedling # 1987/m2
0
1000
2000
Total seed yield 1986 (kg/ha)


Trikkala
3000
2000
1000
0
Seedling # 1987/m2
0
1000
2000
Total seed yield 1986 (kg/ha)


Junee
3000
2000
1000
0
Seedling # 1987/m2
0
1000
2000
Total seed yield 1986 (kg/ha)


Clare
3000
2000
1000
0
Seedling # 1987/m2
0
1000
2000
Total seed yield 1986 (kg/ha)

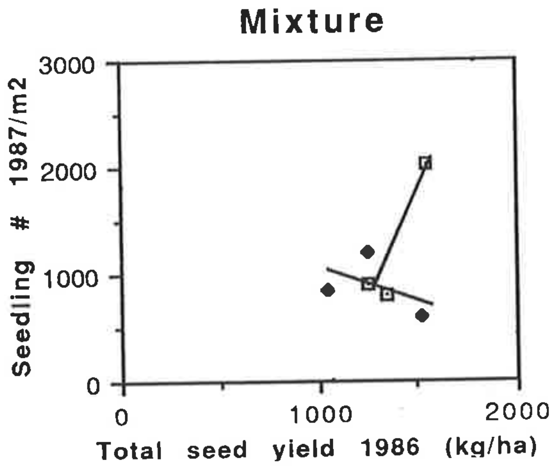
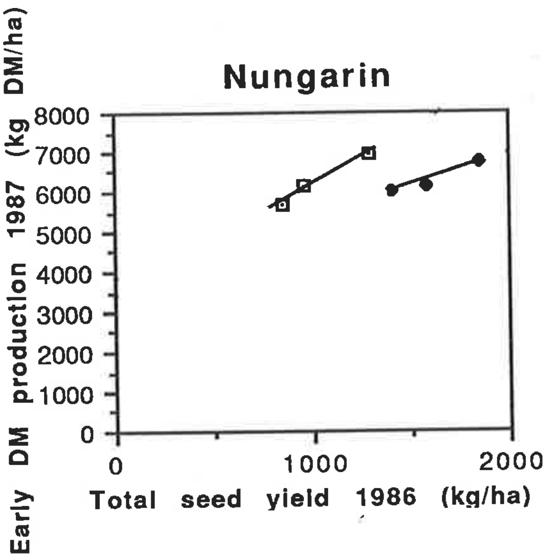
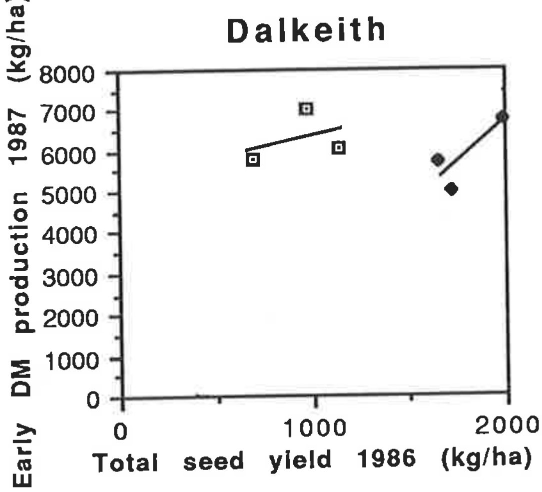
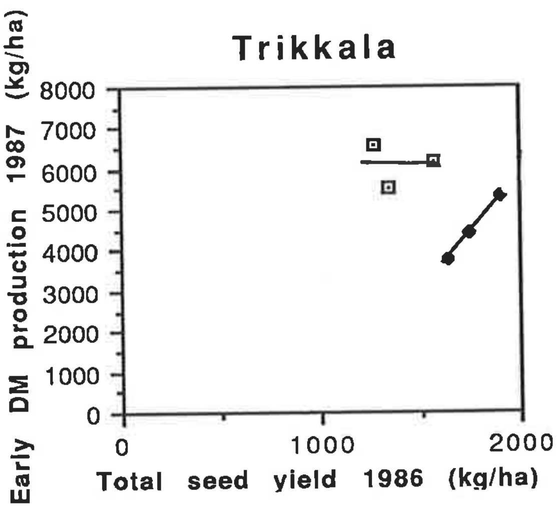

Mixture
3000
2000
1000
0
Seedling # 1987/m2
0
1000
2000
Total seed yield 1986 (kg/ha)

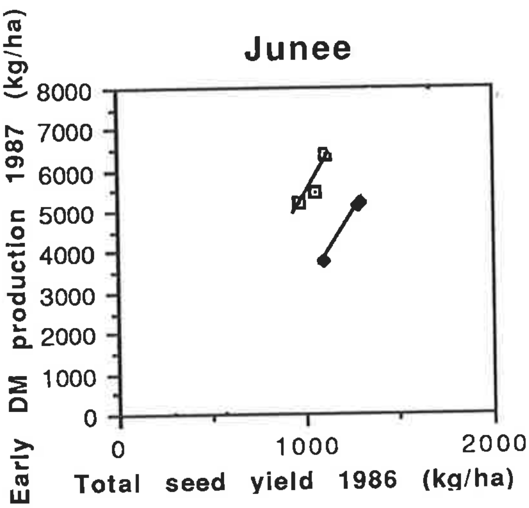
Figure 4.3: The relationship between total seed yield in 1986 and early herbage production.

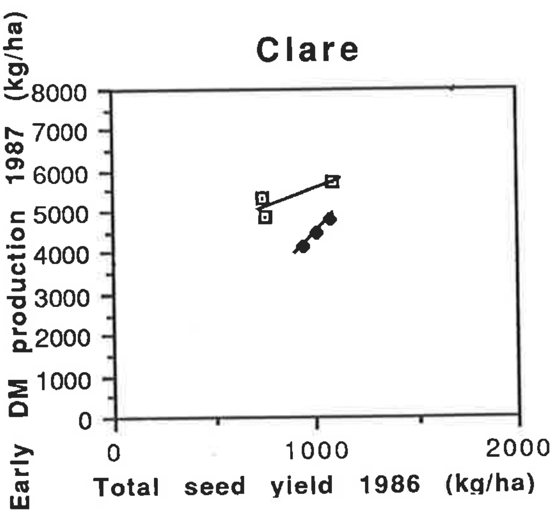
Legend: ⊡ 10 kg/ha
◆ 200 kg/ha


Nungarin
Early DM production 1987 (kg DM/ha)
8000
7000
6000
5000
4000
3000
2000
1000
0
0
1000
2000
Total seed yield 1986 (kg/ha)


Dalkeith
Early DM production 1987 (kg/ha)
8000
7000
6000
5000
4000
3000
2000
1000
0
0
1000
2000
Total seed yield 1986 (kg/ha)


Trikkala
Early DM production 1987 (kg/ha)
8000
7000
6000
5000
4000
3000
2000
1000
0
0
1000
2000
Total seed yield 1986 (kg/ha)


Junee
Early DM production 1987 (kg/ha)
8000
7000
6000
5000
4000
3000
2000
1000
0
0
1000
2000
Total seed yield 1986 (kg/ha)


Clare
Early DM production 1987 (kg/ha)
8000
7000
6000
5000
4000
3000
2000
1000
0
0
1000
2000
Total seed yield 1986 (kg/ha)

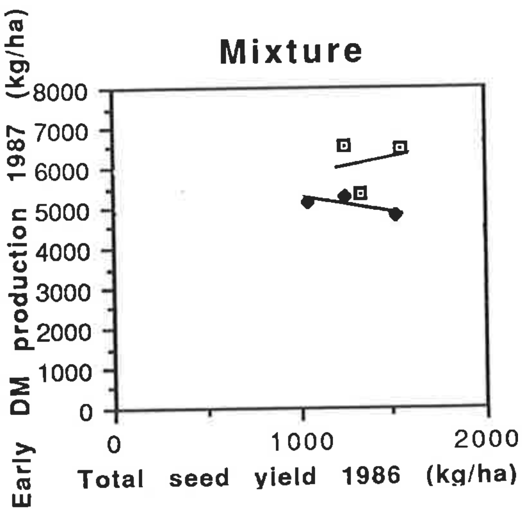

Mixture
Early DM production 1987 (kg/ha)
8000
7000
6000
5000
4000
3000
2000
1000
0
0
1000
2000
Total seed yield 1986 (kg/ha)

Table 4.14: Seed yield (kg/ha): above-ground (AG), below-ground (BG) and total seed yield (T) for the year 1986 at MES.

	Nungarin	Dalkeith	Trikkala	Junee	Clare	Mixture
10 kg/ha						
AG	220	353	964	594	464	679
BG	815	584	444	451	400	704
T	1035	937	1391	1045	864	1384
Seed buried (%)	78.7	62.3	31.9	43.2	46.3	50.9
200 kg/ha						
AG	735	561	1210	1078	591	752
BG	874	1226	443	151	423	523
T	1609	1787	1764	1229	1014	1276
Seed buried (%)	54.3	68.6	25.1	12.3	41.7	40.0

Cultivar x Sowing Rate: n.s. AG; LSD (5%) BG= 250; T = 365

4.3.1.5 Germination test of seed in above-ground burrs in 1986

Tables 4.15 - 4.18 show the means from arcsine-transformed data. In parentheses are the natural percentages. An overall analysis was made then each sowing rate was analysed separately.

(i) Soft (permeable) seed: The total germination from (soft = permeable seed) was taken as the number of seeds which germinated from burrs by the end of the 14 days. Cultivar was the only significant effect for the overall analysis ($P<0.001$, Table 4.15). Trikkala, Clare and the mixture had the highest level of soft seed, whereas Dalkeith had the least soft seed.

(ii) Hard (impermeable) seed: The Sowing Rate x Cultivar interaction was significant ($P<0.01$). Dalkeith had a significant decrease in hard seed at the low sowing rate compared to the high sowing rate.

(iii) Dormant seed: Over both sowing rates, Clare had the least dormant seed ((P<0.001). Nungarin and Dalkeith had the highest level of dormancy, whereas Trikkala, the Mixture and Junee were intermediate.

Table 4.15: Germination tests on seed in above-ground burrs (arcsine transformed), % Soft (S), % Hard (H) and % Dormant (D) for the year 1986 at MES. In brackets are the natural percentage values.

	Nungarin	Dalkeith	Trikkala	Junee	Clare	Mixture
10 kg/ha						
S	12.8 (6.2)	8.1 (2.5)	32.3 (29.2)	15.1 (8.3)	33.1 (30.4)	27.0 (22.4)
H	70.8 (90.2)	65.5 (82.0)	52.1 (62.0)	64.2 (79.5)	44.6 (49.3)	57.7 (67.1)
D	7.1 (3.6)	22.5 (15.5)	14.6 (8.8)	16.7 (12.2)	23.5 (20.3)	16.1 (10.5)
200 kg/ha						
S	12.3 (5.8)	7.8 (2.4)	26.5 (20.6)	13.8 (7.5)	31.7 (28.1)	31.7 (33.1)
H	71.5 (88.2)	78.6 (94.5)	57.5 (70.5)	64.1 (78.5)	41.5 (48.8)	53.9 (68.2)
D	10.9 (6.0)	5.4 (3.1)	14.4 (8.9)	18.2 (14.0)	32.1 (31.7)	16.9 (14.3)

Arcsine means, Cultivar x Sowing Rate: Hard seed, LSD(5%) = 9.00

4.3.1.6 Germination tests of seed in below-ground burrs 1986

(i) Soft seed: Cultivar effect (P<0.001) and Cultivar x Sowing rate was significant (P<0.01, Table 4.16). Both Clare and the Mixture had significant decreases in soft seed at the low sowing rate compared to the high sowing rate: the opposite occurred for Junee.

(ii) Hard seed: Hard seed percentage was greatest for Nungarin and Dalkeith, while Clare had the lowest (P<0.001, Table 4.16). Stocking Rate x Cultivar and Stocking Rate x Sowing Rate were also significant (P<0.01 and P<0.001 respectively, Table 4.17 and 4.18). The highest stocking rate had significantly less hard seed than both the medium and low stocking rates but only at the sowing rate 10 kg/ha. Dalkeith and the Mixture had significant increases in hard seed as the stocking rate decreased, the reverse happened for Clare. Nungarin and Trikkala were unresponsive to stocking rate.

(iii) Dormant seed: Both Cultivar and Cultivar x Sowing Rate interactions were significant ($P<0.001$ and $P<0.05$ respectively, Table 4.16). The dormant seed of the mixture had significantly decreased at the high sowing rate compared to the low sowing rate. Stocking Rate x Cultivar and Stocking Rate x Sowing Rate were also significant (both $P<0.01$, Table 4.17 and 4.18). Low-sowing-rate plot areas had significantly more dormant seed than high-sowing-rate plots if they were in high stocking rate areas. In low stocking rate areas the reverse occurred. Dormant seed increased for Dalkeith and Clare as stocking rate decreased, the opposite was found for Trikkala. Nungarin and the mixture were unresponsive.

Table 4.16: Germination tests on seeds in below-ground burrs (arcsine transformed), % Soft, % Hard, % Dormant and Total (T) = weighted mean of AG + BG for the year 1986 at MES. In brackets are the natural percentage values.

	Nungarin	Dalkeith	Trikkala	Junee	Clare	Mixture
10 kg/ha						
S	11.8	9.9	24.5	15.1	24.6	17.3
	(5.3)	(3.7)	(18.0)	(8.8)	(17.8)	(9.7)
T	(5.6)	(3.2)	(26.7)	(8.5)	(25.7)	(17.2)
H	72.5	68.4	44.8	61.5	43.5	57.5
	(88.9)	(83.0)	(49.8)	(74.1)	(47.7)	(72.2)
T	(89.3)	(82.6)	(59.3)	(77.9)	(48.7)	(69.2)
D	8.4	15.7	32.6	17.1	35.4	23.1
	(5.8)	(13.3)	(32.2)	(17.1)	(34.5)	(18.1)
T	(5.1)	(14.2)	(14.0)	(13.6)	(25.6)	(13.6)
200 kg/ha						
S	9.3	6.6	22.1	8.0	32.7	26.5
	(3.4)	(2.1)	(15.5)	(3.7)	(31.1)	(20.7)
T	(4.7)	(2.2)	(19.6)	(7.0)	(29.2)	(29.4)
H	72.9	69.9	51.4	51.9	39.3	59.6
	(88.3)	(78.2)	(59.5)	(69.5)	(41.6)	(73.7)
T	(88.2)	(84.8)	(68.3)	(77.3)	(46.2)	(69.8)
D	11.1	23.5	27.9	24.7	26.4	7.6
	(8.3)	(19.7)	(25.0)	(26.7)	(27.3)	(5.6)
T	(7.1)	(13.0)	(12.1)	(15.7)	(24.6)	(0.8)

Cultivar x Sowing Rate: LSD (5%) S = 6.9; D = 12.1

Table 4.17: Interrelations of stocking rate and cultivar for percentage hard seed (H) and dormant seed (D) in below-ground burrs for the year 1986 at MES. Only arcsine means are presented.

	Nunagrin	Dalkeith	Trikkala	Junee	Clare	Mixture
Hard seed						
Stocking rate						
LSR	73.0	77.7	48.0	47.0	34.8	63.4
MSR	72.9	68.5	49.3	69.9	45.3	55.6
HSR	72.2	61.4	47.1	53.2	44.2	56.6
Hard seed: LSD (5%) = 12.3						
Dormant seed						
Stocking Rate						
LSR	7.5	7.3	33.8	26.8	42.6	14.0
MSR	13.4	16.2	29.7	8.6	26.7	12.8
HSR	8.4	35.5	27.3	27.3	23.4	19.3
Dormant seed; LSD (5%) = 16.2						

Table 4.18: Interrelations of stocking rate and sowing rate for the percentage hard seed (H) and dormant seed (D) in below-ground burrs for the year 1986 at MES. Only arcsine means are presented.

	LSR	MSR	HSR
10 kg/ha			
H	62.3	61.1	50.8
D	17.5	18.8	29.9
200 kg/ha			
H	52.3	59.4	60.8
D	26.4	17.0	17.2
Hard seed, LSD (5%) = 8.2			
Dormant seed, LSD (5%) = 10.8			

4.3.1.7 Regeneration of sub clover in 1987

The regeneration data in 1987 were analysed by using the overall analysis of variance, then analysing separately for each sowing rate (to give a better comparison between cultivars within the same sowing rate). For the purpose of analysis, the data needed log transformation: however, the natural values will be presented, with any comparisons based on the log-transformed analyses. Initial sowing rate was highly significant ($P<0.001$, transformed data). The high sowing rate treatments had significantly fewer seedlings than the low sowing rate treatments (793 and 1153 respectively).

A Sowing Rate x Cultivar interaction was also significant ($P<0.05$, transformed data) (Table 4.19). The cultivars Dalkeith, Trikkala, Junee and the Mixture had significantly more seedlings on low sowing rate treatments in comparison with the high sowing rate treatments.

Nungarin had the most seedlings while Junee had the least number of seedlings on plots sown originally at 200 kg/ha. At the initial sowing rate of 10 kg/ha, seedling numbers were reduced significantly with higher stocking rates (1635 $\#/m^2$; LSR> 1089 $\#/m^2$; MSR> 735 $\#/m^2$ HSR). Nungarin also had the highest number of seedlings at the initial sowing rate of 10 kg/ha and Clare had the lowest number.

Seedling numbers at the beginning of 1987 determined early herbage production in 1987 although there were some erratic data (Fig 4.4). Nungarin showed clearly that as seedling numbers increased so did the herbage production. Dalkeith showed at the 200 kg/ha sowing rate a decrease in herbage production as the seedling number increased. Trikkala, Junee, Clare and the Mixture had the best herbage production from 10 kg/ha plots even though 200 kg/ha plots had similar plant numbers. Again, this is possibly the result of a "blanketing effect".

Figure 4.4: The relationship between seedling number and early herbage production in 1987.

Legend: ⊡ 10 kg/ha
◆ 200kg/ha

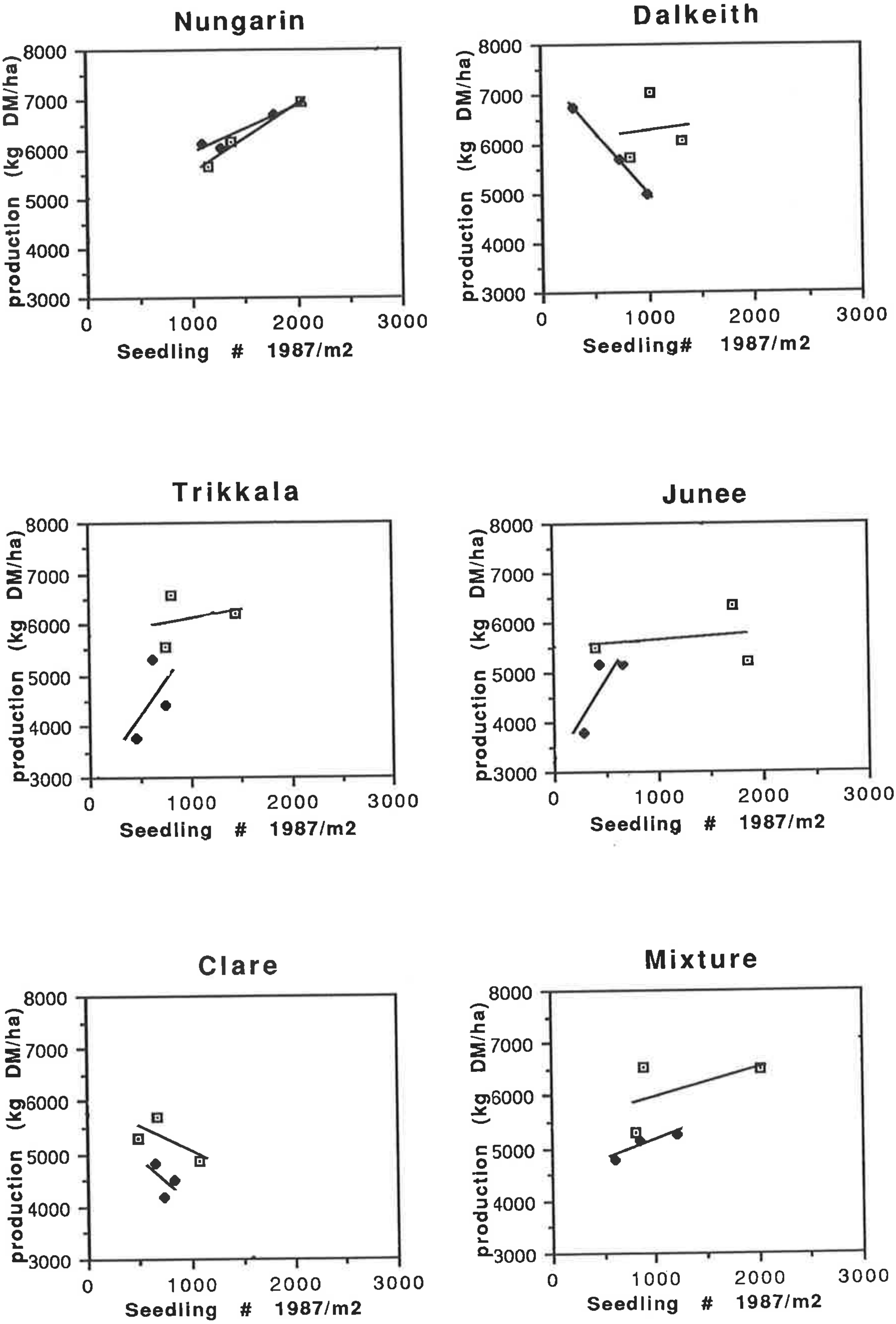

Nungarin
Dalkeith
Trikkala
Junee
Clare
Mixture
production (kg DM/ha)
8000
7000
6000
5000
4000
3000
0
1000
2000
3000
Seedling # 1987/m2

Table 4.19: Regeneration of sub clover seedlings counted on 20 May 1987 at MES (All data show plants /m^2).

	Nungarin	Dalkeith	Trikkala	Junee	Clare	Mixture
Sown at 10 kg/ha in 1986	1529^{c}	1058^{b}	1004^{b}	$1327^{b,c}$	753^{a}	$1246^{b,c}$
Sown at 200 kg/ha in 1986	1390^{c}	$672^{a,b}$	$609^{a,b}$	461^{a}	731^{b}	$888^{b,c}$

Differing superscript letters indicate significant differences (P<0.05), based on log transformed data (comparisons for within a sowing rate only).

4.3.2 Seed harvest 1987

Burr numbers for the 1987 season are presented in Appendix B, Tables 6 - 8.

4.3.2.1 Number of seeds /burr in 1987

(i) Above-ground: Cultivar and Cultivar x Sowing Rate were significant (P<0.01 and P<0.05 respectively). Clare in the second year's seed harvest had significantly more seeds/above-ground burr than the other cultivars on plots initially sown at 200 kg/ha (Table 4.20).

(ii) Below-ground: (See Table 4.20). It should be noted that burrs from the 1986 season would be included because of the difficulty in segregating burrs produced in 1986 from 1987 burrs. Cultivar and Sowing Rate main effects were significant (P<0.001 and P<0.05 respectively). Plots sown originally at 10 kg/ha had more seeds per burr 1.74 seeds/burr compared to 1.52 seeds/burr when sown at 200 kg/ha in 1986.

Cultivar x Sowing Rate was also significant (P<0.05). Nungarin and Dalkeith had the most seeds/burr from plots initially sown at the high rate (P<0.001). This result contrasts with data from above-ground burrs, where both Nungarin and Dalkeith were among the lowest. Junee and Clare had significant reductions in the number of seeds/burr at the original sowing rate 200 kg/ha.

Table 4.20: Number of seeds/burr, above-ground (AG), below-ground (BG) and total (T) at two sowing rates and three stocking rates for the year 1987 at MES.

	Nungarin	Dalkeith	Trikkala	Junee	Clare	Mixture
Sown at 10 kg/ha in 1986						
AG	2.08	2.27	2.08	2.32	2.13	2.24
BG	2.03	2.28	1.46	1.43	1.52	1.75
T	2.05	2.28	1.99	1.85	1.80	1.98
Sown at 200 kg/ha in 1986						
AG	2.27	2.11	2.10	2.73	2.64	2.10
BG	2.35	2.48	1.28	0.99	0.83	1.19
T	2.30	2.29	2.02	2.30	1.99	1.79

Cultivar x Sowing Rate: LSD (5%) AG= 0.34; BG = 0.53

4.3.2.2 Mean seed weight in 1987

(i) Above-ground: Cultivar was the only significant main effect (P<0.001, Table 4.21). Trikkala and Clare had the heaviest seeds. A Stocking Rate x Sowing Rate interaction was also significant (P<0.05, Table 4.22). Mean seed weight was lightest on plots sown initially at 10 kg/ha on high stocking rate plots.

(ii) Below-ground: The Cultivar main effect was the only significant factor (P<0.001). Dalkeith and Clare had the heaviest seeds.

As for the previous year, seed weight was greater for below-ground seed (7.51 mg) compared to above-ground seed (5.40 mg).

Table 4.21: The mean seed weight (mg) from above-ground (AG), below-ground (BG) and total (T) burrs at two sowing rates and three stocking rates for the year 1987 at MES. (mean over both sowing rates)

	Nungarin	Dalkeith	Trikkala	Junee	Clare	Mixture
AG	4.57	5.73	6.04	4.34	6.14	5.61
BG	6.51	8.90	7.36	5.54	9.36	7.39
T	5.50	7.59	6.33	4.71	7.40	6.45

Cultivar effect: LSD (5%) AG= 0.83; BG = 1.16

Table 4.22: Interrelations of stocking rate and sowing rate for above-ground mean seed weight (mg) at two sowing rates and three stocking rates for the year 1987 at MES.

	LSR	MSR	HSR
Plots sown at 10 kg/ha in 1986	5.36	5.74	4.54
Plots sown at 200 kg/ha in 1986	6.51	5.37	4.90

LSD (5%) for Stocking Rate x Sowing Rate Interaction = 0.91

4.3.2.3 Seed number in 1987

(i) Above-ground: The main effects Cultivar, Sowing Rate and the interaction Sowing Rate x Cultivar was highly significant for above-ground seed number (all $P<0.001$, Table 4.23). Plots sown at the high sowing rate had the largest amount of seed ($12,803/m^2$) compared to plots sown initially at the low rate ($7911/m^2$). Nungarin showed a marked decline in seed numbers on plots sown initially at the low sowing rate compared to the high sowing rate.

(ii) Below-ground: Nungarin and Dalkeith had the most seed below-ground at both sowing rates sown in 1986 (Table 4.23). No significant interactions were found.

(iii) Total seed number: Plots sown initially at the high rate had more seed ($20,862/m^2$) in comparison to plots sown initially at the low rate ($17,046/m^2$). The Cultivar main effect and the interaction Cultivar x Sowing Rate was significant for total seed number ($P<0.001$, Table 4.23). This would be due to the above-ground component. Much the same result was found for the previous season. Analyses were made on each sowing rate separately.

Table 4.23: Seed number /m^2: above-ground, below-ground and total at two sowing rates and three stocking rates for the year 1987 at MES.

	Nungarin	Dalkeith	Trikkala	Junee	Clare	Mixture
Sown at 10 kg/ha in 1986						
AG	11967	9354	10289	4904	3200	7753
BG	18617	15260	3536	4567	3550	9280
T	30584	24614	13824	9472	6750	17033
Sown at 200 kg/ha in 1986						
AG	28650	14301	11665	8840	5620	7742
BG	18960	18293	2717	1815	2128	4418
T	47610	32594	14382	10680	7748	12160

Cultivar x Sowing Rate Interaction: LSD (5%) AG= 5015; T = 8767

4.3.2.4 Seed yield in 1987

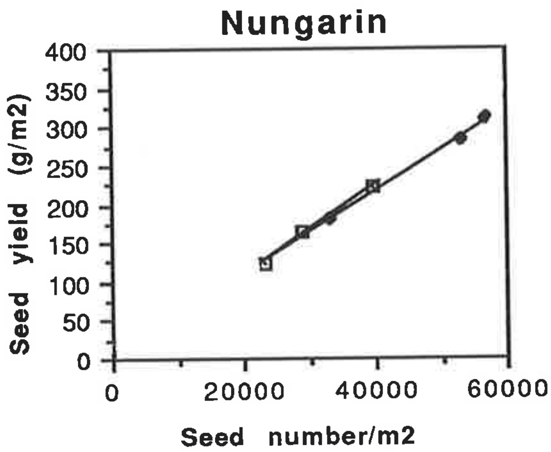
(i) Above-ground: Plots sown initially at the low rate had significantly less seed yield (428 kg/ha) than high sowing rate plots (718 kg/ha, P<0.001). There was a highly significant Cultivar x Sowing Rate interaction for above-ground seed yield (both P<0.001, Table 4.24). The seed yield of Nungarin and Dalkeith was significantly reduced on plots sown initially at the lower sowing rate.

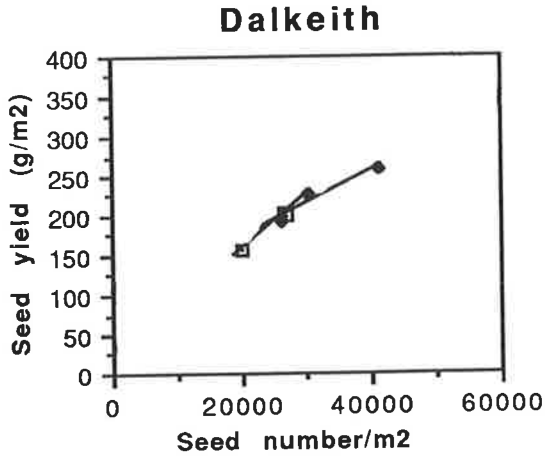
(ii) Below-ground: The only significant effect was Cultivar. The cultivars Nungarin and Dalkeith had the highest overall below-ground seed yield (P<0.001, Table 4.24). The effect of initial sowing rate was not significant (607 and 566 for high and low respectively).

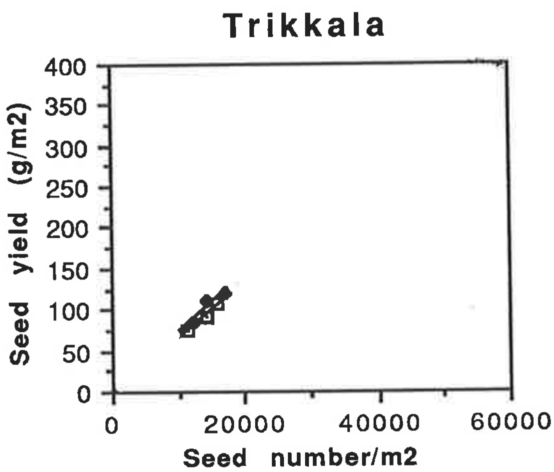
(iii) Total seed yield: The Cultivar and Cultivar x Sowing Rate interaction was significant for total seed yield (P<0.001 and P<0.05 respectively, Table 4.24). Nungarin had a significant decrease in total yield for plots sown initially at the low sowing rate. All cultivars showed a strong relationship between total seed yield and total seed number for the year 1987 (Fig 4.5).

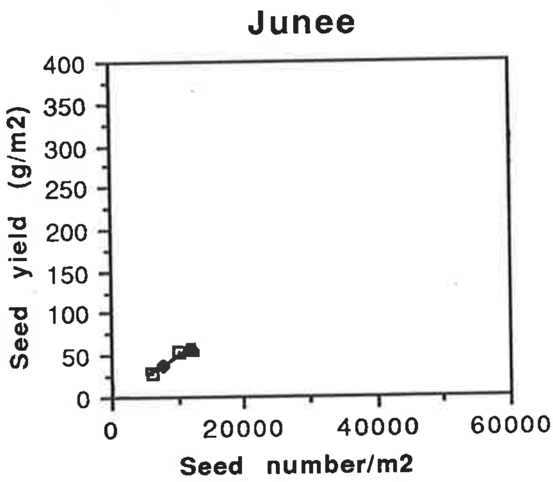
Figure 4.5: The dependence of seed yield on seed number at MES in 1987.

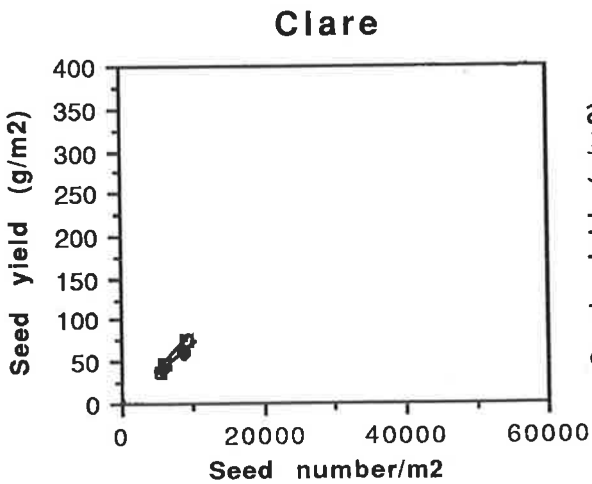
Legend: ⊡ 10 kg/ha
◆ 200 kg/ha


Nungarin
Seed yield (g/m2)
0
50
100
150
200
250
300
350
400
0
20000
40000
60000
Seed number/m2


Dalkeith
Seed yield (g/m2)
0
50
100
150
200
250
300
350
400
0
20000
40000
60000
Seed number/m2


Trikkala
Seed yield (g/m2)
0
50
100
150
200
250
300
350
400
0
20000
40000
60000
Seed number/m2


Junee
Seed yield (g/m2)
0
50
100
150
200
250
300
350
400
0
20000
40000
60000
Seed number/m2


Clare
Seed yield (g/m2)
0
50
100
150
200
250
300
350
400
0
20000
40000
60000
Seed number/m2

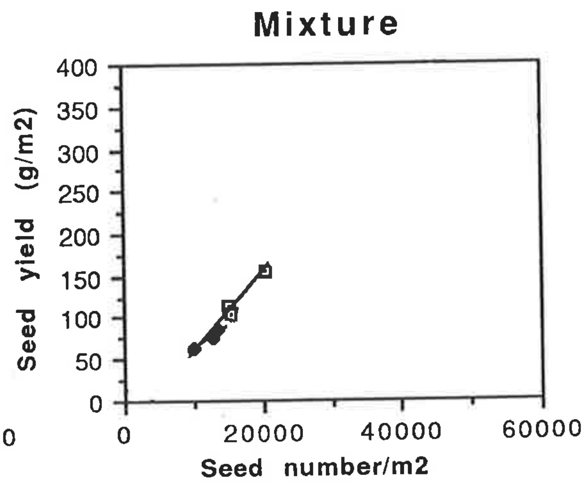
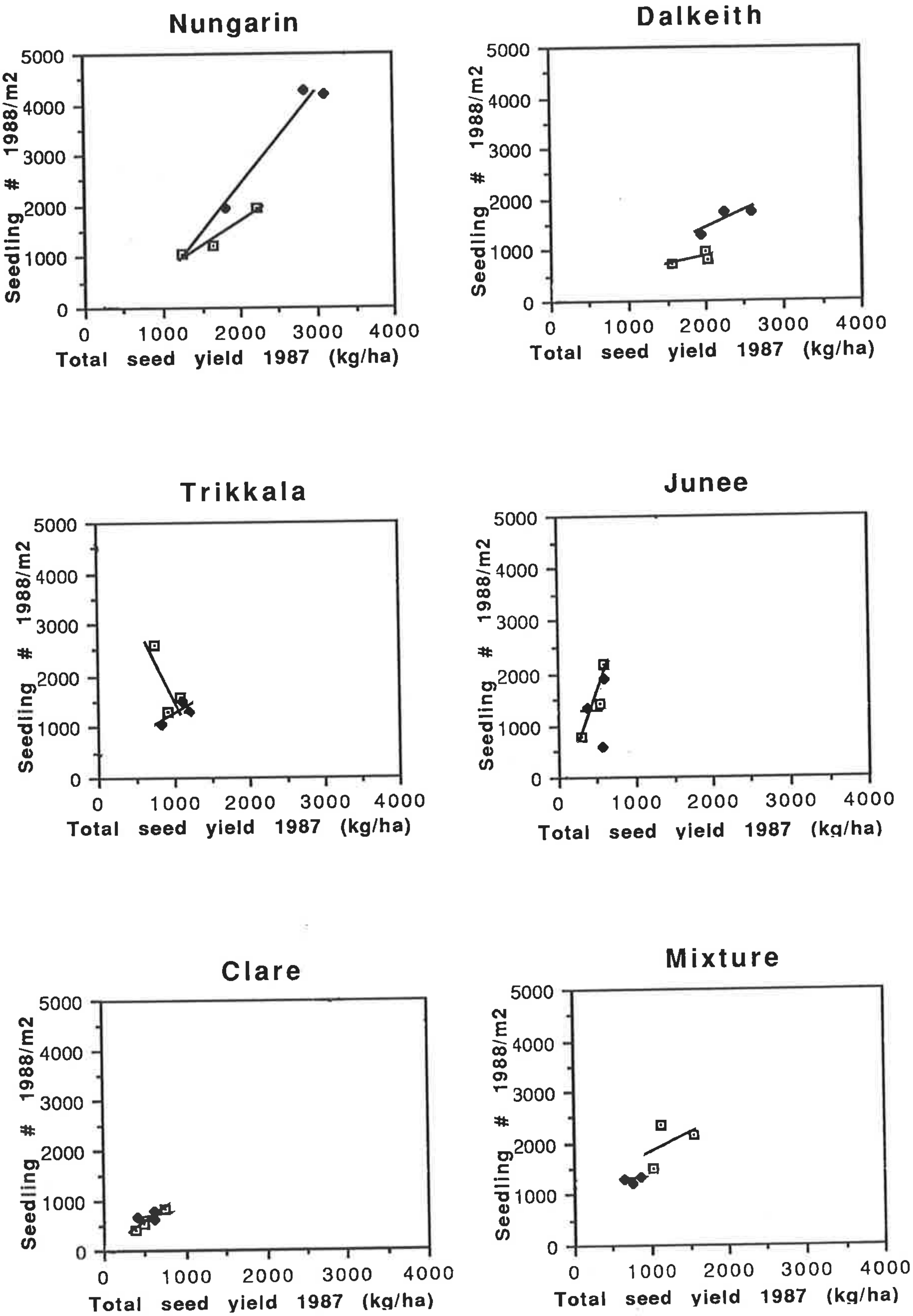

Mixture
Seed yield (g/m2)
0
50
100
150
200
250
300
350
400
0
20000
40000
60000
Seed number/m2

Figure 4.6: The dependence of seedling number in 1988 on total seed yield in 1987 at MES.

Legend: ⊡ 10 kg/ha
◆ 200 kg/ha


Nungarin
Seedling # 1988/m2
0
1000
2000
3000
4000
5000
Total seed yield 1987 (kg/ha)
Dalkeith
Seedling # 1988/m2
Total seed yield 1987 (kg/ha)
Trikkala
Seedling # 1988/m2
Total seed yield 1987 (kg/ha)
Junee
Seedling # 1988/m2
Total seed yield 1987 (kg/ha)
Clare
Seedling # 1988/m2
Total seed yield 1987 (kg/ha)
Mixture
Seedling # 1988/m2
Total seed yield 1987 (kg/ha)

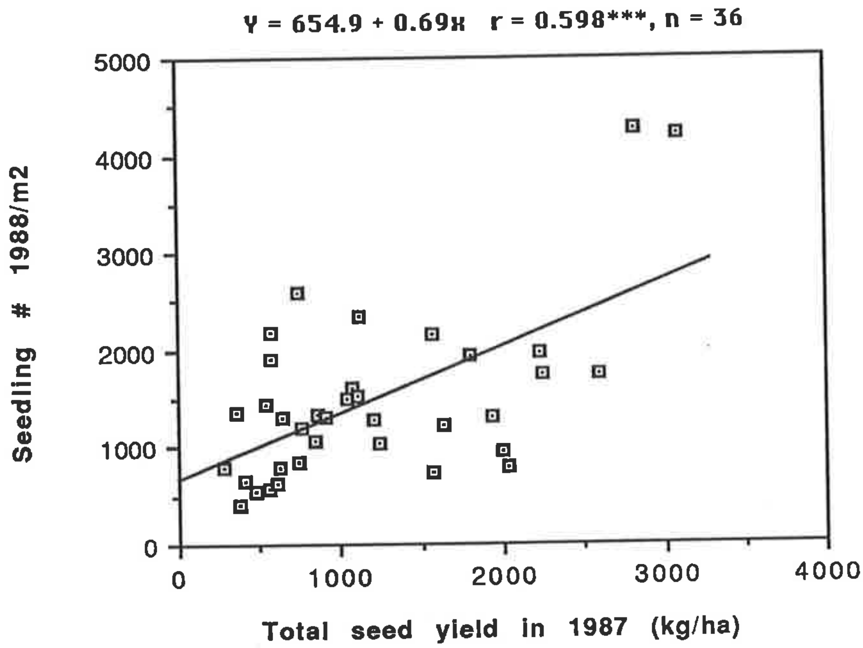


Figure 4.7: The dependence of seedling number in 1988 on total seed yield in 1987 at MES.

Seed yield in 1987 was also related to seedling number in 1988 (Fig. 4.6). Nungarin clearly established the most seedlings in 1988. Generally, as seed yield increased seedling number increased correspondingly at regeneration (Fig. 4.7, plotted data from all cultivars and the Mixture).

Table 4.24: Seed yield (kg/ha), above-ground (AG), below-ground (BG) and total (T) seed yield for the year 1987 at MES.

	Nungarin	Dalkeith	Trikkala	Junee	Clare	Mixture
Sown at 10 kg/ha in 1986						
AG	517	538	612	204	214	482
BG	1184	1329	295	266	327	762
T	1701	1867	908	470	540	1244
Seed buried (%)	69.6	71.2	32.5	56.6	60.6	61.3
Sown at 200 kg/ha in 1986						
AG	1409	882	798	405	368	446
BG	1165	1379	249	100	189	306
T	2574	2261	1047	505	549	752
Seed buried (%)	45.3	61.0	23.8	19.8	34.4	40.7

Cultivar x Sowing Rate Interaction: LSD (5%) AG = 271; T = 584

4.3.2.5 Germination tests of seeds in above-ground burrs for 1987

(i) Soft seed: Cultivar was the only significant main factor (P<0.001, Table 4.25). Clare, then the Mixture and Nungarin had the highest percentage of soft seed.

(ii) Hard seed: The main effect Cultivar was the only significant factor (P<0.001). All cultivars and the Mixture, except for Clare had high hard-seededness.

(iii) Dormant seed: As for the components soft and hard seed, the Cultivar effect was the only significant factor (P<0.01). Clare has the highest percentage of dormant seed.

Table 4.25: Germination tests on seed in above-ground burrs (arcsine transformed), % soft (S), % hard (H) and % dormant (D) for the year 1987 at MES. In brackets are the natural percentage values.

	Nungarin	Dalkeith	Trikkala	Junee	Clare	Mixture
S	12.9 (6.1)	8.8 (3.3)	12.1 (5.6)	10.1 (7.1)	19.7 (13.2)	15.1 (8.2)
H	74.6 (89.0)	77.7 (92.2)	71.9 (79.3)	73.2 (83.0)	57.1 (66.5)	70.9 (84.7)
D	4.9 (4.9)	4.4 (4.5)	9.5 (9.5)	9.9 (9.9)	20.2 (20.3)	7.0 (7.1)

Cultivar effect (Arcsine means): LSD (5%) S = 4.0; H = 6.4; D = 7.8

4.3.2.6 Germination tests of seed in below-ground burrs, 1987

(i) Soft seed: Seed from below-ground burrs had 3.0% soft seed but seed from above-ground burrs had 6.7% soft seed.

(ii) Hard seed: The highest percentage hard seed was found for the cultivars Nungarin and Dalkeith, plus the Mixture. Cultivar main effect only was significant (P<0.01, Table 4. 26).

(iii) Dormant seed: Cultivar was the only significant main effect (P<0.05). In contrast to the previous season, the cultivars had mostly similar dormant seed percentages, while the Mixture had the lowest percentage dormancy.

Table 4.26: Germination tests of seed in below-ground burrs (arcsine transformed), % soft (S), % hard (H), % dormant (D) and total (T) = weighted means of AG + BG for the year 1987 at MES. In brackets are the natural percentage values.

	Nungarin	Dalkeith	Trikkala	Junee	Clare	Mixture
S	6.9	9.0	8.5	7.2	6.6	6.9
	(2.6)	(3.3)	(4.3)	(2.8)	(2.2)	(2.6)
T	(4.5)	(3.3)	(5.4)	(5.4)	(8.2)	(5.7)
H	66.3	68.8	53.1	59.9	57.8	77.4
	(78.2)	(79.6)	(64.0)	(72.2)	(68.8)	(86.9)
T	(84.1)	(85.6)	(77.4)	(78.8)	(67.5)	(85.7)
D	19.1	17.1	31.7	24.9	29.0	10.5
	(19.2)	(17.1)	(31.7)	(25.0)	(29.0)	(10.5)
T	(11.4)	(11.1)	(17.2)	(15.8)	(24.3)	(8.6)

Cultivar effect (Arcsine means): n.s. S; LSD (5%) H = 11.6; D = 14.1

4.3.2.7 Regeneration of sub clover in 1988

Initial sowing rate in 1986 had a significant effect on regeneration in 1988 ($P<0.01$, log transformed). In general there were more plants on plots sown initially at the high rate than on plots sown initially at the low rate(1604 and 1359 plants/m^2 respectively). However, a Sowing Rate x Cultivar interaction was highly significant ($P<0.001$, transformed data - refer to Table 4.27). Nungarin and Dalkeith had higher sub clover densities on plots sown initially at 200 kg/ha whereas Trikkala, Junee and Clare also the Mixture showed no significant differences in plant densities at the two initial sowing rates.

When the sowing rates were analysed separately, Nungarin had the greatest number of plants and Clare the lowest at the high stocking rate. The other cultivars were intermediate. Plots sown initially at 10 kg/ha had also clear cultivar differences: however, Nungarin no longer had the most plants, the Mixture and Trikkala plots had the greatest number of plants.

Table 4.27: Regeneration of sub clover at the Mortlock Experiment Station 1988 (All data show plants/m^2).

	Nungarin	Dalkeith	Trikkala	Junee	Clare	Mixture
Sown at 10 kg/ha in 1986	1407^{b}	831^{a}	$1832^{b,c}$	1475^{b}	605^{a}	2003^{c}
	*6.911	6.371	7.294	6.846	6.165	7.440
Sown at 200 kg/ha in 1986	3468^{c}	1604^{b}	1288^{b}	1285^{b}	690^{a}	1286^{b}
	*8.015	7.134	7.096	6.959	6.416	6.990

Differing superscript letters indicate significant differences, based on log transformed data (comparisons for within a sowing rate only)
* Natural Log transformed data means for the interaction Sowing Rate x Cultivar, LSD(5%) = 0.470

4.4 Discussion and conclusions

4.4.1 Herbage production

Establishment and regeneration: The cultivar of sub clover and plant density had a strong influence on herbage and seed production. Grazing pressure modified the response that cultivar and plant density had on herbage and seed production.

Initial plant density influenced regeneration. The seedling numbers in 1987 were lowest on low stocking rate plots sown initially at 200 kg/ha (Figure 4.8a). This was undoubtably caused by a blanketing effect in 1987 due to the abundance of dry pasture residue, which physically constrains emergence (Carter 1987). On high sowing rate plots sheep under-utilized the dry pasture residues during the summer, thereby leaving excessive dry pasture residue on the surface. Stocking rate also affected regeneration, less seedlings were found on highly stocked areas. This would be the result of increased pressure from sheep eating seedlings.

The high seedling numbers of Nungarin indicate good persistence under continuously grazed conditions (Figure 4.8b). High seedling numbers of Nungarin also ensured high early production. In contrast the cultivar Clare had poor regeneration at MES also in the small-plot experiment at the Waite Institute.

The seedling numbers were generally higher for the 1988 season for all stocking rates and sowing rates. This probably is related to higher total seed yields for the year 1987 and that sheep were no longer grazing the area at emergence in 1988. Higher seed yield in 1987 can be partly attributed to the cumulation of seed from the 1986 season.

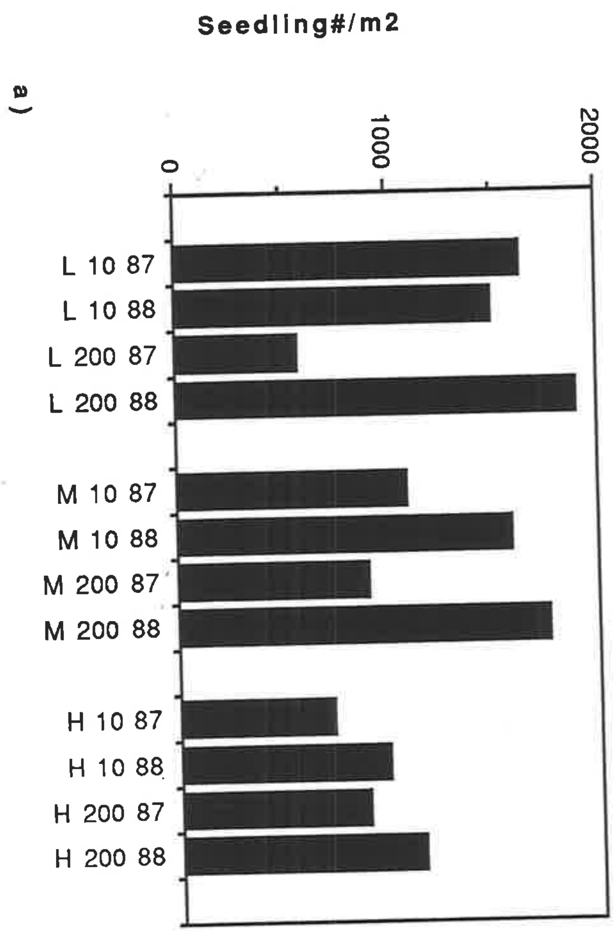
Figure 4.8: a) Seedling number at each stocking rate for the years 1987 and 1988.

Legend: L = Low stocking rate
M = Medium stocking rate
H = High stocking rate

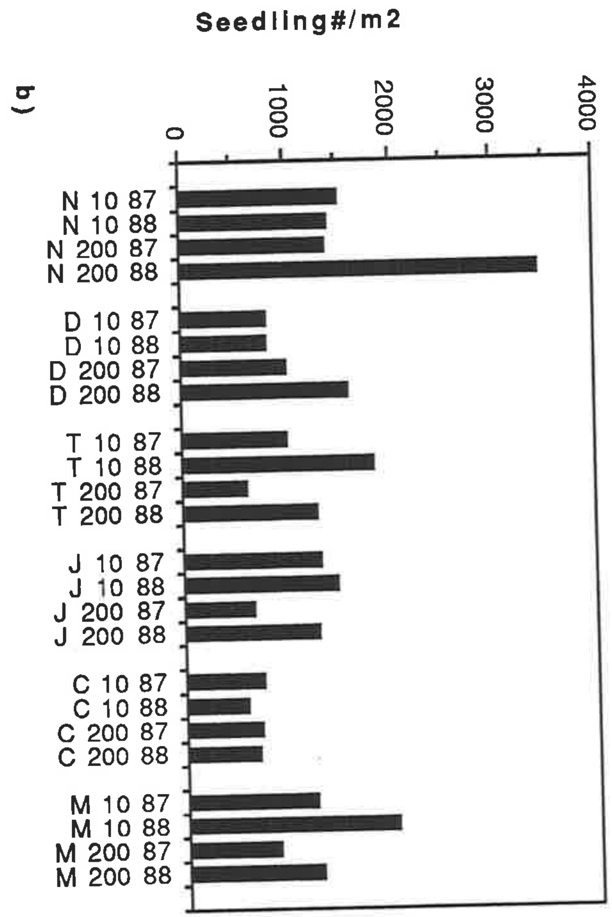
10 = 10 kg/ha
200 = 200 kg/ha

b) Seedling number for each of the cultivars for the years 1987 and 1988.

Legend: N = Nungarin, D = Dalkeith, T = Trikkala, J = Junee, C = Clare, M = Mixture



a)
Seedling#/m2
0
1000
2000
L 10 87
L 10 88
L 200 87
L 200 88
M 10 87
M 10 88
M 200 87
M 200 88
H 10 87
H 10 88
H 200 87
H 200 88



b)
Seedling#/m2
0
1000
2000
3000
4000
N 10 87
N 10 88
N 200 87
N 200 88
D 10 87
D 10 88
D 200 87
D 200 88
T 10 87
T 10 88
T 200 87
T 200 88
J 10 87
J 10 88
J 200 87
J 200 88
C 10 87
C 10 88
C 200 87
C 200 88
M 10 87
M 10 88
M 200 87
M 200 88

<u>Sub clover availability:</u> Plant density has been recognised as an important factor in governing the level of pasture available early in the growing season (Donald 1951; Wolfe 1981). Both the MES and small-plot experiment showed early herbage production was a function of plant density. However, the effect of initial sowing rate had diminished in the 1987 season at MES. Cultivar differences also existed and this cannot be attributed solely to plant density. Clare had low plant density, yet maintained a relatively high sub clover availability early in the season 1986 due mainly to its large seedlings (de Koning 1984; de Koning and Carter 1987a). The cultivars Nungarin, Dalkeith, Junee, Trikkala and the Mixture had high availability because of numerous smaller seedlings. Plant density, continued to influence the availability of sub clover in the pasture throughout the 1986 growing season. The high sowing rate maintained its greater availability under all three stocking rates.

Availability measures the amount of pasture on offer to the grazing animal. Low pasture availability may arise through three causes, (i) the pasture may be growing slowly and/or of low plant density, (ii) the stock find the pasture highly palatable and eat it readily, thereby reducing its availability, or (iii) the stocking pressure may be high. Clare had low availability at both sowing rates in 1986, presumably due in part to its high palatability ((ii) above). It is known that Clare has good winter production (de Koning and Carter 1987b), hence its low availability may well reflect high intake.

Stocking rate influenced availability late in the 1986 season. Nungarin, Dalkeith, Trikkala and Junee did show declines of approximately 2000 kg DM/ha from the low stocking rate to the high stocking rate. Higher utilization of pasture would explain low availabilities at high stocking rates. However, the reason that Nungarin and Dalkeith had low availabilities at the later stages in the growing season may be ascribed to early maturity of these cultivars. Both cultivars were senescing while Trikkala, Junee, Clare and the Mixture continued to grow.

Stocking rate continued to influence the sub clover availability in 1987 of plots sown originally at 10 kg/ha. As found for the previous year, high stocking rate areas had the least pasture available. Early in the season Nungarin, had high pasture availability. The winter productivity of early-maturing cultivars is generally better than mid- to late-season cultivars (Anon 1968; Cameron and Mc Gowan 1968). The high Nungarin plant numbers most likely contributed to this high availability in the MES experiment. However, as in the 1986 season, Nungarin had one of the lowest availabilities toward the end of the season due to early maturity. Later-maturing cultivars such as Clare and Junee maintained high pasture availability and at the final harvest occasion in 1987 the mixture was intermediate. Late maturity of both cultivars governed the availability of pasture later in the season (Wolfe 1981).

Weed yield and botanical composition: Stocking rate, and to a certain extent the initial sowing rate, played an important role in the botanical composition changes. To a smaller extent the cultivars themselves also influenced the botanical composition, but only under lax grazing pressure. Initial plant density had a strong effect on the weed yield. Strong competition is the likely cause for less weeds on high-sowing-rate plots in 1986 because of the large sub clover populations. The low-sowing-rate plots throughout the 1986 season continued to be more weedy compared to high-sowing-rate plots. This result is comparable to the low density swards in the small-plot density experiment in 1985.

Stocking rate had no influence on the 1986 percentage weed component: however, poppies failed to flower on high stocking rate areas compared to the medium and low stocking rate areas where poppies did flower. Thus, in the longer term a higher stocking rate is certain to reduce poppies along with other weeds. In 1987, poppies were no longer prominent, but grasses, especially silver grass were common in the weed population. Plots sown initially at the low sowing rate in 1986 were found to have more grassy weeds than plots sown initially at the high sowing rate.

The ability of cultivars to control weeds depended largely on the grazing pressure. Differences between cultivars were not great at the high stocking rates, mainly because the sheep are acting as the weed controllers. Therefore, under well grazed conditions the cultivar is not expected to contribute to the suppression of weeds. However, on low stocking rate plots, there were observable differences between cultivars. Dalkeith and Junee plots sown at 10 kg/ha on the low stocking rate areas had over 1000 kgDM/ha grasses: by comparison Trikkala and Clare had only 343 and 215 kgDM/ha. This can be attributed to the tall stature of both Trikkala and Clare. Similarly, under non-defoliated conditions of the small-plot density experiment, Clare was also the most successful in terms of weed control. Scott (1971), also found that plots which contained the tallest cultivars also contained fewer weeds.

Observable differences could be seen between stocking rates, even though no statistically-significant differences were found. Stocking rate strongly influenced the type of weed found. Different stocking rates generated different weed species (Carter 1968a,b). Both volunteer clovers, cluster clover (*Trifolium glomeratum*) and woolly clover (*T. tomentosum*) were obvious on high stocking rate areas in 1987 on plots sown initially at 10 kg/ha in 1986. The sparse structure of low density swards would faciliate the invasion by other legumes such as cluster and woolly clover compared to a dense canopy structure of a high density sward. Cameron and Cannon (1970) also found that high stocking rates (up to 19.8 sheep/ha) had increased levels of *Trifolium glomeratum, T. dubium* and *T. campestre,* at the same time sub clover declined. Undoubtably a principle cause of invasion by small seeded legumes is the ability of seed to pass through sheep in a viable state. Similar results were obtained by Carter (1966,1968 a,b,c), Carter and Day (1970), and Dunlop *et al.* (1984,1985). The invasion of small-seeded legumes onto high stocking rate pastures is not detrimental to the overall productivity of the pasture if the pasture is being used for animal production. Grass content increased as stocking rate was reduced. The taller growing grasses have a competitive advantage under lax grazing conditions. This effect was clearly visible in the MES experiment, but not statistically significant. Many researchers have found that the grass content increases as the stocking pressure is reduced (Rossiter and Pack 1956; Carter 1966; Carter and Lake 1985; Rosierie 1987). The results support those of (Sharkey *et al* . 1964) in which changes in botanical composition in response to stocking rate were rapid. The MES experiment illustrated how pastures changed from sub clover dominance in the first year (assisted by spraying Fusilade ®), to widely diverse botanical composition in the second year.

The percentage bare-ground increased as stocking rate increased during the 1987 season. This was not statistically significant, but is biologically important. Bare-ground in a pasture provides sites for colonization by invasive plant species (Carter and Day 1970; Carter and Lake 1985; Lambert *et al*. 1987)

Pasture production: There is no substitute for high density swards to give early feed supply for sheep in the autumn-winter period. Plots sown at 200 kg/ha made more growth early in the 1986 season compared to 10 kg/ha plots because at that stage production was directly proportional to plant density. However, in the second half of the season the high-density plots were probably undergoing intense competition and rapid self-thinning resulting in reduced production, whereas the low-sowing-rate plots continued to grow and gave similar final yields. These results for the later part of the season are similar to those obtained by Donald (1951), Silsbury and Fukai (1982) and Prioul and Silsbury (1982) with sub clover, who found that low density swards had a higher crop growth rate than the high density swards. However, these experiments were ungrazed.

Clare and Junee continued to grow during the latter part of the 1986 and 1987 seasons due to their later maturity, when cultivars such as Nungarin and Dalkeith ceased to grow. Best early production was made by Nungarin: at emergence Nungarin also had the most seedlings. Nungarin plots were also selectively grazed early in the season. Low pasture production from the cultivars Trikkala, Junee and Clare is most likely a result from low plant numbers. However, Clare may also be more easily damaged by grazing because of its tall leafy growth. Francis *et al.* (1976) expressed their concern that the rapid growing leafy types may not recover as well as prostrate types. Research by de Koning and Carter (1987) demonstrated how Clare and Yarloop can be easily damaged and suffer high plant mortality under high stocking pressure when grazing is delayed and there is substantial herbage on offer, whereas the prostrate later-maturing cultivars survived relatively well. Earlier Watkin and Clements (1978) also expressed their doubts concerning erect types such as Clare under heavy grazing.

Stocking rate had very little influence on pasture production of 200 kg/ha plots, but did affect pasture production on 10 kg/ha plots. Pasture production was greater on high and medium stocking rates than at the low stocking rate. This result is similar to that of Carter (1968 a, 1977) but contrasts with those of Dunlop *et al.* (1984) and Curll and Davidson (1983). Reduced growth made on low stocking rate plots is most likely due to plant competition for light due to lax leafy growth causing shading. On high-stocking-rate plots herbage is continually being removed and never reaches the stage where excessive mutual shading occurs. Davidson and Donald (1958) showed that if the defoliation treatment was not too severe, dry matter production increased from a sward defoliated near the ceiling LAI compared to those cut at a very low LAI. However, their experiment did involve a single cut.

<u>Total pasture production:</u> The total pasture production for the 1986 season was greatest for the cultivars Clare and Junee. This result contrasts with work in Victoria that found that total pasture production was the same for all cultivars (Anon. 1968). However, those studies were conducted in Victoria under higher rainfall and different soil conditions. Seasonal conditions may determine whether the total production differs. For example a late finish to the season will favour late-maturing cultivars and if those cultivars grew well throughout the year they will also produce more than early-maturing cultivars. However, the results for 1987 at MES do support those of Anon. (1968). Nungarin and Dalkeith plots gave lowest total production, whereas Trikkala and the

mixture were intermediate. Stocking rate influenced total pasture production in 1986. High-stocking-rate treatments had similar total production to low stocking rates because of the greater growth made by plots grazed at high stocking rates (Carter 1968 a, 1977). Brown (1976a) also found that high stocking rates were associated with higher growth rates in spring.

Sheep bodyweights and greasy wool production: Bodyweight data are presented in Appendix B, Table 1. The sheep had a mean bodyweight of 50 kg/head when first introduced to the area on 5 Sept., 1986. The sheep were re-weighed in the middle of winter the following year (4 July, 1987) when sheep on the-high-stocking rate treatments had the lowest bodyweight (45.7 kg/head). The medium stocking rate sheep were heavier (i.e. 55.2 kg/head) and the low stocking rate sheep were marginally heavier than the medium stocking rate (58.4 kg/ha). Sheep were weighed the day they were removed from the experiment, late in the growing season (12 November, 1987). Sheep from high stocking rate areas had gained weight in spring (i.e. 67.5 kg/head). In addition, sheep from medium- and low-stocking-rate areas had also gained weight over the same period (75.8 and 77.5 kg/head for medium and low stocking rates respectively).

In conclusion, sheep at high stocking rates did not reach the same bodyweights as those on medium and low stocking rate areas, but the animal production per unit area was greater. Sheep grazed at the high stocking rate required supplementary feeding during winter 1987: however, the cost of this feed would have been compensated by the additional wool cut per hectare. In terms of greasy wool produced, the high stocking rate had by far the highest production (118 kg/ha). The sheep at this stage had maintained high individual wool cuts. Often under excessively-high stocking rates the individual wool cut is decreased but the yield per unit area can be high (Carter 1965, 1966, 1977; Allden 1968; Willoughby 1968). The medium and the low stocking rates had 84.5 kg/ha and 23.4 kg/ha greasy wool respectively.

4.4.2 Seed Production

Seed yield and number: The cultivars Nungarin, Dalkeith and Junee were affected by initial plant density and had reduced seed yield on plots sown initially at the low rate. Donald (1954) suggested that reduced yield at low plant densities was due to strong intra-plant competition. This may be the strongest in the early cultivars Nungarin and Dalkeith in the MES experiment. Similarly, Rossiter (1959) found that the early cultivar Dwalganup had one of the lowest seed yields when grown as single plants.

The effect of stocking rate on seed yield was not statistically significant. This is somewhat surprising since low stocking rate plots were highly shaded and this is known to reduce seed yield. Supra-optimal leaf area of dense swards were found to produce less flowering nodes (Rossiter 1961, 1972). Shading was also shown to reduce seed yield due to decreases in the number of inflorescences (Collins *et al* .1978; Dunlop 1985). However, the density range used by Collins et al. (1978) was higher (1800 - 3200 plants/m^2) compared to those of the MES experiment (1125 - 2183 plants/m^2). Rossiter (1961) also found no Cultivar x Grazing interactions for seed yield of the cultivars Dwalganup, Yarloop and Bacchus Marsh. An early-maturing cultivar such as Nungarin may lose a higher proportion of seed than later-maturing cultivars. This was indicated by the dramatic decrease in the amount of seed above-ground due to high stocking pressure. Despite this, Nungarin had the highest seed yield at each stocking rate. Collins (1978) found that defoliation during flowering caused a reduction in seed yield of some cultivars and not others. This was attributable to behaviour of strains to defoliation: however, Collin's experiment did not involve defoliation by grazing. The MES experiment indicates that differences were due to maturity.

Nungarin and Dalkeith had the greatest seed yield below-ground in 1986. Both cultivars are early-season types, and hence have more opportunity to bury their seeds before soil moisture conditions become unfavourable and a hard crust forms on the soil surface in late spring. Clare buried less seed in comparison, because of its later maturity as well as its inherently weaker burr burial capabilities (Barley and England 1970; Francis *et al.* 1972). Nungarin buried the highest percentage of its seed below-ground in 1986 (42%). Later- maturing cultivars buried proportionately less of their seed (Dalkeith 34%, Trikkala 30%, Clare 23%, Junee 21% and the Mixture 25%). The proportion of seed buried followed the same order in 1987, except Trikkala had the highest proportion of seed below-ground. All cultivars showed an increased level of seed buried in 1987 but this is due to some accumulation of 1986 seed. The seed from the cultivars Nungarin and Dalkeith would have the highest level of protection from grazing animals due to high burr burial. No doubt this contributed to high seedling numbers at regeneration.

Trikkala, Clare, Mixture and Junee had reduced total seed yield and numbers in 1987, whereas Nungarin and Dalkeith had increased total seed yield in 1987 compared to 1986. This possibly could be seasonal, since the 1987 season at MES was shorter than 1986, thus favouring the seed production of the earlier-maturing cultivars Nungarin and Dalkeith.

Rossiter (1961) found that individual seed weight from both above- and below-ground burrs was decreased by grazing. Smaller seed was found at high stocking rates at MES, this could result in smaller seedlings for the year of regeneration. This indicates that some stress was imposed on developing seed causing seed size reductions. In addition, the largest burrs may have been eaten while the feed was still green. This would result in the production of smaller seeds at the end of the growing season. Summer-autumn grazing of burrs could further reduce the mean seed size and this effect would be more pronounced under high grazing pressure (de Koning and Carter 1989 a,b). This topic will be further expanded in Chapter 5.

In conclusion, seed yield and number can be affected by the initial sowing rate, but this is dependent on the cultivar. Cultivars such as Nungarin and Dalkeith have depressed yields at the initial sowing rate 10 kg/ha. Stocking rate was never statistically significant for seed yield. Nungarin and Dalkeith are both successful in the second year's seed production. This could be a combination of inherently high seed production and early maturity. The late spring in 1987 was drier than in the previous year (Table 4.1) and this would have favoured the early cultivars. Thus, seed yield in this experiment was also dependent on seasonal weather conditions.

Nungarin and Dalkeith are probably the most suited cultivars under continuously grazed conditions in the Mintaro district of South Australia. Both had prolific seed production combined with good burr burial which is essential for productive self-regenerating pastures.

Germination of seed from burrs: Soft seed percentage was definitely influenced by the season. Above-ground burr from the 1986 harvest had approximately 16 percent soft seed, irrespective of cultivar, sowing rate or stocking rate. The above-ground burr from the 1987 season had approximately 7 percent soft seed. The 1986 growing season finished later than 1987, which may have resulted in the production of more permeable seed. Furthermore, the cultivars which had the highest soft seed percentage in above- and below-ground burrs were the same for both years. Conversely, cultivars with high soft seed had lower hard seed content and higher dormant seed (e.g. Clare above-ground burrs). Clare and the mixture always had the highest soft seed along with the cultivar Trikkala (above- and below-ground burrs). This result was similar to those found under non-defoliated conditions (small-plot density experiment 1985). Therefore, soft seed differences between cultivars are strongly influenced by inherent factors. Sowing rate was not an influential factor with regard to soft seed percentage.

Increased stocking rate may have influenced the seed coat permeability resulting in reduced hard-seededness of below-ground burrs of the cultivar Dalkeith, due to removal of residues resulting in increased exposure of burrs to fluctuating temperatures. Correspondingly, Dalkeith had increased dormant seed as stocking rate increased. The cultivar Dalkeith buried more burrs at the low stocking rate, the level of hard seed was also higher at the low stocking rate. Buried burrs were found to have a higher level of hard-seededness (Collins 1981). Cocks (1984) found with medics that softer seed were formed under less dense swards and this may have been due to less protection from the sun's heat. The progressive reduction of breakdown of hard-seededness in medic seeds with increasing straw cover has been clearly shown by Quigley and Carter (1989). However, Clare produced more below-ground hard seed at the high stocking rate. The percentage soft seed in burrs on heavily stocked areas would be expected to increase over the summer as more and more herbage residue was removed exposing more burrs. In addition, exposing burrs also predisposes them to be more readily eaten by the sheep.

4.4.3 Conclusions

A grazing experiment at the Mortlock Experiment Station, Mintaro during 1986 and 1987 has shown that a low density sward of sub clover (100 plants/m^2) achieved high herbage yield and seed yield if the stocking rate was kept at a medium to low level (e.g. 11 and 7 sheep/ha (d.s.e.). However, the sheep went onto the pasture at a relatively late stage in 1986. Low plant density pastures could not tolerate prolonged high stocking rates through treading and defoliation effects. The experiment showed that high plant density swards could be grazed at higher stocking rates (e.g. 15 sheep/ha (d.s.e). Furthermore, results from the experiment indicated that high density swards (1600 plants/m^2) are at an disadvantage if the grazing pressure is too low. Excessive amounts of dry residues left on the surface over summer can physically impede emergence, while also insulating seeds from the sun's heat which can reduce hard seed breakdown.

Seed production was favoured by high-density swards and the early maturing cultivars had the best seed production if the initial sowing rate was high. This supports the contention that seed yield is strongly correlated to herbage yield. High seed production also increases the over-summer carrying capacity of a pasture. There is some evidence from the MES experiment that early-maturing cultivars have reduced seed yield due to severe grazing during flowering.

The cultivars Nungarin and Dalkeith show the greatest promise in the Mintaro district. Both cultivars have good early production, high seed set and good regeneration. A substantial amount of seed is also buried by both cultivars which will protect that seed from over grazing during the summer-autumn period. Clare, on the other hand showed signs of deterioration in the second year. Regeneration of Clare was reduced on high-stocking-rate plots resulting in poor early-season yields. This contrasts dramatically with the good performance of Clare in the first season at MES and in the small-plot-density experiment of 1985. These results heighten the need for cultivar evaluation to go beyond one year and under continuous grazing. The MES experiment would have provided more information on the persistence of cultivars under grazing if the experiment continued beyond 2 years. However, it gave indications that Nungarin and Dalkeith have the potential for good performance and persistence under continuously grazed conditions.

Mixtures of several cultivars with a range of maturities to fill the range of ecological niches in any sown area show promise in terms of herbage and seed production. High seed production is a prerequisite for good regeneration for general purpose pastures. The mixture at MES was intermediate for all yield parameters. The proportions of the components of the mixture will constantly change according to the season, however a mixture will provide a more stable source of herbage and seed. The more successful components of the mixture will persist, so in a sense natural selection will determine which cultivars are most suited to the environmental conditions and the stocking pressure most commonly used (Carter 1988).

Botanical compostion obviously differed between years at MES. These differences reflect changes in the sward structure rather than seasonal differences between years. Sub clover plant numbers (i.e. density) and grazing pressure had key roles in altering sward structure. Changes to botanical composition are inevitable in grazed ecosystems: however, the medium stocking rate (11 sheep/ha) was relatively more stable which will be important if that pasture is to be used for seed production.

Long term persistence of sub clover-based pastures will be favoured by high sub clover plant numbers and high seed production. Both high sub clover plant numbers and high seed production are strongly influenced by the cultivar. If high plant numbers are maintained the stocking rate can be increased which in turn increases the animal productivity from pasture. Monitoring of soft seed reserves and plant numbers at emergence (Carter *et al.* 1989) are useful aids to assessing the stability, potential productivity, and carrying capacity of sub clover pastures.

5

SUMMER-AUTUMN GRAZING EXPERIMENT AND PEN FEEDING STUDIES 1987 - 1988

5. SUMMER - AUTUMN GRAZING EXPERIMENT AND PEN-FEEDING STUDIES, 1987-88

5.0 Introduction

A shortage of livestock feed in the summer-autumn period is a common feature of livestock production in the Mediterranean-type environment of southern Australia. Over summer there is a gradual decline in the quality and quantity of dry pasture residues, and heavy grazing of this residue may severely deplete seed reserves. Carter (1981) showed that as sheep progressively consumed dry medic residues on a hard-setting soil the sheep first selectived the largest pods that contained the most seed and the largest seed. As grazing continued the residual pods became progressively smaller containing fewer and smaller seed.

The seed reserves of pastures based on sub clover can also be severely depleted although it may be less severe than grazed medic residues because some seed is buried in the soil. However, on the hard-setting soils that are common in the South Australian cereal belt, a lesser percentage of seed is buried and so loss of seed over summer by grazing may greatly reduce seed reserves. Although survival of seed following ingestion by sheep is very important ecologically, most research has focused on nutritional aspects of sub clover residues during summer (Donald and Allden 1959; Hume *et al* . 1968; Wilson and Hindley 1968). While the survival of ingested seed has long been recognized as a means of spreading legumes on non-arable land (e.g. Suckling 1950), only recently have the effects of summer grazing on seed survival and consequent botanical composition and seed production of annual pastures, and the broader ecological implications of these factors been recognized (Carter 1978, Carter and Lake 1985, Jones and Simao Neto 1987, and Simao Neto *et al.* 1987). Furthermore, there is very little detailed understanding of the passage and survival of sub clover seed ingested by sheep.

The aim of the research described in this Chapter is to identify and quantify the main effects of summer-autumn grazing by sheep on the seed and seedling dynamics of sub clover-based pastures. The first experiment is primarily concerned with the impact of sheep grazing dry residues of mixed sub clover cultivars over the summer-autumn period. A mixture of sub clover cultivars was selected because it is more representative of the strategy of having a broad-based mixture for long-term stability of the pasture (Carter 1987). The second experiment was designed to quantify the survival of sub clover seed fed to penned sheep. The seed was fed as intact burrs collected separately from swards of the MES grazing experiment. The same five sub clover cultivars were used in the mixture sown for the summer-autumn grazing experiment. It was expected that seed from the five different cultivars could well have differing levels of survival following passage through the sheep.

5.1 Materials and Methods

5.1.1 Field grazing experiment:

Location and preparation of site: The area used was paddock W16 on a hard-setting red brown earth soil at the Waite Agricultural Research Institute (W A R I), South Australia. The previous cropping history of the paddock was beans in 1983, wheat in 1984, oats in 1985. In 1986 the paddock was limed before sowing on 22 May with a 30 kg/ha sub clover mixture. The mixture comprised five cultivars viz: Nungarin, Dalkeith, Trikkala, Junee and Clare in equal proportions by weight (i.e. the same cultivars as used for the MES grazing experiment). All seed was inoculated with Type C inoculum prior to sowing. The actual sowing rate achieved was 31.5 kg/ha. The seed mixture was sown through the fine side of the grain box with a Horwood Bagshaw combine drill fitted with trailing harrows. Single superphosphate (9% P) was applied at a rate of 100 kg/ha.

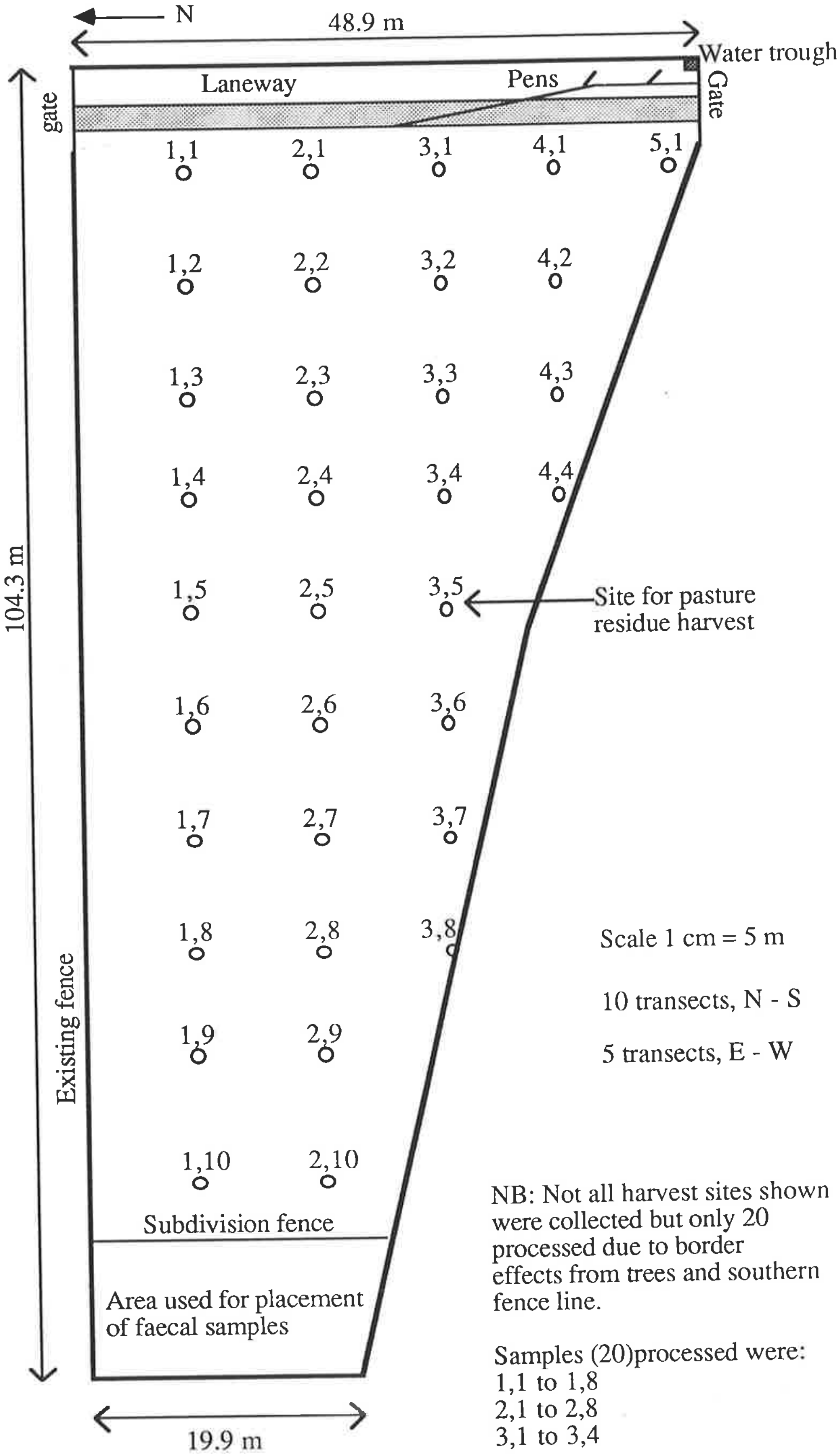
Emergence counts were made on the 3 June, 1986. Fifty quadrats (20 x 30cm) in total were counted along five transects (i.e. 10 quadrats/transect). The average number of seedlings was 121/m^2. On 11 August, 1986 the area was sprayed with 350 ml/ha Rogor (active ingredient 400g/L Dimethoate) to control lucerne flea. The next day wire weed was sprayed using 2,4,DB at 3 litres/ha . On 18 August, 1986 the area was sprayed with Fusilade 212 at 500ml/ha to control grass weeds. The site was grazed normally during the 1986 growing season and seed set. The total area available for grazing was 0.27 ha.

Introduction of sheep: Ten Merino wether sheep, fitted with canvas faecal-collection harnesses, were introduced to the paddock on 2 February, 1987 and continuously grazed the site for the following seventy days (bodyweights of the sheep at the start and the end of grazing are presented in Appendix C, Table 1). Sheep were penned each morning at 0900 hr to allow the removal and replacement of faecal-collecting bags. Faecal samples were weighed and 100g sub-sample taken. The remaining faeces were dried at 45^{o}C in a forced-draught dehydrator and held in reserve. The 100g sub-sample was washed through a square-holed 1mm test sieve. Seed from the washed sample was placed in petri dishes and germinated in a humidified incubator at 19°C. Each Petri dish had 3 filter papers and 5ml distilled water containing 1.6g/litre of the fungicide Thiram added. Dishes were remoistened when necessary. On the seventh day of the germination test all hard seed was scarified using fine sand paper. The total duration of the germination tests were 14 days. Total seed throughput and percentage viable seed [i.e. potential germination of both permeable (soft) and impermeable (hard) seeds] was calculated for the mixture of sub clover cultivars. Every seventh day from 6 February to 10 April a second 100g sample of fresh faeces was taken and placed in the field (10 sheep replicates x 10 weeks = 100 samples) on the soil surface contained within 15.5 cm square white plastic rims to restrict movement and the emergence of seedlings from the faecal pellets counted twice at the break of the season (21 May, 1987 and 28 May, 1987). No seedlings emerged from the faecal pellets during summer.

Harvesting of dry pasture residues: The dry pasture residues on the area were sampled on 30 January 1987. Thirty-three circular samples were taken on a grid pattern using a steel cylinder 28 cm in diameter (See Diagram 5.1). Above-ground samples and below-ground samples to a depth of 2.5 cm (for estimating buried sub clover seed) were taken. Every week, while the sheep grazed the area, harvests of above-ground dry pasture residue were taken. At each grid intersection (see Diagram 5.1) a central sample was taken on the first harvest occasion, subsequent samples were taken 1.5m away on the circumference of a circle surrounding the central harvest site. All harvested sites were marked with a steel peg with coloured tape tied to the top so that previously harvested sites could be avoided. A second below-ground harvest was made after the sheep had been removed. Harvests were taken to measure the disappearance of total pasture residue including burr from the surface. Twenty of the 33 samples were processed fully (grid positions 1.1 - 1.8, 2.1 - 2.8, and 3.1- 3.4) to calculate the number of burr/m^2, number of seed/m^2 and for germination tests on burrs. Those grid positions were selected to avoid a possible border effect from the southern fence which was lined with trees. The number of seeds/m^2 was determined by dissecting 60 burrs at random on each harvest occasion. Germination tests involved the removal of 100 burrs at random from the 20 processed samples on each harvest occasion and these were placed into 4 Petri-dishes (i.e 25 burrs/dish). Burrs were placed in a humidified incubator for 14 days at 19^{o}C to allow germination of sub clover seed in the burrs.

Raised-bed experiment: This experiment was designed to examine the identity and number of soft (permeable) seed in burrs and faecal samples from the field grazing site, but under favourable, well watered conditions. Faecal samples were taken from the oven-dried portions remaining from those samples placed in the field. The amount of dry faeces needed to equal viable seed numbers in the 100g wet faeces is given in Appendix C, Table 3. Burrs were selected at random and the number used contained approximately 100 seeds (The transect samples used are listed in Appendix C, Table 4). In total there were 10 faecal samples from every seventh day (10 sheep replicates x 10 weeks = 100 samples) and 10 burr samples per harvest occasion (10 replicates x 11 harvest occasions = 110 samples). Both burr and faecal samples were placed within 15.5 cm square white plastic rims on a base of sandy loam located in a raised-bed outdoors at the Waite Institute. Burrs and faeces were then covered with 1 cm sandy loam (see Diagram 5.2 for experimental layout). The experiment was sown on the 14 October 1987 and a harvest and count made on the 23 November 1987 and the final harvest on 22 January 1988. Samples were kept well watered throughout the duration of the experiment. The number and identity of plants was recorded.

Diagram 5.1: The paddock site W16 at the Waite Institute and the position of dry residue samples for the summer-autumn grazing experiment, 1987.



Scale 1 cm = 5 m

10 transects, N - S

5 transects, E - W

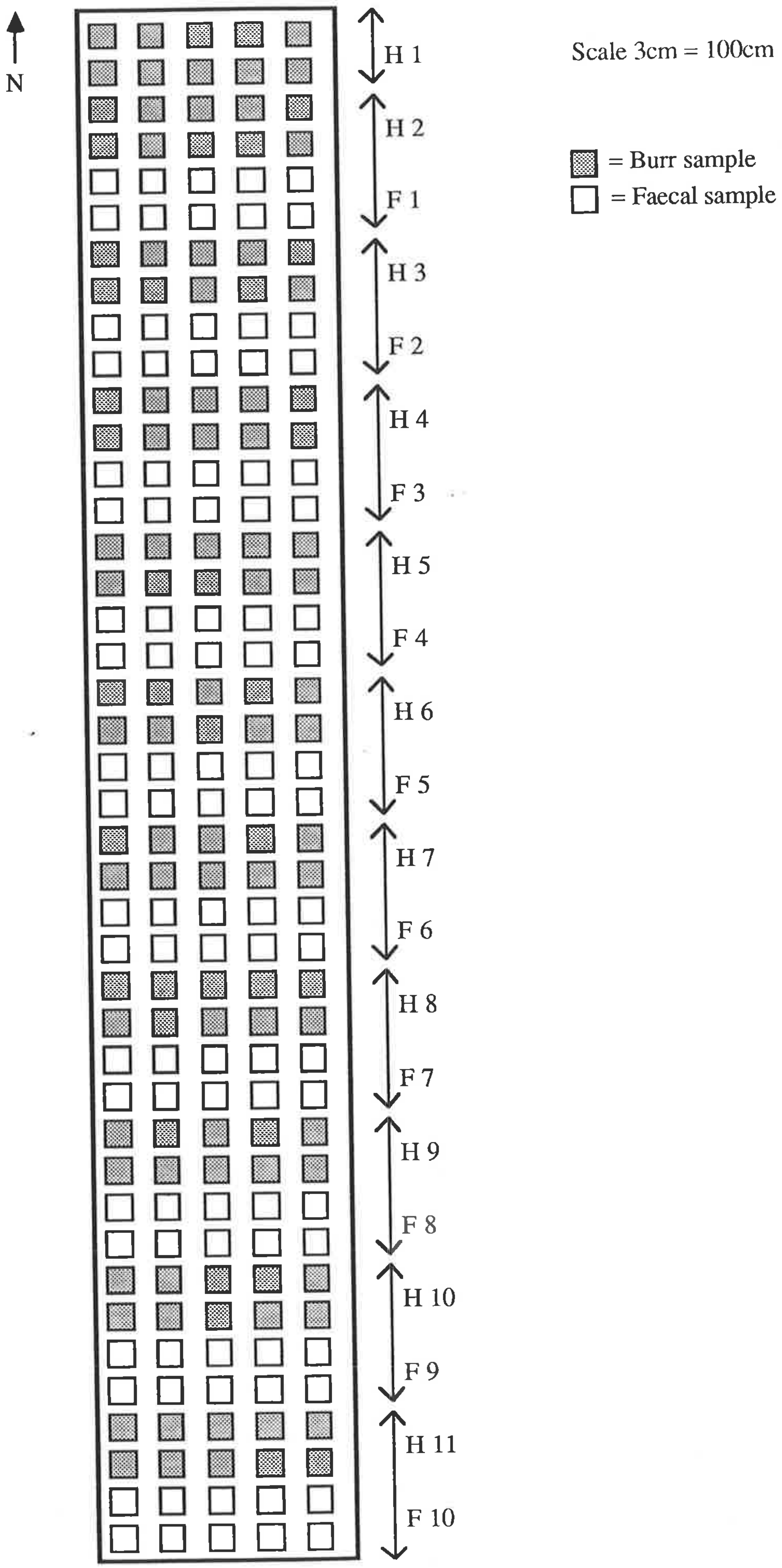
NB: Not all harvest sites shown were collected but only 20 processed due to border effects from trees and southern fence line.

Samples (20)processed were:
1,1 to 1,8
2,1 to 2,8
3,1 to 3,4

Diagram 5.2: The layout of the raised-bed experiment at the Waite Institute, 1987.

H 1;	Burr	samples	taken	on	30.1.87
H 2;	"	"	"	"	9.2.87
H 3;	"	"	"	"	16.2.87
H 4;	"	"	"	"	23.2.87
H 5;	"	"	"	"	2.3.87
H 6;	"	"	"	"	9.3.87
H 7;	"	"	"	"	16.3.87
H 8;	"	"	"	"	23.3.87
H 9;	"	"	"	"	30.3.87
H 10;	"	"	"	"	6.4.87
H 11;	"	"	"	"	13.4.87

F 1;	Faeces	samples	taken	on	6.2.87
F 2;	"	"	"	"	13.2.87
F 3;	"	"	"	"	20.2.87
F 4;	"	"	"	"	27.2.87
F 5;	"	"	"	"	6.3.87
F 6;	"	"	"	"	13.3.87
F 7;	"	"	"	"	20.3.87
F 8;	"	"	"	"	27.3.87
F 9;	"	"	"	"	3.4.87
F 10;	"	"	"	"	10.4.87


N
H 1
H 2
F 1
H 3
F 2
H 4
F 3
H 5
F 4
H 6
F 5
H 7
F 6
H 8
F 7
H 9
F 8
H 10
F 9
H 11
F 10
Scale 3cm = 100cm
= Burr sample
= Faecal sample

Meteorological data at the Waite Agricultural Research Institute for the year 1987 and the average values from 20 years of data are given below.

	Temp °C Max. 1987	Temp °C Max. 20yr mean	Temp °C Min. 1987	Temp °C Min. 20yr mean	Rainfall (mm) 1987	Rainfall (mm) 20yr mean
Jan	24.8	28.2	14.0	16.8	27.0	24.0
Feb	27.6	28.5	16.4	17.4	22.8	25.0
Mar	23.8	25.3	14.4	15.8	28.4	24.0
Apr	23.1	22.0	14.2	13.7	25.8	56.0
May	17.4	17.8	11.2	11.0	139.4	79.0
June	15.8	15.1	9.5	8.9	111.6	73.0
July	14.2	14.4	8.1	8.3	142.4	86.0
Aug	15.1	15.4	8.8	8.7	53.6	74.0
Sept	18.5	17.2	10.2	9.6	22.2	62.0
Oct	20.4	20.6	10.5	11.5	50.6	53.0
Nov	24.3	23.4	14.1	13.3	8.8	38.0
Dec	26.6	26.0	15.0	15.2	47.2	29.0
Annual mean	21.0	21.2	12.2	12.5	*679.8	*623.0

* Yearly total

5.1.2 Pen feeding studies

Nine Merino wethers, each fitted with faecal-collection harness, were penned separately in the Waite Institute animal house (18 January, 1988). The sheep had a two-week settling-in period prior to the start of the experiment. Sheep were weighed at the beginning of the experiment and at the end (Bodyweight data is in Appendix C, Table 2).

Intact burrs of each of the five cultivars used in the MES grazing experiment (Chapter 4) and the summer-autumn grazing experiment 1987 were fed sequentially every seven days to eight of the nine sheep (one spare retained). Burrs from cultivars were fed in the following sequence; Nungarin, 1 February; Trikkala, 8 February; Dalkeith, 15 February; Clare, 22 February; and Junee 29 February 1988. Clare and Trikkala were the only cultivars with clearly-indentifiable seed, hence their order in the feeding sequence. Prior to feeding, burrs were dissected to determine the number of seed/burr. The source of the burrs was from the seed harvest at MES at the end of 1986 (Source A) and additional burr harvested at the end of 1987 (Source B). These were fed separately. Sheep numbers 1 to 6 were fed source A burrs for each of the cultivars except Dalkeith source A which was fed to sheep 1 - 5. Source B burrs were fed to sheep numbers 7 and 8, except source B Dalkeith burrs which was fed to sheep 6, 7 and 8.

Each sheep was fed 50g burrs (except Clare when only 40g was fed because there were less Clare burrs available) mixed in with the normal ration of 800g pellets and 100g chaffed straw. All burrs were consumed within half a day. On the days between burr feeding the normal ration of pellets and straw was fed. It was noted that the majority of seed was voided before the end of 14 days. Therefore, the last collection of faeces was made on the 13 March 1988.

Faeces from the sheep was collected daily at 0900hr, weighed and a 400g sub-sample taken. The remaining faeces was dried at 45^{o}C in a forced-draught dehydrator. The sub-sample was washed through a square-holed, 1mm test sieve and the seed removed and placed in petri dishes. Germination of seed was carried out in a humidified incubator at 19^{o}C for 14 days. On the seventh day all hard seed were scarified. The total seed throughput, percentage total viable seed (soft + hard seed) and percentage hard seed were calculated for each of the cultivars. Germination tests on sub-samples of burrs to determine seed numbers and levels of hard-seededness preceded the actual feeding.

Plate 5.1: General view of sheep fitted with faecal collection harnesses grazing dry sub clover residues in summer-autumn at the Waite Institute, 1987.

Plate 5.2: Close-up view of dry sub clover residues. Left: grazed by sheep for 70-days, Right: ungrazed.

5.2 RESULTS - SUMMER-AUTUMN FIELD GRAZING EXPERIMENT

5.2.1 Dry pasture residues on offer to the sheep

There was a linear decline in the amount of dry residue available over the period of the experiment. At the start of the experiment there was 6619 kg DM/ha, which on day 70 had declined to 2559 kgDM/ha (Fig.5.1, r = -0.929***). Disappearance of sub clover burrs (kg/ha) and percentage burr in the pasture residue in contrast, showed a curvilinear trend (Fig. 5.2 & 5.3, r = -0.987*** and -0.986*** respectively). Explanation of this will be given in the discussion.

Figures 5.4 - 5.8 illustrate the burr components before ingestion by sheep. Highly significant regressions were found for the decline of burrs/m^2, seeds/burr and mean burr weight (mg) (r = - 0.993***, - 0.904*** and - 0.982***, repectively). The disappearance of burrs per unit area followed a quadratic relationship: 4606 burrs/m^2 on day 0, declined to 1294/m^2 on day 70. Individual burr weight decreased linearly (40.5 mg to 22.5 mg, r = - 0.982***). Mean seed weight also decreased but was not statistically significant (r = - 0.429 n.s). On day 0 there were 7936 seeds/m^2 which was reduced to 1522 seeds/m^2 on day 70. The percentage total viable seed (hard and soft) and percentage hard seed and dormant seed in burrs did not change significantly during the 70 - day period (Figures 5.8) but the percentage germinable seed did increase significantly (regression equation; Y = 9.80 + 0.16x, r = 0.692*, n = 11) as time progressed (Figure 5.8).

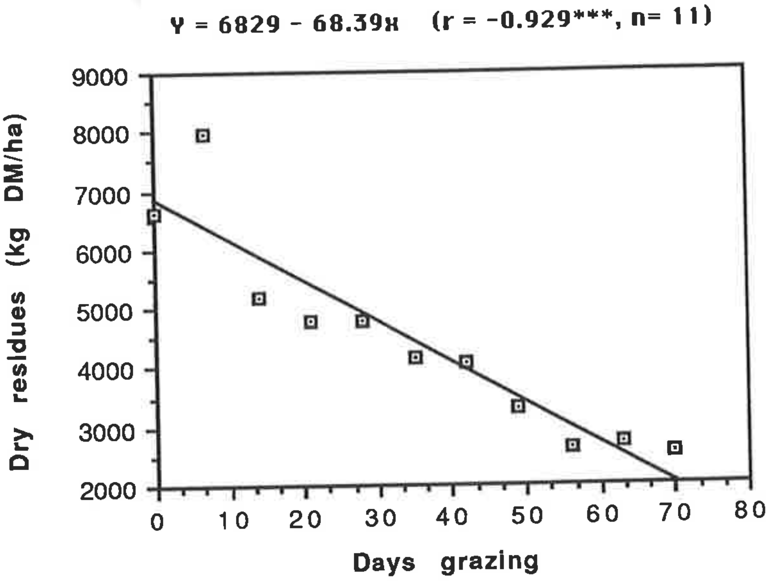


Fig. 5.1 The progressive decline of dry pasture residues (kg DM/ha) grazed by sheep for 70-days during summer-autumn at the Waite Institute, 1987.

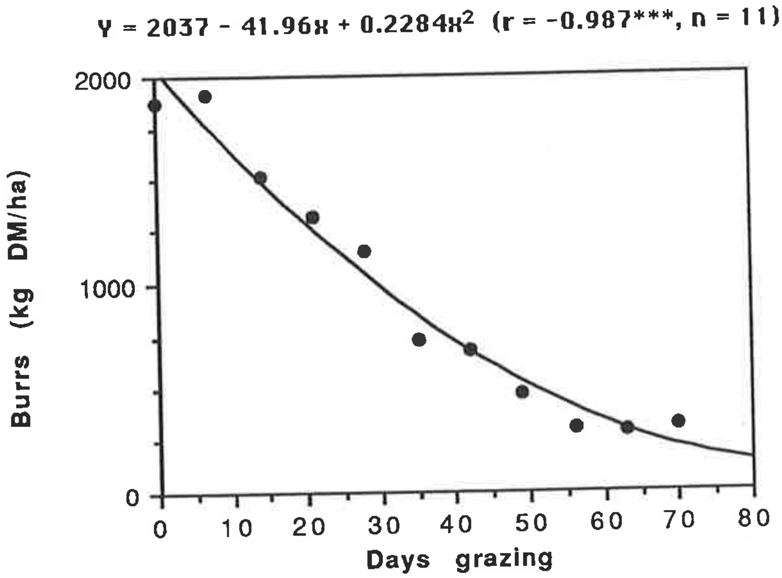


Fig. 5.2: The disappearance of burrs (kg DM/ha) grazed by sheep for 70-days during summer-autumn at the Waite Institute, 1987.

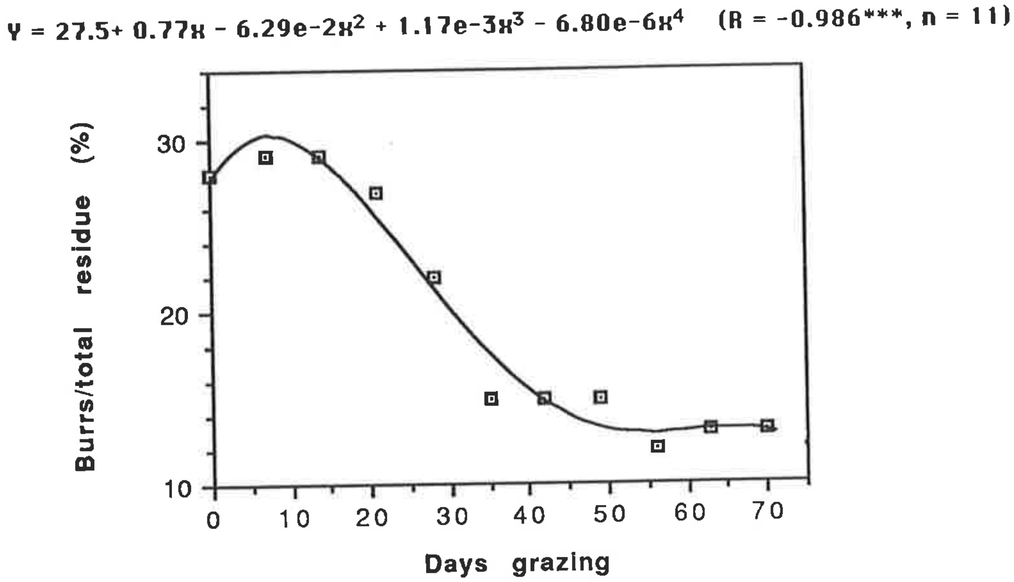


Fig. 5.3: The percentage burrs in dry pasture residues grazed by sheep for 70-days during summer-autumn at the Waite Institute, 1987.

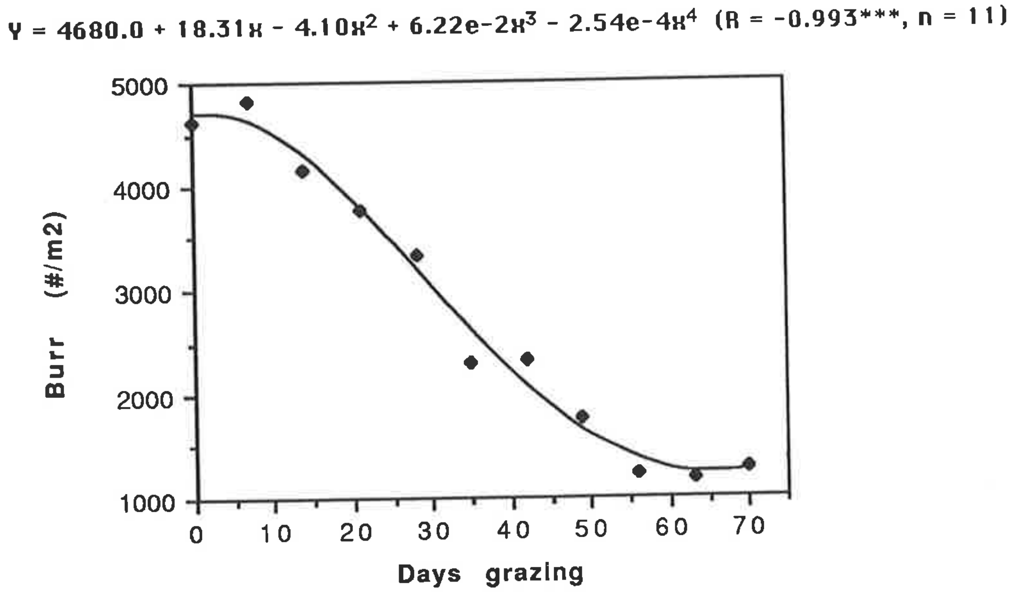


Fig. 5.4: The progressive decline of burr numbers grazed by sheep for 70-days during summer-autumn at the Waite Institute, 1987.

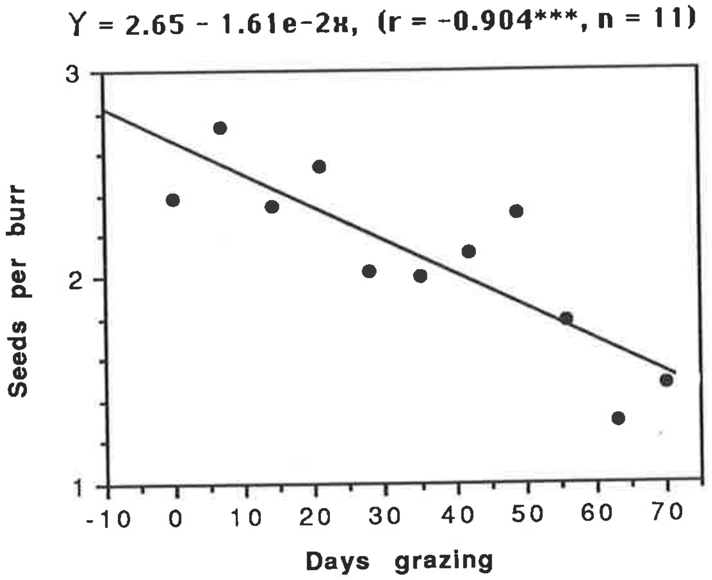


Fig. 5.5: The decrease in seed number per burr while grazed by sheep for 70-days during summer-autumn at the Waite Institute, 1987.

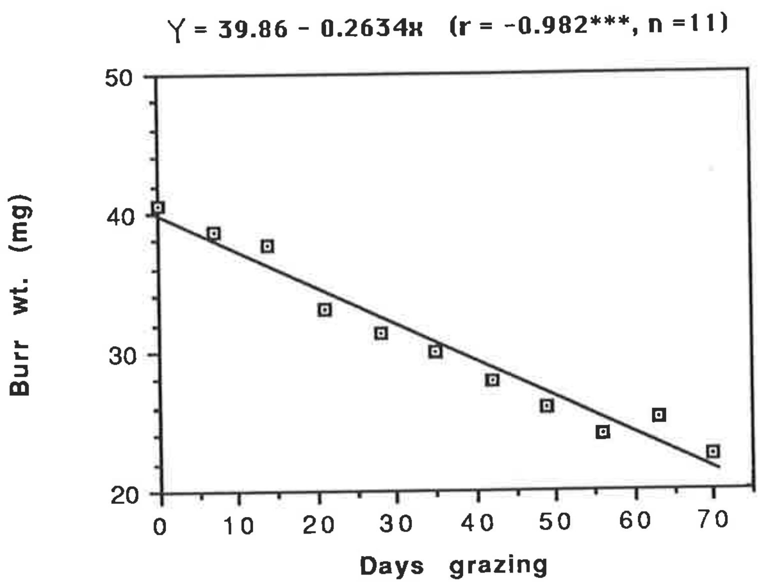


Fig 5.6: The decrease in mean burr weight (mg DM) while grazed by sheep for 70-days during summer-autumn at the Waite Institute, 1987.

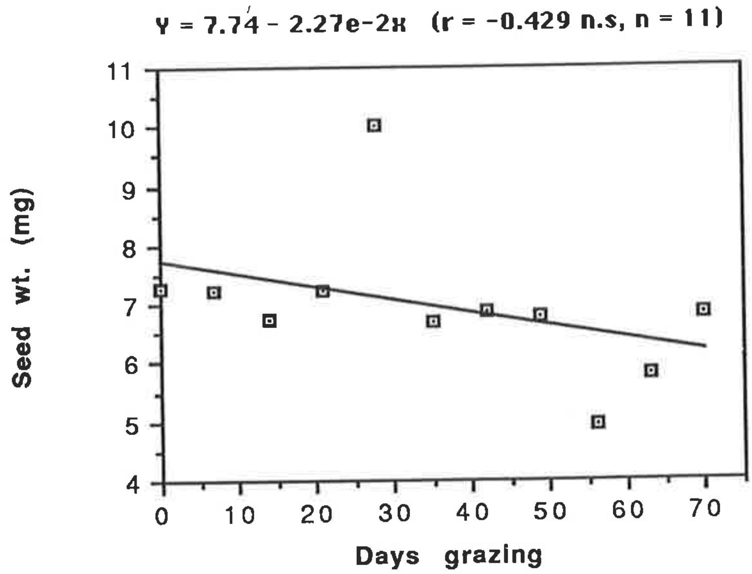


Fig. 5.7: The trend in mean seed weight in burrs while grazed by sheep for 70-days during summer-autumn at the Waite Institute, 1987.

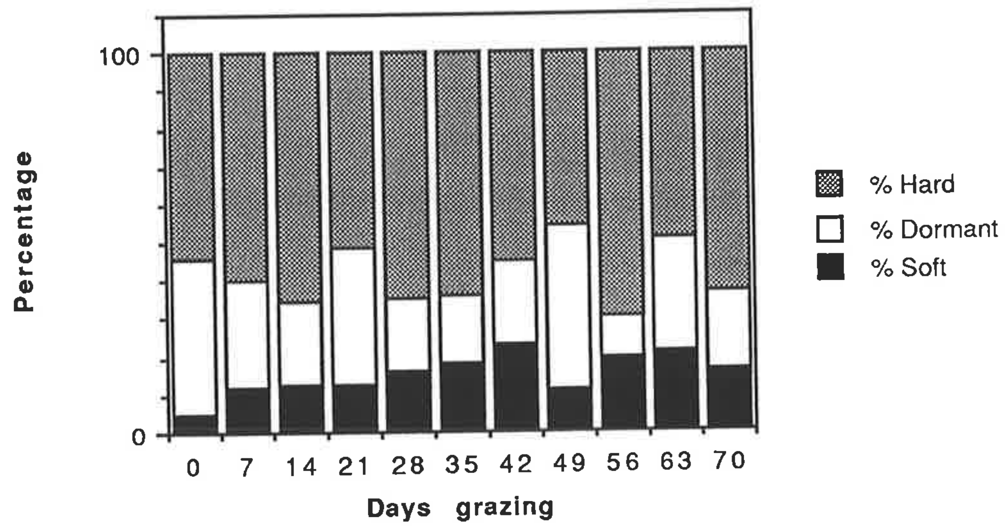


Fig. 5.8: The percentage soft, dormant and hard seed in burrs while grazed by sheep for 70-days during summer-autumn at the Waite Institute, 1987.

5.2.2 Seed survival through the digestive tract of grazing sheep

Data on output of faeces for the 70 day period are summarised in Figure 5.9. Each point represents the total faecal output of ten sheep for a day. However, it should be noted that day 34 data was omitted from figures because eight sheep had scoured and samples could not be used (see Appendix C, Table 5). Throughput data on daily output of total number of seed and total number of viable seed (hard and soft) are presented in Figures 5.10 - 5.11. All follow a similar curve. Initially the seed output is low but with time the number of seed voided increases. A maximum is reached after about 35 days after which the seed voided decreases. Figure 5.10 shows to high points at day 45, this is possibly due to seed trapped in the digestive tract of sheep (Suckling 1950, 1952) and then suddenly released. Total viable seed number for the flock is presented as a cumulative output in figure 5.13. Forty to sixty percent of seeds defaecated were hard seed and the regression was highly significant (Figure 5.14, $R^2 = 0.768^{***}$). The percentage viable (soft) seed voided for the flock increased over the 70 days of grazing (Fig. 5.15). This followed a linear regression ($r = 0.318^{*}$), unlike the complex polynomial curve seen for percentage hard seed. The throughput of total viable seed was estimated at 1.5% (soft = 0.5% and hard = 1.0%) of the intake.

The mean seed weight of seed found in the faeces significantly decreased over the period of the experiment (Fig. 5.12, $r = -0.792^{**}$). In addition, the seed found in the faeces was significantly lighter than those found in the burrs prior to feeding ($P<0.05$ t-test, average 0.8mg difference). This indicates that the smaller, harder seed are the most likely to survive passage through the digestive tract of sheep.

Differences were found between individual sheep. However, individual sheep were mostly consistent in terms of output of total seed. Some sheep consistently voided higher amounts of seed than others and this occurred throughout most of the experiment (See Appendix C, Table 5).

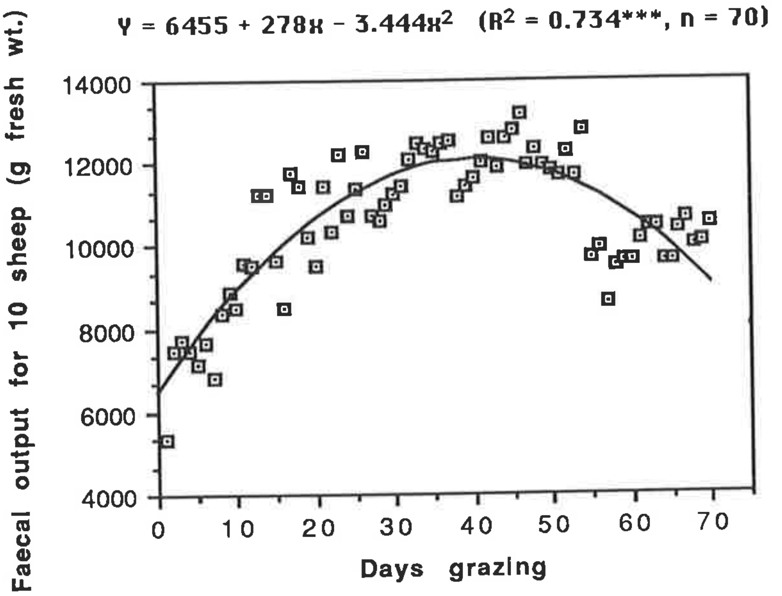


Fig. 5.9: The total output of faeces from the flock (10 sheep) over the 70-day grazing period at the Waite Institute, 1987 (Fresh weights shown).

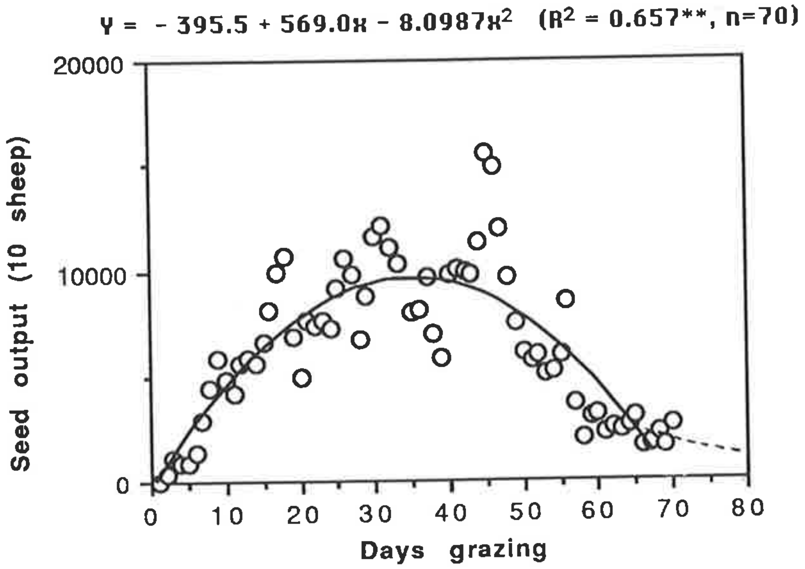


Fig. 5.10: Total seed output in faeces of 10 sheep (the flock) during the 70-day grazing period at the Waite Institute, 1987.

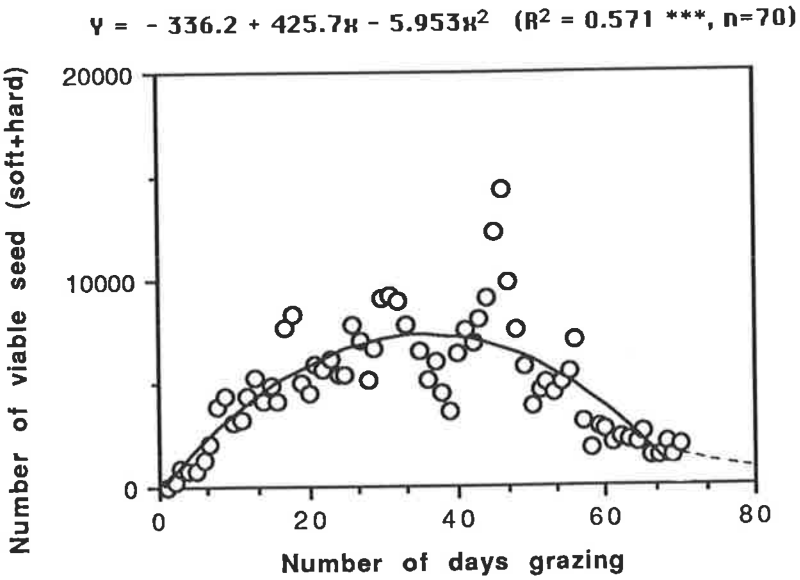


Fig. 5.11: The total number of viable seed (hard and soft) in the faeces of 10 sheep during the 70-day grazing period at the Waite Institute, 1987.

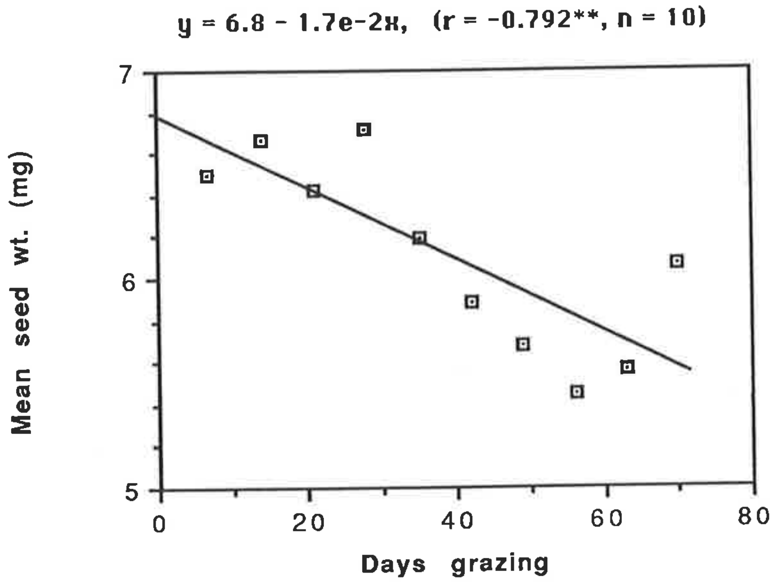


Fig. 5.12: The mean seed weight (mg) of seed in the faeces output from the 10 sheep during the 70-day grazing period at the Waite Institute, 1987.

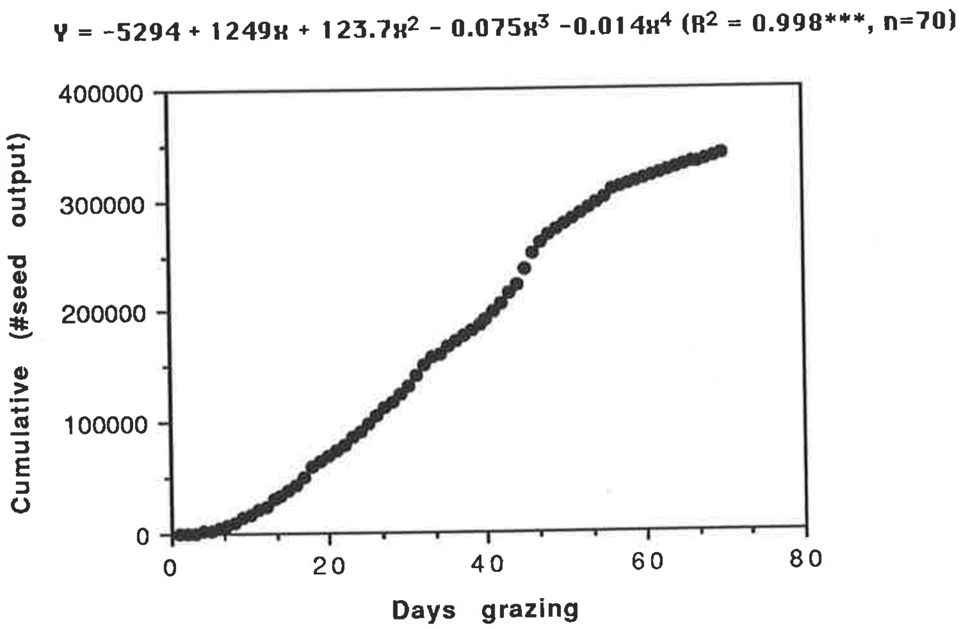


Fig. 5.13: Cumulative viable seed (soft and hard) output for the 10 sheep during the 70-day grazing period at the Waite Institute, 1987.

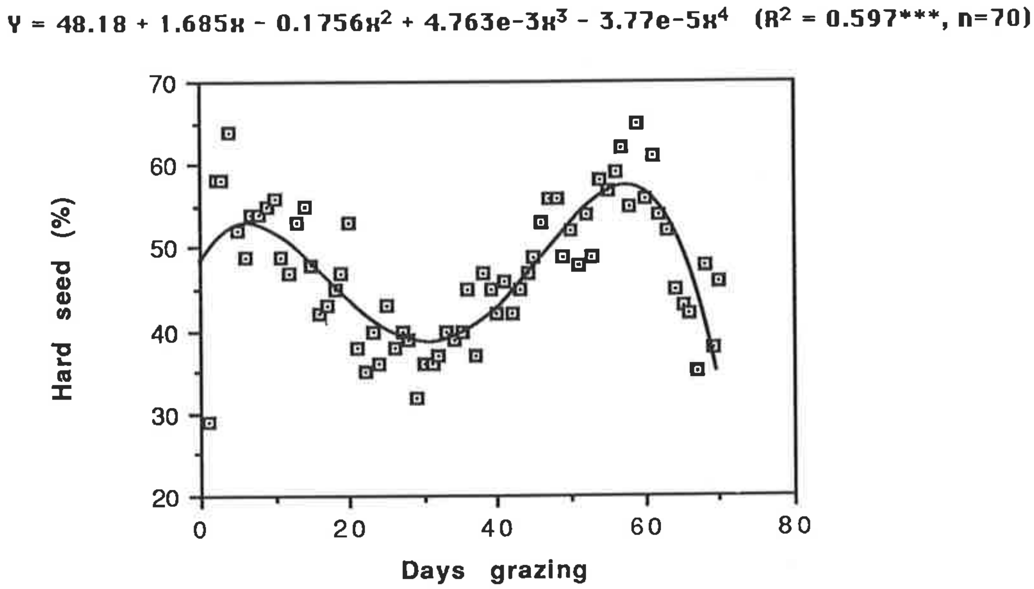


Fig. 5.14: The percentage hard seed in the faeces of sheep grazing in the summer-autumn period at the Waite Institute, 1987.

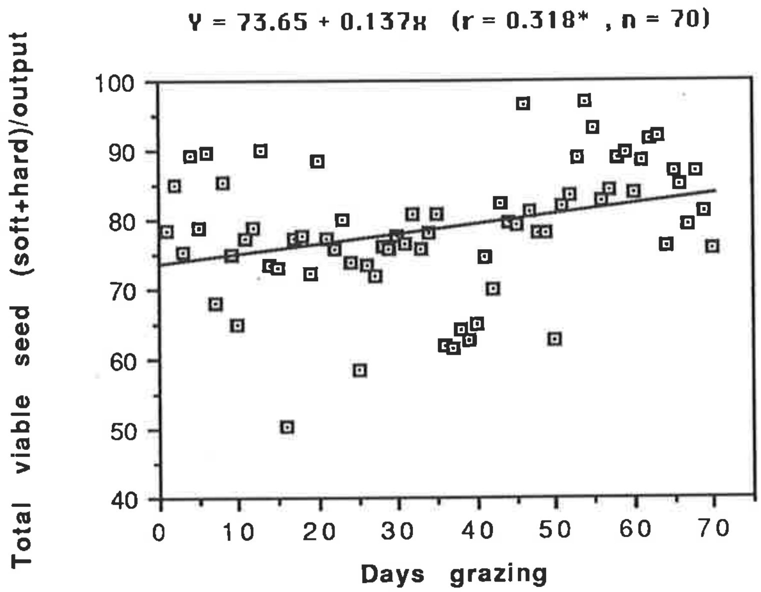


Fig. 5.15: The percentage total viable seed (hard and soft) in the faecal output of sheep grazing in the summer-autumn period at the Waite Institute, 1987.

All sheep had lost an average of 7.5 kg/head liveweight over the 70 day period of the experiment (Appendix C, Table .1).

5.2.3 Seedling emergence from field faecal samples and the raised-bed experiment

Table 5.1 compares the number of seedlings which emerged from the field faecal samples compared to the raised-bed samples. The survival and number of seedlings was much greater for samples placed in the raised-bed. The number of sub clover seedlings emerging from faecal pellets in the field was estimated to be only 0.13% of the total seed ingested (Table 5.1). This can also be seen in Figure 5.16 which illustrates the cumulative number of seedlings to emerge from samples taken over the 70-day grazing period. The figure also represents the number of seedlings that may be present at any time during the 70-day grazing period after rain. However, both field samples and samples placed into the raised-bed only represent those seedlings that were derived from the soft seeds. These seeds are the most likely to contribute to the plant population in the next season, while the hard seed contribute mainly to the long-term seed bank.

Data on total number of seedlings to emerge from burrs is summarised in Table 5.2. Clare, Trikkala and Junee had the highest proportion of seedlings to emerge from burrs in the raised-bed experiment. However, as Table 5.3 shows, it does depend on the stage in the experiment. Junee appears to increase as time progressed. This may be due to more rapid softening of Junee seeds as burrs became progressively exposed, hence more germination. Seedlings from faecal samples comprised mostly Junee and Dalkeith particularly in the later stages of the grazing experiment.

Regeneration of the experimental site was poor, only an average of 63 plants/m^2 (Counted 13 May 1987).

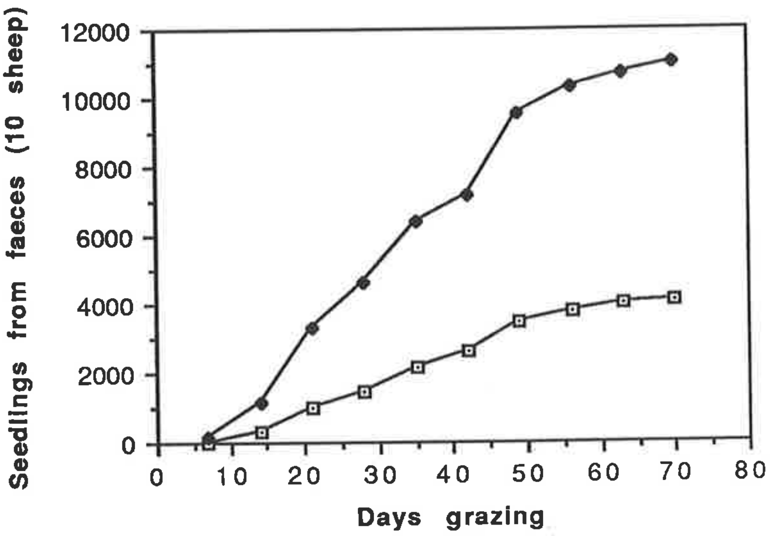


Fig. 5.16: The cumulative number of seedlings to emerge from faecal samples (Numbers based on flock of 10 sheep) in the field (unwatered) and in a raised-bed (watered).

Legend: ⊡ Field emergence
◆ Raised-bed emergence

Table 5.1: The number of seedlings to emerge from faecal samples placed in the field to dry and from a raised-bed where the samples were watered at the Waite Institute, summer-autumn 1987 (data extrapolated to the total flock of 10 sheep).

Days grazing	7	14	21	28	35	42	49	56	63	70
Field Emergence	22	251	759	452	694	410	842	322	213	101
Raised-bed Emergence	157	1001	2154	1303	1751	818	2326	796	418	263

Table 5.2: The number of seedlings to emerge from burrs (approx. 1000 seeds/sampling date) taken from the summer-autumn grazing experiment and germinated in the raised-bed for the identification of cultivars from soft seed.

Days grazing	0	7	14	21	28	35	42	49	56	63	70
Cultivar											
Nungarin	26	16	12	10	18	22	23	14	17	24	10
Dalkeith	15	25	34	26	39	19	33	39	34	32	35
Trikkala	26	41	46	33	53	53	55	36	39	55	27
Junee	14	24	25	44	47	59	75	79	70	67	56
Clare	42	52	97	74	75	85	66	52	51	39	44
Total	123	158	214	187	232	238	252	220	211	217	172

Table 5.3: The percentage of cultivars to emerge from burrs and faecal samples in the raised-bed experiment (soft seed only).

Days grazing	0	7	14	21	28	35	42	49	56	63	70
						Burrs					
Cultivar											
Nungarin	21.5	10	6	5	8	9	9	6	8	11	6
Dalkeith	12	16	16	14	17	8	13	18	16	15	20
Trikkala	21.5	26	21	18	23	22	22	16	19	25	16
Junee	11	15	12	24	20	25	30	36	33	31	33
Clare	34	33	45	39	32	36	26	24	24	18	25
						Faecal samples					
Cultivar											
Nungarin	-	26	19	11	11	15	15.5	17	13	15	4
Dalkeith	-	22	9	14	28	29	29	19.5	29	30	32
Trikkala	-	13	17	24	12	22	14	19.5	15	10	16
Junee	-	22	21	23	31	20	26	27	36	35	32
Clare	-	17	34	28	18	14	15.5	17	7	10	16

5.3 Results - Pen feeding experiment

5.3.1 Burr germination and burr dissection data

Clare and Trikkala burrs had the highest percentage of readily-germinable seed, and the lowest level of hard seed prior to feeding but this was only for source A burrs. Nungarin and Dalkeith had the highest level of hard seed (Table 5.4).

Junee had the highest numbers of seeds per burr. However, it also had one of the smallest seeds (Table 5.5). As a reult the number of seeds fed to penned sheep was greatest for Junee. In contrast, Clare had the largest seed hence less seed was fed.

5.3.2 Survival of seed following ingestion by penned sheep

The mean fresh faecal weights from the eight sheep are given in Appendix C, Fig. 1. Table 5.6 summarises results from feeding burrs of the five cultivars of sub clover. Most seed was voided on the third and fourth days after feeding. The throughput of total viable seed (hard+soft) and hard seed are expressed as percentages of seed fed because of the variable number of seeds fed depending on the cultivar. Analyses of variance were carried out on arcsine transformed data. The percentage of hard seed in the faecal seed output did differ significantly between cultivars ($p<0.001$). Dalkeith had the highest percentage of hard seed in the output while Clare had the lowest. The high proportion of hard seed found in faeces of sheep fed Dalkeith can possibly be ascribed to the high level of hard seed in the burrs before ingestion. However, when percentage soft seed (did not include dormant seed) and hard seed were related to the total number of seeds eaten (i.e. output/input %) differences between cultivars were not significant. Differences between cultivars in percentage total viable seed output would be difficult to detect because of the wide variation between sheep. However, sheep with low seed ouput, mostly had low output for each of the cultivars (See Appendix C, Table 6 for an example of this). Carter (1980) has recorded a consistent three-fold difference in medic seed throughput by three sheep. Sheep # 4 and #5 in the pen feeding had the lowest total viable (soft and hard) seed output regardless of cultivar. This also corresponds to the total seed output.

All cultivars except Trikkala showed a decrease in mean seed weight for seed found in the faeces (Table 5.6) compared to seed in burrs prior to feeding (Table 5.5) but differences were not significant.

Table 5.4: The percentage soft, hard seed and dormant seed for source A (MES burr 1986) and B (MES burr 1987) burrs fed to penned sheep at the Waite Institute in 1988.

	Soft seed (%)		Hard seed (%)		Dormant (%)	
	Source A	Source B	Source A	Source B	Source A	Source B
Cultivar						
Nungarin	5.7	7.5	92.9	85.0	1.4	7.5
Dalkeith	3.1	5.2	90.3	84.4	6.6	10.4
Trikkala	24.6	8.8	68.1	88.9	7.3	2.3
Junee	7.4	5.7	80.0	90.3	12.6	4.0
Clare	29.4	9.1	47.1	80.4	23.5	10.5

Table 5.5: The number of seeds per burr, the individual seed weight and the number of seeds in 50g burrs for sources A and B fed to penned sheep at the Waite Institute in 1988.

	Seed (#/burr)		Mean seed wt. (mg)		No. of seed in 50g burrs*	
	Source A	Source B	Source A	Source B	Source A	Source B
Cultivar						
Nungarin	2.4	2.5	4.9	4.9	4308	4201
Dalkeith	2.5	3.1	6.8	7.0	3128	3119
Trikkala	2.5	2.4	7.9	7.8	3112	3367
Junee	2.9	3.3	5.1	5.1	4130	5015
Clare	2.3	2.6	9.6	6.8	1782	2961

* only 40g of Clare burrs were fed

Table 5.6: The survival of seed from five cultivars of sub clover following ingestion by sheep in pen feeding studies at the Waite Institute in 1988.

	Subterranean clover cultivar					
	Nungarin	Dalkeith	Trikkala	Junee	Clare	
Seed fed(#/sheep)	4281	3125	3176	4351	2077	
Seeds voided(#/sheep)	208	193	139	232	104	
Mean seed wt. of seed voided (mg)	4.35	5.82	8.34	4.77	7.02	
Viable seed Output/input(%)	3.5	5.1	3.4	4.2	3.7	n.s.
Hard seed Output/input(%)	2.9	5.0	3.2	4.0	3.1	n.s.
Hard seed in output(%)	62.7[b] (52.1)	80.5[c] (60.8)	72.7[bc] (57.7)	74.0[bc] (58.4)	61.0[a] (42.7)	

Different superscript letters indicate significant differences calculated on arcsine transformed data. In brackets are the means calculated from the arcsine transformed data.

5.4 Discussion and conclusions

5.4.1 Summer-autumn grazing experiment

The rate of disappearance of total dry pasture residues was constant over the 70 day period of the experiment: however, the disappearance of sub clover burrs (kg/ha) was curvilinear with the greatest reduction occurring after the first two weeks. Selection of burrs was slow at the start because of the abundance of dry leaf and stem with traces of green weeds. However, as the availability of leaf and stem material declined the sheep began to select burrs. Carter (1981) has shown that sheep selectively graze medic residues and select the largest pods containing the most seed and the largest seed first. Similarly, in this experiment the sheep first selected the largest burrs containing the most seed and the largest seed first. Wilson and Hindley (1968) also found that sheep selected sub clover burrs from a sub clover-rye grass pasture. They found that burrs comprised 10.3% of the total dietary intake. Hall (1984) also found that sheep actively selected sub clover burrs, particularly during drought.

The results of this experiment also indicate a severe reduction in total number of viable seeds with time. On day 0 there were 7936 seeds/m^2 which was reduced to 1522 seeds/m^2 on day 70. In addition, sheep had eaten approximately 670 kg/ha seed over the 70-day period. However, during the 70-day grazing period the percentage dormant and the percentage hard seeds in burrs did not change significantly. Nevertheless, it does appear that the percentage germination from burrs did increase with time but this was not accompanied by a decrease in hard seed. It is probable that dormant seed were gradually losing dormancy, hence contributing to the increase in germination (see Figure 5.8).

At the start of grazing very little seed was passed through the sheep, no doubt because the sheep were eating green weeds and dry leaves and stems from sub clover residue in preference to burrs. As the amount of dry leaf and stem declined, burrs became more exposed and were increasingly ingested, resulting in an increase in the viable seed output. The decrease in viable seed output in the final 2 - 3 weeks can be attributed to declining availability of burrs. The cumulative total viable seed output was linear from day 14 to 55. From day 56 to day 70, the number of viable seed voided dropped dramatically. Had the experiment continued beyond 70 days, the rate of viable seed voided would no doubt have fallen gradually resulting in the levelling of Figure 5.13 and the extended tail for Figure 5.11.

Up to two-thirds of the seed found in faeces was hard. However, considering the level of hard seed found in burrs (58%), much hard seed was destroyed. Suckling (1950, 1952) also found that unscarified (98% hard) white clover seed was still destroyed despite having been administered to sheep via gelatine capsules to minimise chewing effects. Nevertheless, seed that remains whole and viable following chewing and digestive processes is most likely hard seed. Sub clover seed is considerably larger than white clover seed, therefore is more prone to chewing damage. Furthermore, Figure 5.14 shows how the percentage hard seed found in the faecal output fell mid-way through the experiment when the greatest number of seed was being passed through the sheep. This effect cannot be attributed to the percentage hard-seededness of the burrs at that time because these were shown not to change at any period during the experiment. One possible explanation is that at that stage sheep were selecting the large burrs of Clare and Trikkala, both of which normally have a higher proportion of soft seed than the other cultivars. The raised-bed experiment also showed that Clare and Trikkala had high soft seed levels throughout the 70-day period of the experiment. The subsequent rise in hard seed percentage may be the result of sheep having to eat whatever burrs are there on offer as burr availability decreased. Burrs at this stage possibly consisted mostly of the smaller burrs of harder-seeded cultivars such as Nungarin and Dalkeith. The final decrease in hard seed found in the faeces could be due to the small amounts of seed being consumed and reduced and slower throughput of digesta, hence the digestive juices are more likely to attack and penetrate the seed coat thus reducing the hard-seededness. This did not occur early in the experiment even though levels of burrs consumed were small because there were also large quantities of dry leaf and stem matter being ingested. Soft seed voided in faeces is unlikely to survive under the hot, dry summer-autumn conditions in southern Australia. Therefore, this soft seed in faeces will not contribute significantly to the regeneration of pasture.

Sheep lost bodyweight during the 70 days (Average 7.5 kg/head, Appendix C, Table 1). Even though bodyweights were not checked weekly, it is possible that the bodyweight loses commenced from day 35 - 40 onwards because this corresponds to the time when daily viable seed outputs were declining and the faecal output decreased. The burr availability at that stage was 725 kg/ha (i.e approximately 300kg/ha seed). This is considerably higher than the minimum level of 10 kg/ha of medic pods required to sustain weight gain of Awassi sheep (Cocks 1988). Squires (1978) found that sheep gained weight when fed burrs and tops. However, in the Waite Institute experiment sheep lost weight on a similar diet. Dry tops disappeared quickly in the Waite Institute experiment and sheep became more dependant on burrs. Squires (1978) found that sheep fed burrs only had a slow decline in weight. Therefore, in the Waite Institute experiment sheep may have begun to lose weight when they became more dependant on burrs for a source of feed but at the same time burrs were decreasing in availability. It should be noted that the stocking density in the Waite Institute experiment was the equivalent of 30 sheep/ha and this high level of grazing pressure may have contributed to the weight loss of sheep. The stocking rates used by Cocks (1988) were lower 5.3 to 16 sheep/ha, while those stocking rates used in Squires (1978) experiment were from 12 to 25 sheep/ha. Furthermore, sheep in the pen-feeding studies did not lose weight: in fact, most gained some weight. This can be related to the higher quality of the diet and that sheep in penned conditions do not have the stress of actively seeking feed as in the case of grazing sheep.

The number of sub clover seedlings emerging from faecal pellets in the field was estimated to be only 0.13% of the seed ingested. Low survival of the imbibed soft seed deposited in faecal pellets is likely to have been due to desiccation. Suckling (1950), suggested that soft seed in dung most probably doesn't survive the period of fermentation or they become desiccated. These results are in contrast to those of Simao Neto *et al.* (1987) who found seedling emergence from faecal pellets were similar to germinations from washed-out samples: however, they used different legume species and kept faeces moist. Nevertheless, the raised-bed experiment at the Waite Institute in which faecal pellets were well watered have some similarities to the laboratory germination tests from washed-out samples. Seed in faeces which was placed in the field represents the normal situation after sheep have defaecated while grazing under field conditions in a Mediterranean-type environment. Not only is it likely that imbibed seeds are desiccated, but any seed which germinates will die unless there is sufficient following summer rainfall to allow establishment. If there is no follow-up rain, those seeds which have begun germinating will find it difficult to emerge from the hardening faecal pellet. It was observed in this experiment that in some cases only the radicle protruded from the pellet before it dried and died through desiccation. Problems may be similar to those of soil pelleting (Campbell 1963) whereby the radicle was often beyond the pellet and prone to desiccation. Therefore, in some dry environments the faecal pellet itself may present a physical barrier to the germinating seed. Observations confirmed this contention. Most faecal pellets were very hard and dry, requiring much water to moisten them. They also dried quickly once wetted. The breakdown of hard seed in faecal pellets found on the soil surface, could be faster due to fluctuating temperatures, particularly on hard-setting soil where little if any dung would be trampled into the soil during summer-autumn. Therefore, in dry climates it would be beneficial to scarify the soil surface to incorporate faecal pellets and any surface burrs.

5.4.2 Pen-feeding studies

One of the most notable aspects of this experiment is the higher survival of total viable seed compared to the field grazing experiment (3.4 - 5.1% for the pen-feeding studies and 1.5% for the summer-autumn grazing experiment). Wilson and Hindley (1968) had also found 5% of the seed eaten by penned sheep to be passed as whole seed in the faeces. Of that seed 51% germinated. However, in their study no mention is made of the hard seed percentage found in faeces. It is probable that the high survival of seed in the animal house at the Waite Institute is due to the higher quality fed (digestibility) compared to the field. Jones and Simao Neto (1987), found that low quality diets had the lowest survival of seed found in faeces. Dry pasture residues in the field always deteriorate with time from exposure to the weather. Suckling (1950, 1952) also found that the grazing of mature white clover stands *in situ* had low seed survival following ingestion. However, the figures quoted were based on the amount of seed available and not the amount of seed eaten. The pen feeding studies described in this thesis showed no statistical differences between cultivars in the percentage total viable seed survival, despite Dalkeith having the highest survival.

Seed size accounted for 80% of the survival of seed in the studies conducted by ICARDA in Alleppo, Syria (Thomson *et al.* 1987). Seed size is unlikely to have influenced the survival of sub clover seed in the pen-feeding studies at the Waite Institute, because the range of seed size was not large enough to show any response. Legume seed used in the study by Thomson *et al.* (1987) had a very wide range in seed size (several Australian medic cultivars, ICARDA medic lines, *Trifolium campestre* and *T. tomentosum*).

Wilson and Hindley (1968) also found that the germination percentage of seed from faeces was very similar to the seed on offer to grazing sheep. However, the summer-autumn grazing experiment and the pen-feeding studies at the Waite Institute showed that the percentage germination was higher for seed in faeces than seed prior to feeding. Wilson and Hindley (1968) used seed and burr, therefore much of the seed prior to feeding may have been scarified as indicated by the 52% germination of seed prior to feeding.

Results from the pen-feeding studies have shown no significant differences between the cultivars in the survival of seed through the digestive tract of sheep. Due to the lack of variation in the survival of the seed from the sub clover cultivars used in this experiment, it is not expected that changes in botanical composition will occur. However, burr size and seed size are potentially important contributors to changes in botanical composition. The summer-autumn grazing experiment demonstrated that sheep selected the largest burrs containing the most seed and the largest seed first. Therefore some cultivars with inherently large burrs (e.g. Clare) are more likely to be selected from dry residues first, thus contributing to botanical composition changes.

5.4.3 Conclusions

Results from the Waite Institute, 1987 experiment have shown how rapidly the seed from a sub clover pasture is depleted by grazing sheep over the summer-autumn period. Excessive grazing during this period may also result in smaller, ecologically-less- fit seed remaining at the end of summer-autumn grazing. Therefore, summer-autumn grazing management of sub clover pastures must ensure that adequate seed reserves are left for either regeneration of the pasture or adding to the seed bank following tillage for a cereal crop. In addition, enough dry pasture residue should be removed to prevent smothering of seedlings (Carter 1987).

Although sub clover buries some seed it would be beneficial to incorporate more seed into the soil by shallow scarification (i.e. no deeper than 3 cm) following grazing by sheep to prevent excessive consumption of seed. This will enhance the seed bank reserve in the soil for regeneration. The sheep themselves can be used to incorporate burr into sands and other light-textured soils.

The removal of some dry pasture residues not only reduces the risk of 'blanketing' seedlings but increases the level of soft seed for the regeneration year. This is due to the removal of the insulative effect that dry residues can have, thus exposing burr/seeds to a wider fluctuation in temperature which is required for hard seed breakdown (Quigley 1989).

If dry pasture residues of sub clover are to be grazed it is important that the amount of seed in the soil seed bank prior to grazing is known. Monitoring of the decline of sub clover burrs/seeds may then be undertaken to avoid excessive depletion of the sub clover seed reserves

6

GENERAL DISCUSSION AND CONCLUSIONS

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6.1 Influence of sub clover plant density on herbage and seed production

Sowing rate or plant density proved to be a very influential factor in herbage production and seed yield in the small-plot experiment of 1985 and in the grazing experiment at MES in 1986 - 87. Early in the growing season pasture production was directly related to plant density. High pasture production led to high seed yield and high seed yield commonly lead to high seedling density at regeneration. Despite the fact that some cultivars have inherently high levels of hard seed, high seed numbers can compensate and ensure good densities at emergence. Persistence of sub clover-based pastures is assured if high seed/seedling production is maintained. A low density sub clover pasture has the potential to produce high herbage production and seed production if maintained at low stocking rates and the weed species are controlled. However, low pasture density depresses autumn-winter production and depresses livestock carrying capacity at that time.

(i) Herbage production: There is no doubt that high-density swards are more productive early in the season, but depending on the cultivar, both herbage yield and seed yield may be depressed if not defoliated or under-utilized. Low utilization of dry pasture residues on the low stocking rate plots resulted in a 'blanketing' of emerging seedlings which reduced pasture availability and total yield (Carter 1954, 1987, 1988; Carter and Wigg 1963). Similarly, in the small-plot experiment, the cultivars Clare, Trikkala and Yarloop had reduced seedling numbers at emergence as the amount of dry herbage residues increased. The opposite occurred for Esperance. Quigley (1988) has demonstrated that excessive cereal straw cover severely reduced the number of emerging medic seedlings. It was suggested that part of the solution was to graze the straw residue. Similarly, the grazing of dry sub clover pasture residues from high density swards is essential, but care needs to be taken not to overgraze and deplete the seed reserves (see general discussion 6.4).

Under continuously-grazed conditions a large initial plant density is important because it governs the level of grazing which can be tolerated. Donald (1954) suggested that high density pastures would be the most useful for grazing. Many, small seedlings can optimise yield early in the season, but a cultivar such as Clare can have fewer, larger seedlings and can yield equally well or better as demonstrated in the small-plot experiment 1985. This was also shown by de Koning (1984) and de Koning and Carter (1987a). However, small-seeded cultivars such as Esperance can lose a high proportion of plants later in the season which may result in reduced herbage and seed yield at the higher densities (Chapter 3). Early defoliation of a high-density sward such as Esperance may well have lessened the number of plants lost. The management strategy is to maximise the utilization of light energy early in the season.

(ii) Botanical composition: Plant density affected botanical composition in both undefoliated swards of the small-plot experiment and the MES grazing experiment. Generally, more weeds were found on low density sub clover plots in both experiments. Undefoliated swards in the 1985 experiment showed differences were due to both density and the cultivar, taller cultivars having a competitive advantage over the more prostrate cultivars. Results from the MES experiment showed that under grazing, cultivar differences contributed little to the reduction of weeds in the pasture, and stocking rate and sub clover plant density were more important. Mostly the high-stocking-rate plots had the highest sub clover content for 200 kg/ha plots in 1987. High-stocking-rate plots sown to 10 kg/ha had substantial invasion of other species such as *Trifolium glomeratum* and *T. tomentosum*. Low stocking rate plots sown at 10 kg/ha had proportionally more grasses. Botanical composition changes are not necessarily detrimental to livestock production so long as the invasive species are relatively productive and palatable to livestock (Carter 1968a; Cameron and Cannon 1970; Carter and Lake 1985).

(iii) Seed yield: Seed yield was affected by the initial plant density. Very high densities were found to reduce the seed yield of some cultivars (for example Esperance in the 1985 experiment). This result is similar to the earlier work of Donald (1954), Rossiter (1959) and Taylor and Rossiter (1967). All researchers found that mid-late maturity strains had reduced seed yields when grown under sward conditions. However, in the small-plot experiment in 1985, Clare (mid-late season cultivar) did not have reduced seed yield under high plant densities. The reason for this is probably due to the large initial seed size of Clare compared to Esperance, so even though both cultivars were sown at equivalent weight of pure germinable seed, Esperance had the greatest number of seedlings. Low density was also found to limit the seed production of cultivars in undefoliated swards and under lax grazing.

Nungarin and Dalkeith had substantial decreases in seed yield in 1987 at MES when the initial sowing rate was 10 kg/ha. Similarly, Bolland (1986) found seed yield was lowest at the low sowing rate of 10 kg/ha. It was the above-ground seed component that was affected by sub clover density, the seed yield found below-ground was mostly unaffected by density and this was the situation for the small-plot experiment in 1985 and at MES. Nevertheless, the percentage of seed buried was affected by sowing rate. Cultivars in both experiments had a reduction in the percentage of the seed yield buried at the higher sowing rates. Strong evidence of this was found in the small-plot experiment with no defoliation. Junee and Trikkala were the only cultivars which showed a reduction in the percentage of seed buried below-ground at the high sowing rate at MES for both years. It was calculated that Junee had a reduction of between 31 to 37% with higher sowing rates, while Trikkala had a 7 to 8% reduction in the percentage of seed found below-ground.

6.2 Influence of grazing on herbage and seed production

Grazing influences on herbage and seed production on many occasions were found not to be statistically significant even though differences between grazing treatments could be clearly seen in the field. Observable differences are likely to have biological significance. Those stocking rate effects that were significant were mostly found on low sowing rate plots indicating that low plant density pastures were more sensitive to grazing pressure. However, a minimum of two replicates is necessary for studying the interrelations of the soil-plant-animal interface.

(i) Regeneration: Continuously stocked pastures unavoidably suffer from plant losses at emergence (Smith *et al.* 1973, Brown 1976a). Removal of seedlings by sheep was not a large problem on 10 kg/ha plots when grazed at the low stocking rate and the dry residue cover was not inhibitory as seen for similarly stocked 200 kg/ha plots. In conclusion, stocking rate modifies the regeneration of sub clover cultivars when sown initially at two contrasting sowing rates mainly through direct effects (treading - Carter and Sivalingam 1977) and defoliation of young plants and indirect effects through accumulation of dry herbage residues and consequent suppression of emergence.

Removal of burr/seed during the summer-autumn period would have contributed to the lower seedling emergence seen on high stocking rate plots (i.e. less seed present at the start of the growing season, therefore less available to germinate and emerge). The active selection by sheep for something green at the beginning of the growing season would also lead to the reduction in seedlings. Those cultivars with large cotyledons (e.g. Clare and Trikkala) would be more susceptible to selection by sheep at high stocking rates because of their more-readily prehendible size and height. This is one area of pasture research that requires more attention, particularly in view of the use of mixtures. The question needs to be answered as to whether large seedlings are more likely to be selected by sheep when grown in a mixture of cultivars with smaller seedlings. This has ecological implications in terms of yield, botanical composition and persistence of pastures in the long term. The aim is to acheive the highest possible level of regeneration. High density regeneration leads to better winter production, higher carrying capacity and the ability to achieve greater animal productivity and potentially increase profitability.

(ii) Botanical composition: The type of invasive species was a result of grazing pressure (i.e. grasses at the low stocking rate; small seeded annual legumes at the high stocking rate). This has been shown earlier by other researchers under a range of different environments (Carter 1966, 1977; Cameron and Cannon 1970; Carter and Day 1970). However, grazing pressure is not the only determinant of botanical composition changes, as stressed by Taylor (1985). In the MES experiment, initial sowing rate also influenced botanical composition. The results from the MES experiment indicate how rapidly changes in botanical composition can occur, hence adding to the difficulty in interpreting results from such studies. However, the study also highlights the fact that systems involving grazing are very dynamic (Carter and Lake 1985).

(iii) Pasture availability and total pasture production: Depending on the sub clover cultivar, high or medium stocking rates made the best growth supporting those results of Carter (1966, 1977) and Brown (1977). However, the MES experiment was run only for two years and sheep on high stocking rate areas needed supplementary feed. High stocking rate areas may not continue to have good growth if the experiment proceeded beyond two years: Carter (1968 a,b, 1977) found that high stocking rates led to failure of the pasture in the fourth year and Brown (1976 a,b) found that the total pasture production was greatly reduced at high stocking rates in the third year at Kybybolite, in the south-east of South Australia. However, dense plant populations can sustain a high stocking rate and invariably when a high stocking rate treatment 'crashes' it is the result of greatly reduced pasture production often following a "false break" to the season (emergence followed by death of annual pasture species through drought). Though not statistically significant, generally the high and medium stocking rate pasture areas made the best growth. Better growth was maintained by the earlier cultivars (Nungarin and Dalkeith) compared to the same cultivars in low stocking rate areas. The 1987 season was much drier than the 1986 season and it would appear that high stocking rates helped maintain better growth of the early cultivars, irrespective of the sowing rate. The later cultivars Junee and Clare made good growth which could partly be attributed to late maturity. Carter (1966) and Brown (1976a) also found that heavily-stocked areas remained greener for longer, because those pastures were able to continue to grow following rain in late spring. So it would appear that high stocking rates may be beneficial in extending the period of pasture growth.

(iv) Animal production: A highly-productive pasture grazed at a high stocking rate can greatly increase animal production. However, the needs of different livestock must be kept in mind. The requirements of wethers are not so high as those for ewes 'in lamb' or ewes with lambs at foot. Simply, ewes cannot be grazed at high stocking rates without risking production decreases and lamb losses. Nevertheless, wethers can be maintained at higher rates in the short term and the increases in wool production per hectare are great. The animal production per hectare (i.e. greasy wool weight) was much higher for high stocking rate areas.

(v) Seed production: Rossiter (1972) suggested that grazing low density swards may greatly affect seed yield, because sub clover cv. Dwalganup grown as single plants had reduced seed yield when defoliated at flower initiation or early flowering. In contrast, swards were found to have increased seed yield. Some evidence can be found to support this contention in the MES experiment, particularly at the end of the first season when there were large differences in sub clover populations following high and low sowing rates. The difference between the two sowing rates at the high stocking rate was approximately 1 tonne seed for Dalkeith. Later-maturing cultivars did not have the same magnitude of seed yield reduction. This may imply that on relatively pure swards of sub clover which are of low plant density (i.e those swards at 10 kg/ha at MES 1986) care needs to be taken when grazing the earlier cultivars at high stock densities particularly if a large seed yield is sought. However, the MES data in 1987 also indicate that heavy grazing on relatively high plant populations can also reduce seed yield.

Overall, mean seed weight had also decreased in the 1987 season compared to the 1986 season. This may be a seasonal difference, but could also indicate the beginning of long-term changes in seed size because of grazing. Rossiter (1961) also found a decrease in mean seed weight due to grazing. Both above- and below-ground seed components appear to have been influenced by high stocking rates at MES. The production of smaller seed will result in smaller seedlings at regeneration. Possibly the smaller seedlings could be ecologically less-fit, particularly if they are to emerge following a cropping sequence but not if regenerating in a long term pasture (Carter *et al.* 1989).

The proportion of burrs buried has also been shown to be affected by defoliation (Rossiter and Pack 1972; Walton 1975; Collins 1981). In the MES experiment Nungarin and Dalkeith buried a high proportion of seed. Hence, both cultivars are suited to persist well under grazing conditions. These results support the results of the above research workers.

6.3 Herbage and seed production differences between cultivars and the mixture

Production of herbage and seed varied between cultivars in the small-plot experiment and the MES grazing experiment. As commercial seed with a range of seed sizes was used in both experiments, it was not surprising that there were cultivar differences in plant densities following the sowing of equivalent weights of pure germinating seed.

(i) Botanical composition: Cultivars differ in the ability to compete with weeds as seen most clearly in the small-plot experiment, but only in the late stages of the growing season at the higher sub clover plant densities. Ability to compete with weeds under undefoliated conditions is also related to cultivar height. Similarly, Scott (1971) found that the plots containing the tall sub clover cultivars had the least weeds. Differences between cultivars in the ability to compete with weeds was not very clear at MES and this was probably due to grazing. Grazing is known to reduce the morphological differences between plants, particularly when the stocking rate is increased (Stuth *et al* 1985). This has implications for complex pasture mixtures, especially if there are tall and prostrate cultivars growing together as in the MES experiment. Tall cultivars such as Clare would be less likely to dominate at the high stocking rates, but may dominate the sward at low stocking rates. Rossiter and Pack (1972) found that increasing stocking rate restricted the taller Woogenellup cultivar thereby improving the competitive performance of Geraldton, a prostrate cultivar. In the MES experiment the individual cultivars of sub clover were too difficult to separate from the herbage harvested, hence no record of cultivar composition in the mixture was obtained from grazed areas. More-detailed examination of mixture swards under grazing is required. One can only speculate that Clare and Trikkala could be the dominant cultivars on low stocking rate plots at both sowing rates. Conversely the cultivars Nungarin, Dalkeith and Junee may be the most dominant at high stocking rates because of their more prostrate growth habit.

(ii) Herbage production: In the year of sowing at MES and in the small-plot experiment in 1985 there were no significant differences between cultivars in sub clover yield early in the growing season. This result supports the contention of Lawson and Rossiter (1958), given that equivalent weight of pure germinating seed is sown, differences between cultivars will be minimal. Differences between the yield of cultivars developed later in the growing season in both experiments which probably reflected differences in maturity. However, the second year at MES (i.e. the year of regeneration) did show cultivar differences in the cumulative winter growth but this was probably due to differences in seedling density at the high sowing rate which resulted from the constraint on emergence imposed by varying amounts of dry herbage residues. Both Nungarin and Dalkeith had the highest seedling numbers at regeneration and the highest yields. The early cultivars such as Nungarin and Dalkeith did have reduced growth late in the season at MES compared to other later maturing strains such as Clare and Junee. Nevertheless, had the seasonal breaks been late, the production of late-maturing cultivars could have been reduced. This was demonstrated in the small-plot experiment with the use of two sowing times which represented different breaks to the season. Clare had the greatest reduction in herbage yield when it was sown late in the small-plot experiment compared to early cultivars. As a result, late-sown Clare plots were not much different in yield to the other cultivars. Early sowing did result in production differences with Clare having the superior yield. Similarly, Dear and Loveland (1984) found cultivar differences in herbage yield of sub clover when sown early. This effect could also influence the cultivar composition of a mixture. Late seasonal breaks could reduce the yield of late-maturing cultivars when grown in a mixture or as pure swards. Late spring rains can also favour late-maturing cultivars and may, infact, cause some germination of seed of early-maturing cultivars.

(iii) Seed yield: Seed yields varied with cultivars: however, cultivar differences were dependent on the sowing rate (sub clover plant number) in the small-plot experiment. Both Clare and Yarloop had the highest total seed yield (above- + below-ground components), but only at the two highest sowing rates. Under grazing at MES, cultivar differences existed at both sowing rates (10 and 200 kg/ha). Seasonal conditions will also influence seed yield: in both years at MES, Nungarin and Dalkeith had the highest total seed yields while Clare had one of the lowest. Donald (1954) stated that the relationship between density and seed production was not expected to remain constant because of seasonal influences. High herbage yield did not always produce high seed yield. Clare had high pasture production in 1986 at MES but had one of the lowest seed yields. Yet in the small-plot experiment it had high herbage production and seed production. Defoliation by grazing probably affected the seed yield of Clare at MES. Flowers on tall sub clover cultivars would be more accessible to grazing livestock than prostrate cultivars. In addition Clare does not have good burr burial ability (Barley and England 1970; Francis *et al.* 1972) which would also predispose more burrs to be eaten by livestock.

Cultivars with large seeds produced large seed in subsequent years; small- seeded cultivars produced small seeds. This was shown to be partially dependent on sowing rate (small-plot experiment). Clare had the heaviest seeds in the small-plot experiment and the MES experiment: however, large seed size was not sufficient to compensate for low seed numbers for the total seed yield of Clare in the MES experiment.

The level of hard-seededness of sub clover in burrs will vary with cultivar, the degree of burr burial, defoliation and seasonal conditions at the time of seed maturation. Nevertheless, a cultivar such as Clare used in both the small-plot experiment and MES experiment generally had the lowest level of hard seed and the highest proportion of soft seed. In the MES and small-plot experiments the below-ground burr component contained proportionally more dormant seed, this was the situation for all cultivars. There is also some evidence that there is considerable microbial attack of seed in below-ground burrs. Taylor (1984) found evidence of microbial decomposition of hard seeds in the field. The evidence from the small-plot experiment and MES may suggest microbial attack or insect attack from crickets may occur early in burrs while they are relatively immature.

Experiments of one year duration (small-plot density experiment 1985) which are not defoliated do not provide information about the persistence of sub clover cultivars. For example Clare had one of the best herbage and seed productivities in the small-plot experiment, but showed signs of deterioration under continuously grazed conditions in the second season at MES. In terms of early herbage production, seed yield and regeneration, the cultivars Nungarin and Dalkeith are the most suited to the Mintaro environment and are likely to persist under continuous grazing. The influence of grazing and density interrelations on seed yield needs more research.

6.4 The grazing of dry sub clover pasture residues and seed survival following ingestion by sheep

Evidence from the pen-feeding studies indicate that no particular cultivar has an advantage in terms of the percentage total viable seed voided (hard and soft seed) following ingestion by sheep. In a mixture this may imply that no cultivar will be at a disadvantage in terms of survival of seed ingested. The range of seed sizes between cultivars used in the pen-feeding studies and the summer-autumn grazing experiment were not large enough to produce differences in the survival of seed from the various cultivars. Thomson *et al.* (1987) found that seed size accounted for 80% of the survival of seed. The range of seed sizes used by Thomson *et al.* was more varied. Small-seeded legumes have a much higher survival rate (Dore and Raymond 1942; Suckling 1950, 1952; Powell and Mapes 1955; Vercoe and Pearce 1960; Carter 1980; Carter *et al.* 1989). In addition, the high variability between sheep would also mask any differences. However, the small-seeded cultivar Esperance may have had a higher survival if it was used in the pen-feeding studies. However, results tended to indicate that hard seed level could be more important for the range of cultivars used. Furthermore, there was some evidence that hard-seeded cultivars such as Dalkeith had a higher percentage of hard seed in the faecal output compared to the other cultivars.

The stocking rate (30 sheep/ha) used in the summer-autumn grazing experiment represents the high stocking densities that are common over the summer-autumn period on many pasture ley-cereal properties. The experiment also illustrated the efficiency of sheep in harvesting sub clover burr and seed from the surface of hard-setting soils. Cultivars which produce proportionally more seed above-ground are likely to lose more seed over summer-autumn due to grazing (e.g. Clare). Furthermore, results show the selectivity by sheep for the largest burrs first (Chapter 5). Similar results were obtained on grazed dry medic pastures (Carter 1981) whereby the largest pods containing the largest seed and the most seed was selected first by sheep. Sub clover burrs selected from the summer-autumn grazing experiment 1987 also contained the most seed and the largest seed, although the decrease in the overall seed size in burrs (hard and soft seed) was not statistically significant. However, the hard seed in burrs was found to significantly decrease in size over the 70 day grazing period (eqn: $Y = 7.1 - 0.12x$, $r = 0.700$ *). The evidence indicates that grazing by sheep at high stocking rates during the green season can also reduce the size of seed produced and the number of seed produced. Reductions in seed size due to grazing were shown earlier by Rossiter (1961). This was commonly the situation for the earlier cultivars as discussed previously. Further decreases in seed size can result over the summer-autumn period. Selectivity of large burrs has further implications, particularly those cultivars which inherently produce large burrs (e.g. Clare). Therefore, part of the reason why large leafy cultivars such as Clare have allegedly not produced well under heavy grazing may reflect the heavy selection pressure on large burrs formed on the soil surface. In addtion, Clare has a higher proportion of seed set on the soil surface. In a mixture, cultivars with large burrs are the ones most likely to be selected first by the sheep. Part of this effect can be seen in the results from the raised-bed experiment. Both Nungarin and Clare had a decrease in the proportion of soft seed as time progressed. Sheep grazing a mixture of dry medic residues may have stronger pod selectivity because of the wider range of pod sizes (e.g. snail medics vs barrel medics).

The survival of sub clover seed in the pen-feeding studies and particularly the summer-autumn grazing experiment indicates that the regeneration of seedlings from sheep faecal pellets is unlikely to contribute significantly to the overall regeneration of that pasture. In addition, sub clover seed is probably not suitable for the use of dissemination on non-arable land, because the survival of seed is not great enough compared to the other pasture species such as white clover (*Trifolium repens*) and balansa clover (*T. balansae*) (Dore and Raymond 1942; Suckling 1950, 1952; Powell and Mapes 1955; Carter 1976, 1980, 1981; Carter *et al.* 1989). Therefore, the successful continuation of sub clover-based pastures should focus on leaving sufficient seed reserves above-ground rather than relying solely on below-ground reserves and the little regeneration from faecal pellets. The regeneration of the summer-autumn grazing experiment site was not satisfactory (63 plants /m^2). Many of those seedlings may have come from below-ground burrs. Long-term continuous hard grazing may result in a progressive reduction in seed size as the season progresses. Resulting pastures may become ecologically-less-fit if following a cropping sequence. This problem will be heightened if insufficient seed/seedling numbers are produced from one year to the next.

There was evidence to suggest that the percentage germination of seed in burrs increased over the period of the summer-autumn grazing experiment. It was postulated that increased germination may be the result of burrs becoming exposed to the sun's heat as the amount of dry residues was progressively consumed by sheep. However, the results from the summer-autumn grazing experiment also indicate that the increased germination is not the result of reduced hard seed percentages, but a reduction in the percentage dormant seed. So in the short-term (i.e. 70 days grazing) breakdown of physiological dormancy is more probable rather than the breakdown of hard seed.

6.5 Practical implications of research

Results from these studies indicate that high density swards should be grazed at moderately to high levels throughout the green season. This will minimize the deleterious effects that high plant density can have on both herbage yield late in the growing season and seed production. Furthermore, pastures which have low plant densities are best grazed at medium to low levels of stocking rate. If seed set is reasonable at the end of the growing season and the regeneration of the pasture is at least 1,000 - 1,500 plants /m^2 then the pasture could be grazed at a higher stocking rate the following year. Low-density pastures can achieve a production level similar to high-density swards if grazed moderately and seed production ensured. This also implies that moderate to low stocking rates should follow in the summer and autumn. In the Mintaro district (MES site location) the standard stocking rate on continuously-grazed pastures is the medium level (i.e 11 sheep/ha). Hence, there is scope for increased stocking rates for Merino wethers if pastures have initially high plant densities. Low stocking rates can have deleterious effects on the regeneration of high-density productive pastures due to the "blanketing" effect caused by excessive dry pasture residues.

Grazing over summer and autumn is recommended but should be carefully monitored, because results from the summer-autumn experiment indicate how rapidly seed can be depleted from the soil surface. The stage at which to remove sheep or reduce stocking rate will depend on the initial availability of dry pasture residues and seed, stocking rate and the extent of the seed bank (germinable and impermeable seed)above-and below-ground. More reasearch is required to determine the ideal stage at which sheep should be removed. At the same time it is important to avoid trampling and excessive fragmentation of dry residues. Notably in the summer-autumn period fragmentation lead to clumping of residues and bare-ground, which could lead to an uneven distribution of seedlings at regeneration allowing weed species to colonize the bare areas.

Results at this stage indicate that the cultivars with large burrs should be treated with more caution when grazing over summer. Similarly, cultivars which set a high proportion of seed above-ground should be grazed with care. Caution is also required when grazing during the green season especially if a seed crop is sought, and particularly for early-maturing cultivars because there is greater likelihood of proportionally more flowers and immature burrs being removed. Furthermore, high seed yield ensures better persistence (Carter 1982). High seed yield at the beginning of summer is also important as a source of feed for sheep grazing that pasture over summer (Hutton 1968). Initial high seed yields may allow grazing to continue for longer on that pasture.

The increased appearance of the annual volunteer clovers *Trifolium glomeratum* and *T. tomentosum* could be used as indicators that the grazing pressure is high in the Mintaro environment. Carter (1965,1966) and Carter and Day (1970) found the same species of clover on high stocking rate pastures. Similarly, Brown (1976 a) found the increased invasion of *Poa annua* and *Juncus bufonius* indicated the grazing pressure was too high and the total productivity decreased. However, at MES the invasion of both *T. glomeratum* and *T. tomentosum* did not result in a reduction in total herbage production. Furthermore, invasive species may not necessarily be inferior in terms of animal production/unit area (Carter 1966; Allden, 1968; Cameron and Cannon 1970 and Carter and Lake 1985). However, long-term production of that pasture could be affected, particularly if sub clover is expected to regenerate after a cropping sequence. Carter (1968) and Carter and Lake (1985) demonstrated that *T. glomeratum* increased as stocking rate increased from 7.4 to 22 sheep /ha (1.1 kg to 438 kg/ha seed for 7.4 and

22 sheep/ha respectively). *Trifolium glomeratum* seed production differences were reflected in botanical composition and appear to be due to differential seed digestibility of *T. glomeratum* compared to other pasture species present. Botanical composition changes are inevitable and may not be detrimental to the pasture production or animal production depending on the invading species.

It has been assumed for too long that seed production of sub clover pastures can take care of itself. However, there are critical levels of seed reserves required for good regeneration of a sub clover-based pasture. These levels are similar to those required for medic-based pasture (500 kg/ha, very good seed reserve) (Carter 1982; Carter *et al.* 1982 and Carter 1985). Satisfactory seed reserves for sub clover-based pasture in the high rainfall (700- 880mm annually) dairy pastures of the Adelaide Hills was between 249 and 382 kg/ha (Carter and Cochrane 1985). Drier regions such as the Mintaro district (603 and 513 mm annually for the years 1986 and 1987) would require more seed than the higher-rainfall zone to act as a buffer against 'false breaks' to the season (i.e. 200 kg/ha<). Below-ground seed reserves at Mintaro for the cultivars Junee and Clare were below 200 kg/ha in 1987. This is insufficient for the Mintaro environment and poor regeneration resulted. It is the below-ground seed yield that is more likely to contribute to regeneration under continuously grazed conditions, so cultivars such as Nungarin and Dalkeith would be the most successful.

6.6 Future work

The summer autumn grazing experiment conducted at the Waite Institute was on hard-setting red brown earth soil. A similar study is required on sandy textured soils. Seed/seedling survival is expected to be better on sandy textured soils due to increased natural burr burial by cultivars and also sheep will trample additional burrs into the soil while grazing residues over summer. Furthermore, the influence of grazing on herbage production during the green season and the seed production on sandy textured soils is warranted. In addition erosion risks need to be addressed. The influence of soil texture on productivity and persistence of sub clover-based pastures is little understood.

Any future studies involving grazing of sub clover cultivars in pure swards or as a mixture should include at least two widely-contrasting densities. The results from MES highlight the suggestion made by Walton (1975) that sward density is very important when considering experiments which evaluate sub clover genotypes for seed yield under defoliation. In addition, more detailed information is required on the performance of mixtures during the green season and over the summer-autumn period.

Pen-feeding studies involving a wider range of seed sizes of sub clover would be useful in determining with clarity whether seed size is important for sub clover cultivars. There are some inherently-small-seeded cultivars which may have an advantage. For example, the Esperance seed used in the 1985 small-plot experiment had an average seed size of only 4.5 mg. This was half the size of the other cultivars used in the same experiment (Yarloop, Trikkala and Clare). Possibly the selection of different burr sizes by sheep could be tested further under animal house conditions. Such studies could involve the feeding of an inherently-large burr size cultivar (e.g. Clare) mixed with a small burr size cultivar (e.g. Esperance).

Dry pasture residues of known availability and burr content should be grazed at differing stocking densities. It needs to be qualified and quantified as to whether burr disappearance would be slower under low stocking rates. There could be the possibility that sheep at low stocking rates may actively select burrs despite an abundance of dry herbage. More active selection of burrs could occur as the quality of the dry residues in the field deteriorate. The assessment of any annual pasture species should include the feeding of seed to animals, especially those grazing animals most likely to utilize that pasture species. Future pasture studies would be the most beneficial if both the animal and pasture production parameters were examined, thereby adding to the limited knowledge of the pasture factors which influence animal production and the animal influences on the pasture production and long-term persistence.

6.7 Main Findings and Conclusions

1. Small-plot density experiment

The main findings were: (i) Dry matter production was strongly related to plant density early in the season (i.e. the greater the plant number the greater the yield. (ii) Differences in the herbage yield of cultivars late in the season were due to differences in maturity. (iii) Seed production was positively correlated with herbage production at low and medium densities: however, high density swards (e.g. 14,000 plants/m^2) which were undefoliated had reduced herbage production and seed production and subsequent regeneration. (iv) Differences in the ability of cultivars to suppress weeds only occurred at high plant densities.

2. Grazing Experiment at Mortlock Experiment Station

The main findings and conclusions were: (i) Low-density swards (e.g. 150 plants/m2) should be grazed with caution (7 to 11 sheep/ha in the Mintaro district of South Australia) throughout the growing season and the summer-autumn period, whereas high-density pastures (1,500 to 2,000 plants/m^2) can be grazed at higher stocking rates (e.g. 15 sheep/ha) during the growing season and at the beginning of summer. (ii) Changes in botanical composition were rapid and were influenced by initial sub clover plant density and further modified by stocking rate. (iii) Under grazing, cultivars did not show any differing ability to suppress weeds. (iv) Seed yield of some cultivars (e.g. Nungarin and Dalkeith) were significantly reduced if the initial sowing rate was 10 kg/ha compared to 200 kg/ha.

3. Summer-autumn Seed Intake Experiment

The main findings were: (i) Sheep were efficient harvesters of sub clover burr and seed during the summer-autumn period: first they selected the largest burr, containing the most seed and the largest seed leading to a progressive decline in burr weight, seeds/burr and seed size. (ii) Seedling emergence from faecal pellets was poor and would not contribute significantly to the regeneration of sub clover pastures in Mediterranean climatic zones. (iii) An estimated 1% (hard) seed of the total sub clover seed ingested survived chewing and passage through the digestive tract of sheep grazing dry pasture residues. These results indicate that summer-autumn grazing should be carefully managed and the quantity of seed on the surface and in the top 2.5cm of soil monitored to ensure that there is sufficient seed to ensure regeneration of a high-density pasture.

4. Animal House Feeding Experiment

The main findings were: (i) The survival of seed in faeces was higher (2.9 to 5% hard) than the survival of seed ingested in the summer-autumn field experiment (1% hard). These differences possibly reflect the higher-quality feed in the animal house. (ii) The percentage viable seed found in the faeces of pen-fed sheep did not differ between cultivars.

5. Conclusions

Overall, the findings from the research described in this thesis support the view that management factors have far greater impact on the potential productivity and value of subterranean clover than differences ascribed to cultivars of sub clover. However, there remains a need for further research into pasture management to enhance the understanding of the complex soil-plant-animal interaction. Such research will need to involve grazing livestock. Animal experiments are expensive but defoliation by mechanical means can not simulate the influences the grazing animal has on pastures (e.g. treading, selectivity of plants and plant parts, spread of nutrients and seed). Such grazing influences need to be imposed on any new pasture species to assess persistence under grazed conditions.

7
APPENDICES

APPENDIX A

Table A.1: Summary of the Sowing Time x Cultivar and Sowing Time x Cultivar x Sowing Rate data for sub clover plant numbers at Harvest 2 (Natural logarithms).

Cultivar	Yarloop	Trikkala	Esperance	Clare
Early sown				
Sowing Rate (kg/ha)				
1	0.00	0.97	3.09	1.41
4	1.60	2.93	3.64	2.93
16	4.04	3.89	5.29	4.48
64	5.00	4.83	6.76	5.93
256	6.99	7.32	8.03	7.23
1024	7.63	8.55	9.55	8.90
Mean	4.21	4.74	6.06	5.15
Late sown				
Sowing Rate (kg/ha)				
1	0.91	1.71	1.13	1.19
4	3.01	2.04	4.11	2.56
16	3.94	4.39	5.77	4.42
64	5.76	5.79	6.53	5.82
256	7.31	7.51	8.16	7.28
1024	8.36	8.64	10.16	8.86
Mean	4.88	5.01	5.98	5.02

Interactions: Sowing Time x Cultivar, LSD (5%) = 0.40
Sowing Time x Cultivar x Sowing Rate, LSD (5%) = 0.95

Table A.2: The density of sub clover plants for the six sowing rates at each harvest occasion. (Data show # plants/m^2)

Cultivar	Sowing Rate	Harvest1	Harvest2	Harvest3	Harvest4	Harvest5
Yarloop	1	10	3	4	2	17
	4	17	16	23	18	44
	16	57	67	77	60	144
	64	208	254	288	237	268
	256	1037	1346	1379	1320	913
	1024	2293	3887	2882	2073	1146
Trikkala	1	15	8	0	3	8
	4	13	25	22	17	28
	16	93	78	86	112	135
	64	343	273	366	340	249
	256	1155	1754	1926	1658	1033
	1024	3564	6844	5937	3390	1818
Esperance	1	17	17	14	13	38
	4	57	67	66	46	31
	16	205	276	236	157	252
	64	825	907	918	761	587
	256	4748	3756	3529	4273	1944
	1024	14010	21015	22600	5985	2439
Clare	1	3	7	11	18	43
	4	30	25	30	27	70
	16	62	89	149	73	121
	64	432	361	374	408	247
	256	1842	1517	1712	1378	845
	1024	4569	8275	6878	2988	1203

Table A.3: Summary of the least significant differences at the 5% level for cultivar effect on sub clover plant numbers.

Sowing Rate	Harvest1	Harvest2	Harvest3	Harvest4	Harvest5
1	n.s.	7 **	10 *	6 ***	26 *
4	n.s.	17 ***	21 ***	20 *	27 *
16	63 **	55 ***	68 ***	50 **	n.s.
64	318 *	226 ***	196 ***	117 ***	175 **
256	n.s.	534 ***	1038 **	520 ***	619 **
1024	n.s.	3123 ***	6064 ***	885 ***	973 *

n.s. = not significant; $P<0.05$ = *; $P<0.01$ = **; $P<0.001$ = ***

Table A.4: Summary of the Cultivar x Sowing Rate data for plant numbers from Harvests 3 to 5. (Data transformed to natural logarithms)

Cultivar	Yarloop	Trikkala	Esperance	Clare
Harvest 3				
Sowing Rate (kg/ha)				
1	0.85	1.00	1.94	2.01
4	2.22	2.67	4.05	3.19
16	3.90	4.22	5.31	4.83
64	5.52	5.79	6.78	5.81
256	7.16	7.50	8.03	7.35
1024	7.87	8.59	9.79	8.78
Interaction: Cultivar x Sowing Rate, LSD (5%) = 0.94				
Harvest 4				
Sowing Rate (kg/ha)				
1	0.40	0.80	2.25	2.71
4	2.34	2.10	3.20	3.01
16	3.87	4.49	4.80	4.00
64	5.37	5.72	6.58	5.90
256	7.10	7.32	8.32	7.20
1024	7.51	8.09	8.65	7.92
Interaction: Cultivar x Sowing Rate, LSD (5%) = 0.62				
Harvest 5				
Sowing Rate (kg/ha)				
1	2.08	0.98	3.02	3.41
4	3.12	2.81	3.07	3.74
16	4.71	4.74	5.37	4.63
64	5.39	5.33	6.29	5.35
256	6.68	6.88	7.32	6.63
1024	6.93	7.34	7.52	6.99
Interaction: Cultivar x Sowing Rate, LSD (5%) = 0.72				

Table A.5: Summary of the Sowing Time x Cultivar and Sowing Time x Cultivar x Sowing Rate transformed data for sub clover yield at Harvest 2 (Data on kg DM/ha transformed to natural logarithms).

Cultivar	Yarloop	Trikkala	Esperance	Clare
Early sown				
Sowing Rate (kg/ha)				
1	0.00	0.61	1.49	0.90
4	0.94	1.97	2.34	2.44
16	3.08	2.71	3.94	3.96
64	4.10	3.59	5.29	5.41
256	6.10	6.17	6.36	6.51
1024	6.88	6.99	7.26	7.56
Mean	3.52	3.67	4.44	4.46
Late sown				
Sowing Rate (kg/ha)				
1	0.29	0.54	0.40	0.42
4	1.37	0.80	1.68	1.35
16	2.13	2.42	3.26	3.12
64	3.91	3.73	3.78	4.17
256	5.45	5.34	5.92	5.52
1024	6.69	5.90	6.81	6.98
Mean	3.31	3.12	3.64	3.59

Interaction: Sowing Time x Cultivar, LSD (5%) = 0.32

Sowing Time x Cultivar x Sowing Rate, LSD (5%) = 0.81

Table A.6: Summary of the transformed data on Sowing Time x Cultivar at Harvest 5 for weed yield. (Mean of six sowing rates).

	Yarloop	Trikkala	Esperance	Clare
Early sown	7.50	7.77	8.09	7.19
Late sown	7.64	7.74	7.88	7.67

LSD = 0.32

Table A.7: Summary of the sub clover Cultivar x Sowing Rate transformed yield data from Harvest 3 to Harvest 5. (Yield data in kg/ha transformed to natural logarithms).

Cultivar	Yarloop	Trikkala	Esperance	Clare
Harvest 3				
Sowing Rate (kg/ha)				
1	0.98	0.19	1.71	2.34
4	2.51	2.07	3.26	3.62
16	3.38	3.82	4.62	5.23
64	5.51	5.40	6.05	5.52
256	7.23	7.08	7.17	7.41
1024	7.66	7.84	8.21	8.23
Interaction: Cultivar x Sowing Rate, LSD (5%) = 0.72				
Harvest 4				
Sowing Rate (kg/ha)				
1	0.68	0.88	2.43	4.12
4	2.97	3.00	3.86	4.19
16	5.48	5.53	5.13	6.01
64	6.48	6.28	7.21	7.82
256	7.35	7.98	8.10	8.16
1024	8.28	8.35	8.39	7.77
Interaction: Cultivar x Sowing Rate, LSD (5%) = 1.19				
Harvest 5				
Sowing Rate (kg/ha)				
1	3.78	1.73	5.05	6.31
4	5.07	4.85	5.08	6.36
16	7.46	7.16	7.32	7.71
64	8.07	7.97	7.96	8.23
256	8.64	8.46	8.28	8.46
1024	8.69	8.61	8.32	8.64
Interaction: Cultivar x Sowing Rate, LSD (5%) = 0.97				

Table A.8: The sub clover yield (kg DM/ha) for each sowing rate and harvest occasion.

Cultivar	Sowing rate	Harvest1	Harvest2	Harvest3	Harvest4	Harvest5	Harvest6
Yarloop	1	1	0	6	10	173	766
	4	1	3	33	64	410	1026
	16	5	19	94	318	2244	2787
	64	20	63	337	1328	3445	5918
	256	102	357	1457	2992	5808	7082
	1024	212	1012	2225	4045	6293	8628
Trikkala	1	0	1	1	8	126	803
	4	1	6	13	80	382	1746
	16	8	17	75	354	1477	3371
	64	26	50	307	1052	3191	5455
	256	94	363	1378	3203	4875	6678
	1024	239	865	2578	4313	5567	7733
Esperance	1	0	3	13	21	348	654
	4	3	9	31	151	332	2485
	16	11	39	136	462	1849	3281
	64	44	140	515	1568	3002	3691
	256	222	499	1489	3365	4082	5197
	1024	579	1332	3739	4427	4236	4205
Clare	1	0	2	24	117	626	1300
	4	3	10	57	162	1416	2879
	16	6	47	256	580	2363	5683
	64	49	144	510	2862	3987	6697
	256	220	496	1853	3576	5077	6022
	1024	449	1611	3791	4413	5795	6670

Table A.9: Summary of least significant differences at the 5% level for cultivar effect on sub clover yield.

Sowing rate	Harvest1	Harvest2	Harvest3	Harvest4	Harvest5	Harvest6
1	n.s.	1 **	16 *	26 ***	278 **	n.s.
4	n.s.	n.s.	20 **	n.s.	504 ***	1258 *
16	n.s.	20 *	71 ***	n.s.	n.s.	1438 **
64	n.s.	39 ***	n.s.	614 ***	n.s.	1496 **
256	n.s.	51 ***	n.s.	n.s.	1050 *	n.s.
1024	n.s.	488 *	646 ***	n.s.	1032 **	1380 ***

n.s. = not significant; P<0.05 = *; P<0.01= **; P<0.001 = ***

Table A.10: Summary of the Sowing Rate x Cultivar transformed data for weed yield at Harvests 1,3 and 6. (Yield data in kg DM/ha transformed to natural logarithms).

Cultivars	Yarloop	Trikkala	Esperance	Clare
Harvest 1				
Sowing Rate (kg/ha)				
1	2.98	1.97	1.45	2.59
4	3.35	1.80	1.52	2.24
16	2.06	2.31	2.64	1.49
64	1.66	2.04	1.75	2.06
256	2.04	1.97	2.34	1.68
1024	0.56	0.42	0.97	0.67
Interaction: Sowing Rate x Cultivar, LSD (5%) = 1.28				
Harvest 3				
Sowing Rate (kg/ha)				
1	6.34	6.68	6.53	6.61
4	6.51	6.55	6.01	6.62
16	6.53	5.99	6.44	6.39
64	6.14	6.13	6.40	6.45
256	5.72	6.00	6.21	5.90
1024	5.18	5.44	5.23	4.72
Interaction: Sowing Rate x Cultivar, LSD (5%) = 0.65				
Harvest 6				
Sowing Rate (kg/ha)				
1	8.71	8.64	8.63	8.57
4	8.53	8.64	8.45	8.42
16	8.70	8.33	8.53	8.18
64	7.96	7.91	8.50	7.58
256	7.41	7.68	7.81	7.11
1024	6.41	6.48	8.38	6.15
Interaction: Sowing Rate x Cultivar, LSD (5%) = 0.68				

Table A.11: The amount of weed (kg DM/ha) at each harvest occasion and all sowing rates.

Cultivar	Sowing rate	Harvest1	Harvest2	Harvest3	Harevst4	Harvest5	Harvest6
Yarloop	1	29	137	703	2092	3794	6421
	4	36	135	799	1915	4153	5345
	16	20	189	730	1867	3853	6481
	64	6	129	489	1258	2727	3652
	256	9	146	373	727	1133	2249
	1024	0	75	258	487	816	1482
Trikkala	1	8	124	882	1948	5784	6268
	4	6	203	740	2055	4043	6303
	16	12	151	682	1879	3898	4461
	64	29	114	527	1293	2157	3970
	256	8	93	442	738	1736	3262
	1024	0	40	312	264	1206	1010
Esperance	1	3	159	714	1774	3877	5923
	4	4	163	768	2008	4305	4960
	16	16	174	843	1778	3700	5315
	64	6	129	773	1525	3423	5318
	256	12	82	629	875	2268	2868
	1024	0	71	243	575	2463	5036
Clare	1	29	287	765	1977	4053	5658
	4	10	196	872	1753	3500	5566
	16	4	116	709	1889	3480	4340
	64	8	134	754	1028	2090	2501
	256	6	111	461	1002	1299	2172
	1024	0	25	249	324	940	798

Table A.12: Summary of LSD (5%) values of cultivar main effect on weed yield (kg DM/ha).

Sowing rate (kg/ha)	Harvest1	Harvest2	Harvest3	Harvest4	Harvest5	Harvest6
1	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
4	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
16	n.s.	n.s.	n.s.	n.s.	n.s.	1552
64	n.s.	n.s.	n.s.	n.s.	908	n.s.
256	n.s.	n.s.	n.s.	n.s.	741	n.s.
1024	n.s.	n.s.	n.s.	n.s.	1133	1608

n.s = not significant.

Table A.13: Sub clover seed weights from the 1985 growing season (Seed weight (mg) mean of two sowing times)

	Sowing rate	Yarloop	Trikkala	Esperance	Clare
Above-ground	1	7.4	8.1	5.7	7.3
	4	7.8	8.2	5.8	8.4
	16	8.5	7.9	5.9	8.3
	64	8.9	7.9	5.6	8.8
	256	8.2	7.2	4.8	8.3
	1024	7.5	7.2	4.9	8.4
Below-ground	1	8.1	7.7	5.5	9.0
	4	9.3	8.8	5.3	8.8
	16	9.6	8.9	5.7	8.0
	64	10.9	8.7	4.9	7.6
	256	8.0	7.2	4.7	7.8
	1024	7.4	7.4	4.7	8.1

Table A.14: The percentage of sub clover soft seed at each sowing time, sowing rate and cultivar from above- and below-ground burrs.

<u>Early sown</u>

	Sowing rate	Yarloop	Trikkala	Esperance	Clare
Above-ground	1	9.5	12.0	20.3	37.0
	4	7.7	9.7	5.7	28.8
	16	4.0	7.4	32.2	10.1
	64	3.7	13.3	6.1	18.2
	256	2.3	5.7	5.8	22.0
	1024	2.0	7.0	5.5	14.8
Below-ground	1	26.7	16.7	2.4	10.2
	4	16.0	13.0	3.6	5.1
	16	10.5	8.7	13.9	1.4
	64	6.7	15.3	4.9	10.4
	256	2.7	10.7	4.3	4.2
	1024	8.0	3.4	10.3	6.2
<u>Late sown</u>					
Above-ground	1	5.5	6.7	15.8	34.9
	4	9.7	6.7	11.4	35.9
	16	13.6	22.4	29.6	23.5
	64	10.0	8.7	11.3	31.1
	256	9.3	29.3	24.9	23.7
	1024	3.7	5.3	15.3	24.5
Below-ground	1	25.0	11.1	16.5	0.7
	4	25.3	11.1	8.5	6.3
	16	26.7	24.0	21.2	6.2
	64	8.7	12.0	9.7	5.5
	256	8.7	9.4	14.5	4.2
	1024	18.7	6.4	4.8	4.9

Table A.15: The percentage of sub clover hard seed at each sowing time, sowing rate and cultivar for above- and below-ground burrs.

	Sowing rate	Yarloop	Trikkala	Esperance	Clare
Early sown					
Above-ground	1	42.9	66.7	61.2	63.0
	4	76.7	62.4	93.9	58.0
	16	75.0	72.3	55.8	47.9
	64	73.0	60.0	66.4	81.0
	256	64.0	53.7	56.4	75.5
	1024	59.0	56.7	50.0	64.5
Below-ground	1	33.3	20.8	19.4	33.8
	4	50.7	42.7	40.0	32.4
	16	52.0	31.3	33.4	30.4
	64	52.0	30.7	32.2	31.7
	256	10.7	25.8	37.0	28.2
	1024	32.7	16.7	21.9	23.5
Late sown					
Above-ground	1	64.0	53.3	54.5	57.2
	4	71.3	38.5	79.6	59.3
	16	61.7	60.7	68.1	48.3
	64	74.7	63.7	64.3	59.7
	256	62.0	44.3	63.7	76.8
	1024	68.3	69.3	71.2	75.5
Below-ground	1	75.0	55.6	24.8	31.8
	4	29.3	55.6	54.5	27.6
	16	54.0	44.0	57.0	36.6
	64	44.7	49.4	42.4	31.1
	256	32.0	27.4	37.6	42.1
	1024	18.0	30.8	30.3	41.4

Table A.16: The percentage of sub clover dormant seed at each sowing time, sowing rate and cultivar for above- and below-ground burrs.

	Sowing rate	Yarloop	Trikkala	Esperance	Clare
Early sown					
Above-ground	1	47.6	21.3	18.5	0.0
	4	15.7	28.0	0.8	13.3
	16	21.0	20.3	11.9	42.0
	64	23.4	26.7	27.6	0.9
	256	33.7	39.9	37.9	0.3
	1024	39.0	36.4	37.6	20.7
Below-ground	1	40.0	62.5	78.2	51.1
	4	33.3	44.3	56.4	62.6
	16	37.5	60.1	52.8	68.3
	64	41.3	54.1	63.0	58.0
	256	86.7	63.6	58.8	67.7
	1024	59.3	80.0	67.9	70.4
Late sown					
Above-ground	1	30.5	40.0	29.7	8.0
	4	19.0	48.7	8.6	4.8
	16	25.0	17.0	2.3	28.9
	64	15.3	27.7	24.5	9.3
	256	28.7	23.4	11.5	0.0
	1024	28.0	25.4	13.5	0.0
Below-ground	1	0.0	33.3	58.7	67.6
	4	45.4	33.3	37.0	66.2
	16	19.3	32.0	21.9	57.3
	64	46.7	38.7	47.9	63.2
	256	59.4	63.3	47.9	53.9
	1024	63.4	62.9	64.9	54.0

Table A.17: Main cultivar effect for the percentage soft seed, hard seed and dormant seed at each sowing time, above- and below-ground.

	Yarloop	Trikkala	Esperance	Clare	Significance level
Soft seed (%)					
Early sown:					
Above-ground	4.2	8.8	12.6	21.8	***
Below-ground	9.8	10.6	7.3	6.2	***
Late sown:					
Above-ground	8.9	15.4	18.3	27.6	***
Below-ground	17.6	11.3	13.8	4.6	***
Hard seed (%)					
Early sown:					
Above-ground	68.3	61.3	63.9	65.0	*
Below-ground	37.9	27.2	30.8	30.0	*
Late sown:					
Above-ground	67.3	57.8	68.7	63.7	**
Below-ground	40.2	39.3	43.4	35.1	n.s
Dormant seed (%)					
Early sown:					
Above-ground	27.5	29.8	22.4	12.9	***
Below-ground	52.3	62.2	61.9	63.0	*
Late sown:					
Above-ground	23.9	25.7	12.9	8.9	***
Below-ground	42.3	49.4	42.9	60.3	**

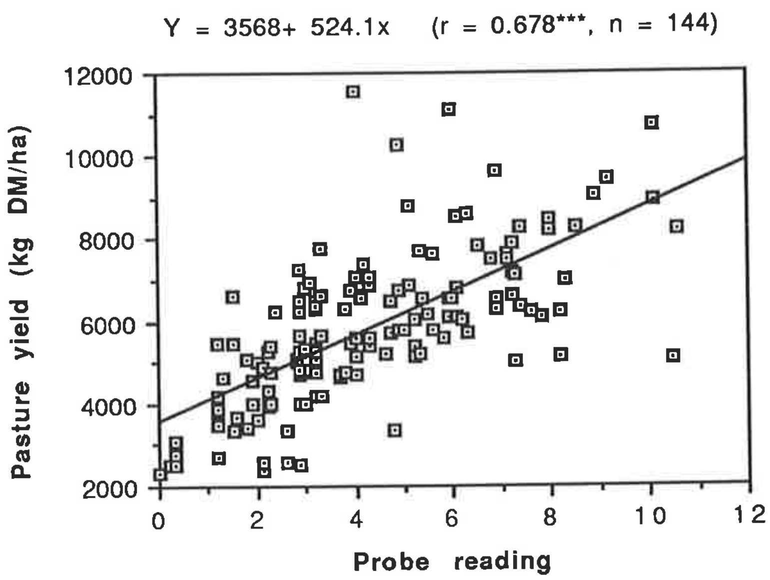
n.s. = not significant, * = $P<0.05$, ** = $P<0.01$, *** = $P<0.001$

APPENDIX B

Table B.1: The sheep bodyweights (kg/head) at three stages in the experiment, 4.9.86, 4.6.87 and 12.11.87 and also the greasy wool weights (kg/head) on 19.3.87.

	Bodyweight (kg) 4.9.86	Bodyweight (kg) 4.6.87	Bodyweight (kg) 12.11.87	Greasy Wool (kg/head) 19.3.87
BLOCK I				
H.S.R.				
sheep # 1	49.5	45.4	65.8	7.550
# 2	49.5	46.4	63.6	6.800
# 3	50.5	40.8	62.0	9.100
# 4	50.5	45.2	61.2	7.750
# 5	50.5	45.0	65.6	9.100
# 6	49.5	40.0	64.2	8.200
# 7	49.5	43.4	60.0	8.300
M.S.R.				
# 8	51.0	57.0	76.4	6.350
# 9	49.5	53.0	68.8	8.100
# 10	48.5	56.6	75.0	7.900
# 11	48.5	54.2	74.0	8.800
# 12	51.0	58.2	79.4	8.800
L.S.R.				
# 13	48.5	58.4	75.0	7.800
# 14	49.0	65.4	89.6	8.800
# 15	50.0	60.2	78.6	9.000
BLOCK II				
H.S.R.				
# 16	51.0	54.4	77.8	8.000
# 17	50.0	46.0	70.6	7.850
# 18	50.0	55.0	73.4	6.600
# 19	48.0	42.6	68.6	7.950
# 20	50.0	46.6	71.2	8.800
# 21	50.0	44.6	73.6	6.900
# 22	49.5 (49.9)	44.4 (45.7)	67.6 (67.5)	8.150 (7.932)
M.S.R.				
# 23	49.5	55.8	70.8	6.850
# 24	48.5	58.2	82.2	8.950
# 25	49.0	51.6	71.2	8.150
# 26	48.0	50.0	74.2	6.300
# 27	49.5 (49.3)	57.0 (55.2)	85.8 (75.8)	8.800 (7.900)
L.S.R.				
# 28	49.5	56.4	70.4	5.600
# 29	50.5	64.0	87.0	7.050
# 30	51.5 (49.8)	45.8*(58.4)	64.6 (77.5)	8.500 (7.792)

* The original sheep in this treatment died and was replaced, hence the lower weight.
In brackets are the overall treatment means for both Blocks I and II.



Appendix B, Figure 1: Relationship between pasture yield and electronic pasture probe reading.

Table B.2: The percentage bare-ground on 19.10.87 (Levy point data) at MES.

	L.S.R.	M.S.R	H.S.R		Cultivar means
Sown at 10 kg/ha in 1986					
Nungarin	2.5	0.0	17.5		6.7
Dalkeith	2.5	0.0	10.0		4.2
Trikkala	0.0	0.0	12.5		4.2
Junee	0.0	0.0	12.5		4.2
Clare	0.0	0.0	30.0		10.0
Mixture	0.0	0.0	7.5		2.5
Stocking Rate means	0.8	0.0	15.0	n.s.	n.s.
Sown at 200 kg/ha in 1986					
Nungarin	5.0	0.0	15.0		6.7
Dalkeith	22.5	2.5	7.5		10.8
Trikkala	0.0	0.0	12.5		4.2
Junee	2.5	0.0	17.5		6.7
Clare	0.0	2.5	15.0		5.8
Mixture	2.5	0.0	10.0		4.2
Stocking Rate means	5.4	0.8	12.9	n.s.	n.s.

Table B.3: The above-ground burr#/m2 for the year 1986 at MES.

	L.S.R	M.S.R	H.S.R	Cultivar means
10 kg/ha				
Nungarin	2337	2203	1497	2012
Dalkeith	1769	2575	1788	2044
Trikkala	5595	4018	5461	5025
Junee	4682	4973	3473	4376
Clare	2053	2767	1743	2188
Mixture	3446	3569	4632	3882
Stocking rate means	3314	3351	3099	
200 kg/ha				
Nungarin	6896	5929	5043	5956
Dalkeith	3515	2986	3327	3276
Trikkala	6670	7656	5588	6638
Junee	6175	6999	6854	6676
Clare	3112	2867	2195	2725
Mixture	3956	5315	4175	4482
Stocking Rate means	5054	5292	4530	

Table B.4: The below-ground burr#/m2 for the year 1986 at MES.

	L.S.R	M.S.R	H.S.R	Cultivar means
10 kg/ha				
Nungarin	5092	3584	3235	3970
Dalkeith	3972	2621	1934	2842
Trikkala	1485	1934	921	1447
Junee	1984	2694	959	1879
Clare	898	1646	1236	1290
Mixture	3599	2371	2088	2686
Stocking rate means	2838	2475	1729	
200 kg/ha				
Nungarin	4037	6946	4693	5225
Dalkeith	5327	4644	4628	4866
Trikkala	1090	1520	2448	1686
Junee	745	1140	1336	1074
Clare	1102	1589	1980	1557
Mixture	1600	2084	2007	1897
Stocking rate means	2317	2987	2849	

Table B.5: The above-ground burr#/m^2 for the year 1987 at MES.

	L.S.R	M.S.R	H.S.R	Cultivar means
Sown at 10 kg/ha in 1986				
Nungarin	7249	5135	4475	5620
Dalkeith	4678	4390	2897	3988
Trikkala	5069	3857	4747	4558
Junee	1972	2287	1731	1997
Clare	1324	1289	1428	1347
Mixture	3281	2767	3531	3193
Stocking rate means	3929	4931	3135	
Sown at 200 kg/ha in 1986				
Nungarin	14272	13992	6543	11602
Dalkeith	6209	7625	5234	6356
Trikkala	4505	5108	6179	5264
Junee	3561	2291	3703	3185
Clare	1608	2107	2383	2033
Mixture	2598	4279	3711	3529
Stocking rate means	5459	5900	4626	

Table B.6: The below-ground burr#/m^2 for the year 1987 at MES.

	L.S.R	M.S.R	H.S.R	Cultivar means
Sown at 10 kg/ha in 1986				
Nungarin	9694	5123	7834	7550
Dalkeith	5146	6067	4958	5390
Trikkala	453	545	1478	825
Junee	2928	2763	1078	2256
Clare	2663	1232	1017	1637
Mixture	4340	3227	3089	3552
Stocking rate means	4204	3160	3242	
Sown at 200 kg/ha in 1986				
Nungarin	7234	6658	5656	6516
Dalkeith	4977	8661	4659	6099
Trikkala	748	211	645	535
Junee	1305	898	956	1053
Clare	737	1362	1343	1147
Mixture	1370	1892	2306	1856
Stocking rate means	2729	3280	2594	

Table B.7: The total burr #/m^2 for the year 1986 at MES.

	L.S.R.	M.S.R.	H.S.R.	Cultivar means
10 kg/ha				
Nungarin	7429	5787	4732	5982
Dalkeith	5741	5196	3722	4866
Trikkala	7080	5952	6382	6472
Junee	6666	7667	4432	6255
Clare	2951	4411	2979	3478
Mixture	7045	5940	6720	6568
Stocking rate means	6152	5826	4828	
200 kg/ha				
Nungarin	10933	12875	9736	11181
Dalkeith	8842	7630	7955	8142
Trikkala	7760	9176	8036	8324
Junee	6920	8139	8190	7750
Clare	4214	4456	4175	4282
Mixture	5556	7399	6182	6379
Stocking rate means	7371	8279	7379	

Table B.8: The total burr#/m^2 for the year 1987 at MES.

	L.S.R.	M.S.R.	H.S.R.	Cultivar means
Sown at 10 kg/ha in 1986				
Nungarin	16943	10258	12309	13170
Dalkeith	9824	10457	7855	9378
Trikkala	5522	4402	6225	5383
Junee	4900	5050	2809	4253
Clare	3987	2521	2445	2984
Mixture	7621	5994	6620	6745
Stocking rate means	8133	8091	6377	
Sown at 200 kg/ha in 1986				
Nungarin	21506	20650	12199	18118
Dalkeith	13186	16286	9893	12455
Trikkala	5353	5319	6824	5799
Junee	4866	3189	4659	4238
Clare	2345	3469	3726	3180
Mixture	3968	6171	6017	5385
Stocking rate means	8188	9180	7220	

Table B.9: Regeneration of sub clover seedlings counted on 20 May, 1987 at MES (All data show plants /m^2).

	L.S.R	M.S.R	H.S.R	Cultivar. means
Sown at 10 kg/ha in 1986				
Nungarin	2040	1388	1161	1529
Dalkeith	1332	1019	823	1058
Trikkala	1453	819	740	1004
Junee	1861	1723	398	1327
Clare	1090	683	485	753
Mixture	2034	902	802	1246
Stocking Rate means	1635^c	1089^b	735^a	
Sown at 200 kg/ha in 1986				
Nungarin	1103	1786	1282	1390
Dalkeith	288	733	994	672
Trikkala	465	623	740	609
Junee	285	434	665	461
Clare	738	644	829	731
Mixture	600	1209	855	888
Stocking Rate means	580	905	894	

Differing superscript letters indicate significant differences ($P<0.05$), based on log transformed data (comparisons for within 10 kg/ha sowing rate only).

Table B.10: Regeneration of sub clover at the Mortlock Experiment Station 1988 (All data show plants/m^2).

	L.S.R	M.S.R	H.S.R	Cultivar means
Sown at 10 kg/ha in 1986				
Nungarin	1961	1043	1216	1407
Dalkeith	960	805	729	831
Trikkala	1599	2589	1307	1832
Junee	1447	2195	783	1475
Clare	841	551	423	605
Mixture	2159	2343	1505	2003
Stocking Rate means	1494	1588	994	
Sown at 200 kg/ha in 1986				
Nungarin	4203	4261	1948	3468
Dalkeith	1758	1757	1299	1604
Trikkala	1518	1064	1281	1288
Junee	1915	1363	576	1285
Clare	659	787	625	690
Mixture	1311	1335	1213	1286
Stocking Rate means	1894	1761	1155	

Table B.11: Available pasture: sub clover, weeds and total on 23 Oct., 1986 at MES. (kg DM/ha)

		L.S.R	M.S.R	H.S.R	Cultivar means
10 kg/ha					
Nungarin	Sub clover	4980	1454	2535	2990
	Weeds	234	248	92	192
	Total	5214	1702	2627	3182
Dalkeith	S	2885	2513	1329	2242
	W	168	290	300	253
	T	3053	2803	1629	2495
Trikkala	S	3062	1553	2271	2295
	W	167	384	168	239
	T	3229	1937	2439	2534
Junee	S	3803	1899	2252	2651
	W	137	377	118	211
	T	3940	2276	2370	2862
Clare	S	1858	1829	1567	1751
	W	179	240	137	185
	T	2037	2069	1704	1936
Mixture	S	3076	2157	2306	2513
	W	191	439	140	257
	T	3267	2596	2446	2770
Stocking Rate means	: S	3277	1901	2043	
	W	179	329	159	
	T	3456	2230	2202	
200 kg/ha					
Nungarin	S	5802	3694	4490	4662
	W	29	9	7	15
	T	5831	3703	4497	4677
Dalkeith	S	6323	4189	3762	4758
	W	0	41	14	18
	T	6323	4230	3776	4776
Trikkala	S	6315	4674	3819	4936
	W	54	42	3	33
	T	6369	4716	3822	4969
Junee	S	5944	5069	4681	5232
	W	45	90	24	53
	T	5989	5159	4705	5285
Clare	S	5160	2844	3059	3688
	W	12	0	0	4
	T	5172	2844	3059	3692
Mixture	S	5929	4416	3468	4604
	W	111	5	0	39
	T	6040	4421	3468	4643
Stocking Rate means	: S	5912	4148	3880	
	: W	42	31	8	
	: T	5954	4179	3888	

Table B.12: Available pasture: sub clover, weeds and total on 27 Nov., 1986 at MES. (kg DM/ha)

		L.S.R	M.S.R	H.S.R	Cultivar means
10 kg/ha					
Nungarin	Sub clover	5405	2589	3200	3731
	Weeds	508	992	554	685
	Total	5913	3581	3754	4416
Dalkeith	S	4161	3430	2881	3491
	W	347	527	416	430
	T	4508	3957	3297	3921
Trikkala	S	6397	4516	4613	5175
	W	731	1444	130	768
	T	7128	5960	4743	5943
Junee	S	7266	5486	4119	5624
	W	291	516	105	304
	T	7557	5992	4224	5928
Clare	S	3864	5189	2705	3919
	W	167	475	71	238
	T	4031	5664	2776	4157
Mixture	S	5550	6283	4411	5415
	W	686	480	308	490
	T	6236	6763	4719	5905
Stocking Rate means	: S	5441	4582	3655	
	: W	455	739	263	
	: T	5896	5321	3918	
200 kg/ha					
Nungarin	S	7319	5641	4374	5778
	W	14	7	22	14
	T	7333	5648	4396	5792
Dalkeith	S	6254	5500	4483	5412
	W	0	28	64	31
	T	6254	5528	4547	5443
Trikkala	S	8405	7219	6169	7264
	W	19	34	0	18
	T	8424	7253	6169	7282
Junee	S	8252	8019	6246	7505
	W	20	149	13	60
	T	8272	8168	6259	7565
Clare	S	7275	6661	4902	6279
	W	0	50	6	19
	T	7275	6711	4908	6298
Mixture	S	8208	7646	4884	6913
	W	0	16	10	8
	T	8208	7662	4894	6921
Stocking Rate means	: S	7619	6781	5176	
	: W	9	47	19	
	: T	7628	6828	5195	

Table B.13: Available pasture: sub clover, weeds and total on 16 Sept, 1987 at MES. (kg DM/ha)

		L.S.R	M.S.R	H.S.R	Cultivar means
Sown at 10 kg/ha in 1986					
Nungarin	Sub clover	3800	2580	1235	2538
	Grass	868	217	50	378
	Broadleaf	55	238	403	232
	Total	4723	3035	1688	3148
Dalkeith	S	2678	1573	1073	1774
	G	1213	415	95	574
	B	57	623	248	309
	T	3948	2611	1416	2657
Trikkala	S	2250	1690	1210	1717
	G	343	353	38	244
	B	32	385	278	232
	T	2625	2428	1526	2193
Junee	S	2523	2035	578	1712
	G	1135	343	38	505
	B	32	25	560	209
	T	3690	2403	1176	2426
Clare	S	2338	945	327	1203
	G	215	343	78	212
	B	42	705	428	392
	T	2595	1993	833	1807
Mixture	S	3080	1943	1200	2074
	G	920	403	8	444
	B	67	125	247	147
	T	4067	2471	1455	2665
Stocking Rate means	: S	2778	1794	937	
	: G	782	345	51	
	: B	48	352	360	
	: T	3598	2491	1348	
Sown at 200 kg/ha in 1986					
Nungarin	S	3913	2963	1430	2768
	G	275	208	13	165
	B	65	182	205	151
	T	4243	3353	1648	3084
Dalkeith	S	1875	2433	1403	1903
	G	448	223	38	236
	B	10	127	130	89
	T	2333	2783	1571	2228
Trikkala	S	2180	1308	1038	1508
	G	260	108	25	131
	B	350	528	127	335
	T	2790	1944	1190	1974
Junee	S	1043	1475	748	1088
	G	298	170	40	169
	B	578	500	170	416
	T	1919	2145	958	1673
Clare	S	1500	1095	633	1076
	G	118	128	38	94
	B	545	685	133	454
	T	2163	1908	804	1624
Mixture	S	2230	2095	933	1753
	G	60	143	20	74
	B	57	275	153	162
	T	2347	2513	1106	1989
Stocking Rate means	: S	2123	1895	1030	
	: G	243	163	29	
	: B	268	383	153	
	: T	2634	2441	1212	

Table B.14: Pasture availability data (kg DM/ha) derived from Electronic Pasture Probe readings on the last harvest occasion on 25 Nov., 1987 at MES.

	L.S.R	M.S.R	H.S.R	Cultivar means
Sown at 10 kg/ha in 1986				
Nungarin	4134	4695	3778	4202
Dalkeith	3804	5256	4554	4538
Trikkala	3846	5429	4040	4438
Junee	4407	5219	4213	4611
Clare	5298	6021	3988	5104
Mixture	4658	5245	4459	4790
Stocking Rate means	4355	5314	4171	
Sown at 200 kg/ha in 1986				
Nungarin	3673	4381	4187	4082
Dalkeith	3872	4606	3909	4129
Trikkala	4134	4014	4276	4140
Junee	4501	5141	4459	4700
Clare	5036	4790	4381	4737
Mixture	4354	4580)	3961	4297
Stocking Rate means	4260	4585	4197	

Table B.15: Botanical composition: percentage overlapping cover of sub clover, grass, other legumes and broadleaf weeds (Levy Point Quadrat data, grazing experiment at MES on 19.10.87).

		L.S.R.	M.S.R.	H.S.R.	Cultivar means
Sown at 10 kg/ha in 1986					
Nungarin	Sub clover	79.5	39.0	38.3	52.2
	Grass	17.0	31.3	5.7	18.0
	Other Leg.	2.7	29.7	44.5	25.7
	Broadleaf	0.8	0.0	11.5	4.1
Dalkeith	S	65.2	49.2	46.0	53.5
	G	33.8	24.0	18.8	25.5
	OL	0.0	24.0	31.4	18.5
	B	1.0	2.8	3.8	2.5
Trikkala	S	89.3	76.0	57.0	74.0
	G	8.8	12.3	3.5	8.2
	OL	0.5	11.7	34.2	15.5
	B	1.5	0.0	5.3	2.3
Junee	S	69.0	72.5	49.8	63.8
	G	31.0	15.3	1.2	15.8
	OL	0.0	9.7	47.5	19.1
	B	0.0	2.5	1.5	1.3
Clare	S	84.0	51.2	45.0	60.1
	G	7.3	12.5	18.2	12.7
	OL	3.2	34.3	34.0	23.8
	B	5.5	2.0	2.8	3.4
Mixture	S	74.5	80.0	45.5	66.4
	G	25.5	10.5	3.2	13.1
	OL	0.0	9.0	48.0	19.0
	B	0.0	0.5	3.3	1.3
Stocking Rate means	: S	76.8	61.2	46.9	
	: G	20.6	17.7	8.4	
	: OL	1.1	19.8	40.0	
	: B	1.5	1.3	4.7	
Sown at 200 kg/ha in 1986					
Nungarin	S	89.0	64.4	49.2	67.6
	G	6.7	12.8	20.5	13.3
	OL	2.5	18.5	30.3	17.1
	B	1.8	4.3	0.0	2.0
Dalkeith	S	69.0	66.0	42.0	59.0
	G	27.3	21.8	16.0	21.7
	OL	3.8	12.2	42.0	19.3
	B	0.0	0.0	0.0	0.0
Trikkala	S	77.7	67.4	74.2	73.0
	G	6.5	3.3	2.5	4.1
	OL	14.5	29.3	17.3	20.1
	B	1.3	0.0	7.0	2.8
Junee	S	70.0	38.4	57.9	55.4
	G	21.5	20.8	12.8	18.3
	OL	8.5	38.5	29.3	25.4
	B	0.0	2.3	0.0	0.9
Clare	S	89.0	75.2	81.5	81.9
	G	3.2	8.0	9.5	6.9
	OL	0.0	15.5	9.0	8.2
	B	7.8	1.3	0.0	3.0
Mixture	S	85.8	69.4	62.7	72.7
	G	10.8	10.8	10.0	10.5
	OL	1.0	18.8	25.3	15.0
	B	2.5	1.0	2.0	1.8
Stocking Rate means	: S	80.1	63.5	61.2	
	: G	12.7	12.9	11.9	
	: OL	5.0	22.1	25.4	
	: B	2.2	1.5	1.5	

Table B.16: Pasture production between Harvests 1 and 2 (H1-H2 = 50 days), Harvests 2 and 3 (H2-H3 = 35 days), and total production (kg DM/ha) at MES in 1986.

		L.S.R	M.S.R	H.S.R	Cultivar means
10 kg/ha					
Nungarin	H1-H2	4125	3203	2691	3340
	H2-H3	2325	4670	3772	3589
	Total *	7088	8440	6918	7482
Dalkeith	H1-H2	3780	3020	3538	3446
	H2-H3	2536	3910	2954	3133
	Total	6691	8012	7114	7272
Trikkala	H1-H2	3854	2156	3156	3056
	H2-H3	4420	5706	4765	4964
	Total	8991	8425	8334	8583
Junee	H1-H2	3528	1680	3410	2873
	H2-H3	4531	5630	4532	4897
	Total	8561	7962	8467	8330
Clare	H1-H2	3555	2090	3053	2900
	H2-H3	3903	5037	5506	4815
	Total	7776	8029	8991	8265
Mixture	H1-H2	3598	3084	3457	3380
	H2-H3	4180	5372	5349	4967
	Total	8246	8873	9171	8763
Stocking Rate means	H1-H2	3740	2539	3218	
	H2-H3	3649	5054	4479	
	Total	7892	8290	8166	

* All total production figures include the first pasture availability cut before the experiment was grazed by sheep.

		L.S.R	M.S.R	H.S.R	Cultivar means
200 kg/ha					
Nungarin	H1-H2	4171	4523	4348	4347
	H2-H3	1917	3241	1191	2116
	Total	8438	9977	7763	8726
Dalkeith	H1-H2	5116	4686	4650	4817
	H2-H3	1720	1194	2197	1703
	Total	9271	8064	8747	8694
Trikkala	H1-H2	4893	4356	4715	4655
	H2-H3	3120	4420	3077	3539
	Total	9445	10564	9236	9748
Junee	H1-H2	4610	4314	3995	4306
	H2-H3	3908	4180	3262	3783
	Total	10820	10696	9252	10256
Clare	H1-H2	5305	3746	5025	4692
	H2-H3	4241	4429	4774	4148
	Total	10621	11825	11964	11470
Mixture	H1-H2	4841	4887	4297	4675
	H2-H3	3429	3773	1755	2986
	Total	10548	10748	8300	9865
Stocking Rate means	H1-H2	4823	4419	4505	
	H2-H3	2889	3539	2709	
	Total	9857	10313	9210	

Table B.17: Pasture production: cumulative winter growth (emergence to Harvest 1, E-H1), Harvest 1 to Harvest 2 (H1-H2) and total production at MES in 1987.
(All data in kg DM/ha)

		L.S.R	M.S.R	H.S.R	Cultivar means
Sown at 10 kg/ha in 1986					
Nungarin	E-H1	6939	6157	5663	6253
	H1-H2	548	1410	2155	1371
	Total	7487	7568	7818	7624
Dalkeith	E-H1	6081	7053	5757	6297
	E-H1	758	3582	4266	2869
	Total	6839	1035	10022	9166
Trikkala	E-H1	6208	6577	5556	6114
	H1-H2	3153	4300	3102	3518
	Total	9362	10877	8658	9632
Junee	E-H1	5204	6354	5490	5682
	H1-H2	1760	5133	3940	3611
	Total	6964	11486	9430	9293
Clare	E-H1	4850	5696	5309	5285
	H1-H2	2513	5108	5325	4315
	Total	7362	10804	8309	8825
Mixture	E-H1	6482	6520	5316	6106
	H1-H2	1985	3707	3908	3200
	Total	8468	10227	9224	9306
Stocking Rate means	: E-H1	5960	6393	5515	
	: H1-H2	1786	3873	3783	
	: Total	7747	10266	8910	
Sown at 200 kg/ha in 1986					
Nungarin	E-H1	6142	6708	6032	6294
	H1-H2	406	3110	4119	2545
	Total	6548	9818	10150	8839
Dalkeith	E-H1	6759	5729	5005	5831
	H1-H2	1400	2212	3573	2395
	Total	8159	7942	8578	8226
Trikkala	E-H1	3775	5309	4425	4503
	H1-H2	3130	5521	5545	4732
	Total	6905	10830	9970	9235
Junee	E-H1	3779	5186	5160	4708
	H1-H2	3965	5295	4328	4530
	Total	7744	10481	9488	9238
Clare	E-H1	4189	4830	4516	4512
	H1-H2	4821	4448	7804	5691
	Total	9009	9278	12320	10203
Mixture	E-H1	4787	5243	5143	5058
	H1-H2	3837	3419	4658	3971
	Total	8624	8662	9800	9029
Stocking Rate means	: E-H1	4905	5501	5047	
	: H1-H2	2926	4001	5004	
	: Total	7832	9502	10051	

Table B.18: Seed yield (kg/ha): Above-ground (AG), Below-ground (BG) and Total seed yield (T) for the year 1986 at MES.

		L.S.R	M.S.R	H.S.R	Cultivar means	Cultivar % seed buried
10 kg/ha						
Nungarin	AG	255	241	163	220	78.7
	BG	1035	721	690	815	
	T	1291	961	854	1035	
Dalkeith	AG	306	445	309	353	62.3
	BG	837	523	391	584	
	T	1142	967	700	937	
Trikkala	AG	1074	771	1048	964	31.9
	BG	543	506	284	444	
	T	1565	1277	1332	1391	
Junee	AG	635	675	471	594	43.2
	BG	334	437	584	451	
	T	969	1112	1055	1045	
Clare	AG	436	587	370	464	46.3
	BG	324	500	375	400	
	T	760	1088	745	864	
Mixture	AG	603	624	810	679	50.9
	BG	951	629	532	704	
	T	1553	1253	1342	1384	
Stocking Rate means	:AG	551	557	528		
	:BG	671	553	476		
	:T	1213	1110	1005		
200 kg/ha						
Nungarin	AG	851	732	622	735	54.3
	BG	730	1118	775	874	
	T	1581	1849	1397	1609	
Dalkeith	AG	601	511	569	561	68.6
	BG	1382	1146	1150	1226	
	T	1984	1656	1720	1787	
Trikkala	AG	1327	1191	1112	1210	25.1
	BG	308	389	632	443	
	T	1635	1912	1744	1764	
Junee	AG	997	1130	1107	1078	12.3
	BG	106	176	172	151	
	T	1103	1307	1279	1229	
Clare	AG	675	622	476	591	41.7
	BG	275	456	537	423	
	T	951	1078	1014	1014	
Mixture	AG	664	892	701	752	40.0
	BG	855	364	350	523	
	T	1519	1257	1053	1276	
Stocking Rate means	:AG	853	846	765		
	:BG	609	608	603		
	:T	1462	1510	1368		

Table B.19: Seed number/m^2: Above-ground (AG), Below-ground (BG) and Total (T) seed number at two sowing rates and three stocking rates for the year 1986 at MES.

		L.S.R	M.S.R	H.S.R	Cultivar means
10 kg/ha					
Nungarin	AG	5223	4923	3345	4497
	BG	13540	9181	9172	10631
	T	18763	14427	12516	15236
Dalkeith	AG	4352	6335	4399	5029
	BG	10380	6594	4910	7294
	T	14732	12928	9309	12323
Trikkala	AG	13428	9643	13106	12059
	BG	4819	5557	2636	4337
	T	18247	14950	15742	16313
Junee	AG	12640	13428	9377	11815
	BG	5171	6822	2600	4864
	T	17811	20250	11977	16679
Clare	AG	4281	5770	3633	4561
	BG	2723	4689	3580	3664
	T	7004	10459	7213	8225
Mixture	AG	9305	9636	12507	10483
	BG	11233	7345	6354	8311
	T	20538	16982	18860	18793
Stocking Rate means	:AG	8205	8289	7728	
	:BG	7978	6698	4875	
	:T	16182	14999	12603	
200 kg/ha					
Nungarin	AG	17482	15030	12783	15098
	BG	11621	18436	12414	14157
	T	29103	33465	25197	29255
Dalkeith	AG	8612	7315	8152	8026
	BG	16611	13934	13883	14809
	T	25223	21249	22035	22836
Trikkala	AG	16607	19064	13913	16528
	BG	3116	4005	6644	4588
	T	19723	23068	20557	21116
Junee	AG	18524	20999	20561	20028
	BG	1770	2405	2873	2349
	T	20294	23403	23434	22377
Clare	AG	7578	6981	5345	6635
	BG	2581	4284	5180	4015
	T	10159	11264	10525	10649
Mixture	AG	9258	12437	9770	10489
	BG	3916	4973	5001	4630
	T	13175	17410	14771	15119
Stocking Rate means	:AG	13010	13637	11754	
	:BG	6603	8006	7666	
	:T	19613	21643	19420	

Table B.20: Number of seeds/burr for above- (AG) and below-ground (BG) burrs at two sowing rates and three stocking rates for the year 1986 at MES (Data based on dissection of 20 burrs).

		L.S.R	M.S.R	H.S.R	Cultivar means
10 kg/ha					
Nungarin	AG	2.73	2.40	2.48	2.53
	BG	2.75	2.33	2.30	2.46
Dalkeith	AG	2.70	2.53	2.13	2.45
	BG	2.73	2.33	1.98	2.34
Trikkala	AG	2.60	2.48	2.40	2.49
	BG	2.18	1.95	2.18	2.10
Junee	AG	3.03	2.80	3.00	3.00
	BG	2.33	2.70	1.90	2.31
Clare	AG	2.13	2.15	3.10	2.46
	BG	2.65	2.73	2.28	2.55
Mixture	AG	1.98	2.55	2.50	2.34
	BG	3.03	2.33	2.50	2.62
Stocking Rate	:AG	2.53	2.51	2.60	
means	:BG	2.61	2.39	2.19	
200 kg/ha					
Nungarin	AG	2.73	2.40	2.48	2.53
	BG	2.58	2.35	2.25	2.39
Dalkeith	AG	2.70	2.53	2.13	2.45
	BG	2.60	3.03	2.73	2.78
Trikkala	AG	2.60	2.48	2.40	2.49
	BG	2.03	2.18	2.30	2.17
Junee	AG	3.03	2.98	3.00	3.00
	BG	0.83	2.10	2.48	1.80
Clare	AG	2.13	2.15	3.10	2.46
	BG	2.15	1.70	2.38	2.08
Mixture	AG	1.98	2.55	2.50	2.30
	BG	1.60	1.73	2.05	1.79
Stocking Rate	:AG	2.53	2.51	2.60	
means	:BG	1.96	2.18	2.36	

Table B.21: The mean seed weight (mg) of the above-ground and below-ground burrs also total burrs at two sowing rates and three stocking rates for the year 1986 at MES.

		L.S.R	M.S.R	H.S.R	Cultivar means
10 kg/ha					
Nungarin	AG	5.65	5.00	4.25	4.97
	BG	8.35	7.13	7.04	7.50
Dalkeith	AG	7.60	7.05	6.05	6.90
	BG	7.58	8.70	7.50	7.92
Trikkala	AG	8.25	8.50	6.75	7.83
	BG	10.32	11.20	8.58	10.03
Junee	AG	5.65	5.35	3.65	4.88
	BG	6.87	6.25	6.25	6.46
Clare	AG	10.30	11.15	8.70	10.05
	BG	9.68	11.50	10.03	10.40
Mixture	AG	6.55	7.30	5.60	6.48
	BG	9.07	7.43	8.48	8.33
Stocking Rate	:AG	7.33	7.39	5.83	
means	:BG	8.64	8.70	7.98	
200 kg/ha					
Nungarin	AG	5.45	4.60	4.50	4.85
	BG	6.70	6.07	5.99	6.25
Dalkeith	AG	6.80	7.65	6.15	6.87
	BG	8.93	8.56	7.38	8.29
Trikkala	AG	7.70	8.90	7.55	8.05
	BG	9.05	9.76	7.88	8.89
Junee	AG	5.55	5.75	4.80	5.37
	BG	5.03	6.47	5.98	5.83
Clare	AG	9.45	9.35	8.35	9.05
	BG	11.72	11.75	8.27	10.58
Mixture	AG	7.35	7.45	6.35	7.05
	BG	8.33	7.47	6.56	7.45
Stocking Rate	:AG	7.05	7.28	6.28	
means	:BG	8.29	8.35	7.01	

Table B.22: Germination tests on seed in above-ground burrs (arcsine transformed), % Soft (S), % Hard (H) and % Dormant (D) for the year 1986 at MES. (Natural percentage values are shown in brackets)

		L.S.R	M.S.R	H.S.R	Cultivar means
10 kg/ha					
Nungarin	S	9.8	16.7	12.0	12.8 (6.2)
	H	76.6	67.7	68.0	70.8 (90.2)
	D	3.6	10.3	7.7	7.1 (3.6)
Dalkeith	S	10.1	6.4	7.6	8.1 (2.5)
	H	67.2	66.2	63.3	65.5 (82.0)
	D	20.1	22.6	24.8	22.5 (15.5)
Trikkala	S	30.7	37.8	28.4	32.3 (29.2)
	H	52.1	48.8	55.5	52.1 (62.0)
	D	19.3	9.4	15.1	14.6 (8.8)
Junee	S	13.8	8.8	22.6	15.1 (8.3)
	H	64.2	64.9	63.5	64.2 (79.5)
	D	19.2	19.7	11.2	16.7 (12.2)
Clare	S	34.6	38.6	26.0	33.1 (30.4)
	H	41.2	42.4	50.1	44.6 (49.3)
	D	28.8	16.5	25.2	23.5 (20.3)
Mixture	S	22.2	33.8	25.0	27.0 (22.4)
	H	63.8	51.4	58.0	57.7 (67.1)
	D	12.2	17.0	19.3	16.1 (10.5)
Stocking Rate means	: S	20.2	23.7	20.3	
	: H	60.9	56.9	59.7	
	: D	17.2	15.9	17.2	
200 kg/ha					
Nungarin	S	8.3	12.6	16.1	12.3 (5.8)
	H	72.0	77.4	65.0	71.5 (88.2)
	D	15.1	0.0	17.6	10.9 (6.0)
Dalkeith	S	3.5	8.4	11.6	7.8 (2.4)
	H	84.5	73.0	78.4	78.6 (94.5)
	D	3.3	11.0	2.0	5.4 (3.1)
Trikkala	S	21.8	29.2	28.5	26.5 (20.6)
	H	59.0	54.8	58.7	57.5 (70.5)
	D	20.1	12.7	10.2	14.4 (8.9)
Junee	S	9.3	14.5	17.7	13.8 (7.5)
	H	65.9	63.8	62.7	64.1 (78.5)
	D	18.1	18.8	17.6	18.2 (14.0)
Clare	S	31.9	31.1	32.0	31.7 (28.1)
	H	41.6	44.6	38.2	41.5 (48.8)
	D	37.4	27.0	31.8	32.1 (31.7)
Mixture	S	23.2	38.3	33.6	31.7 (33.1)
	H	53.0	50.1	58.8	53.9 (68.2)
	D	26.7	14.6	9.4	16.9 (14.3)
Stocking Rate means	: S	16.3	22.3	23.3	
	: H	62.7	60.6	60.3	
	: D	20.1	14.0	14.8	

Table B.23: Germination tests on seeds in below-ground burrs (arcsine transformed), % Soft (S), % Hard (H) and % Dormant (D) for the year 1986 at MES.
(Natural percentage values are shown in brackets)

		L.S.R	M.S.R	H.S.R	Cultivar means
10 kg/ha					
Nungarin	S	12.7	5.5	17.3	11.8 (5.3)
	H	77.3	74.5	65.7	72.5 (88.9)
	D	0.0	14.0	11.2	8.4 (5.8)
Dalkeith	S	8.3	11.6	9.7	9.9 (3.7)
	H	81.7	68.1	55.4	68.4 (83.0)
	D	0.0	15.7	31.5	15.7 (13.3)
Trikkala	S	26.4	26.2	20.9	24.5 (18.0)
	H	43.5	51.1	39.8	44.8 (49.8)
	D	33.7	25.6	38.5	32.6 (32.2)
Junee	S	13.6	13.6	18.0	15.1 (8.8)
	H	60.3	76.4	47.8	61.5 (74.1)
	D	20.2	0.0	31.2	17.1 (17.1)
Clare	S	25.0	25.7	23.0	24.6 (17.8)
	H	41.2	46.0	43.4	43.5 (47.7)
	D	37.8	31.6	36.7	35.4 (34.5)
Mixture	S	12.3	22.8	16.9	17.3 (9.7)
	H	69.7	50.3	52.4	57.5 (72.2)
	D	13.5	25.5	30.2	23.1 (18.1)
Stocking Rate means	: S	16.4	17.6	17.6	
	: H	62.3	61.1	50.8	
	: D	17.5	18.8	29.9	
200 kg/ha					
Nungarin	S	8.3	10.7	8.7	9.3 (3.4)
	H	68.7	71.4	78.7	72.9 (88.3)
	D	15.0	12.8	5.5	11.1 (8.3)
Dalkeith	S	6.9	9.6	3.5	6.6 (2.1)
	H	73.7	68.8	67.3	69.9 (78.2)
	D	14.5	16.6	39.5	23.5 (19.7)
Trikkala	S	16.6	22.0	27.8	22.1 (15.5)
	H	52.4	47.4	54.4	51.4 (59.5)
	D	33.8	33.8	16.2	27.9 (25.0)
Junee	S	2.1	9.5	12.3	8.0 (3.7)
	H	33.7	63.3	58.6	51.9 (69.6)
	D	33.5	17.2	23.5	24.7 (26.7)
Clare	S	25.7	34.0	38.3	32.7 (31.1)
	H	28.4	44.6	45.0	39.3 (41.6)
	D	47.4	21.8	10.1	26.4 (27.3)
Mixture	S	26.7	29.1	23.6	26.5 (20.7)
	H	57.2	60.9	60.7	59.6 (73.7)
	D	14.4	0.0	8.4	7.6 (5.6)
Stocking Rate means	: S	14.0	19.2	19.0	
	: H	52.3	59.4	60.8	
	: D	26.4	17.0	17.2	

Table B.24: Seed yield (kg/ha): Above-ground (AG), Below-ground (BG) and Total (T) seed yield for the year 1987 at MES.

		L.S.R	M.S.R	H.S.R	Cultivar means	Seed buried (%)
Sown at 10 kg/ha in 1986						
Nungarin	AG	654	490	405	517	69.6
	BG	1570	751	1232	1184	
	T	2225	1241	1637	1701	
Dalkeith	AG	632	598	383	538	71.2
	BG	1374	1432	1182	1329	
	T	2006	2030	1565	1867	
Trikkala	AG	704	550	583	612	32.5
	BG	368	194	324	295	
	T	1071	744	908	908	
Junee	AG	209	233	171	204	56.6
	BG	331	349	118	266	
	T	540	582	289	470	
Clare	AG	209	235	198	214	60.6
	BG	541	251	188	327	
	T	750	485	386	540	
Mixture	AG	511	458	478	482	61.3
	BG	1050	673	562	762	
	T	1562	1130	1040	1244	
Stocking Rate means	:AG	486	427	370		
	:BG	872	608	601		
	:T	1359	1035	971		
Sown at 200 kg/ha in 1986						
Nungarin	AG	1825	1617	786	1409	45.3
	BG	1272	1209	1014	1165	
	T	3097	2827	1800	2574	
Dalkeith	AG	917	1018	710	882	61.0
	BG	1337	1577	1223	1379	
	T	2254	2595	1934	2261	
Trikkala	AG	736	754	904	798	23.8
	BG	368	85	295	249	
	T	1104	839	1199	1047	
Junee	AG	463	286	465	405	19.8
	BG	123	80	96	100	
	T	586	366	561	505	
Clare	AG	306	383	415	368	34.4
	BG	101	243	223	189	
	T	407	626	616	549	
Mixture	AG	340	550	448	446	40.7
	BG	300	302	314	306	
	T	640	852	762	752	
Stocking Rate means	:AG	765	768	622		
	:BG	584	583	528		
	:T	1348	1351	1145		

Table B.25: Seed number /m^2: Above-ground (AG), Below-ground (BG) and Total (T) at two sowing rates and three stocking rates for the year 1987 at MES.

		L.S.R	M.S.R	H.S.R	Cultivar means
Sown at 10 kg/ha in 1986					
Nungarin	AG	15183	11326	9392	11967
	BG	24549	11802	19499	18617
	T	39732	23129	28891	30584
Dalkeith	AG	11014	10349	6701	9354
	BG	16153	16170	13456	15260
	T	27167	26519	20157	24614
Trikkala	AG	11770	8938	10158	10289
	BG	4194	2287	4126	3536
	T	15965	11225	14283	13824
Junee	AG	4833	5851	4029	4904
	BG	5495	6137	2069	4567
	T	10328	11989	6098	9472
Clare	AG	3190	3327	3083	3200
	BG	5885	2680	2086	3550
	T	9074	6007	5169	6750
Mixture	AG	8191	7027	8041	7753
	BG	12142	8242	7455	9280
	T	20333	15269	15496	17033
Stocking Rate means	:AG	9030	7803	6901	
	:BG	11403	7886	8115	
	:T	20433	15690	15016	
Sown at 200 kg/ha in 1986					
Nungarin	AG	36699	33112	16138	28650
	BG	20069	20037	16776	18960
	T	56768	53149	32915	47610
Dalkeith	AG	14631	16688	11585	14301
	BG	15960	24445	14473	18293
	T	30591	41133	26058	32594
Trikkala	AG	10423	11151	13419	11665
	BG	3664	987	3501	2717
	T	14088	12138	16920	14382
Junee	AG	10083	6222	10214	8840
	BG	2221	1380	1844	1815
	T	12304	7676	12058	10680
Clare	AG	4588	5853	6418	5620
	BG	1141	2766	2477	2128
	T	5730	8619	8895	7748
Mixture	AG	5785	9468	7973	7742
	BG	4175	4213	4867	4418
	T	9960	13686	12840	12160
Stocking Rate means	:AG	13702	13749	10958	
	:BG	7872	8971	7323	
	:T	21573	22732	18281	

Table B.26: Number of seeds/burr: Above-ground (AG), Below-ground (BG) and Total (T) at two sowing rates and three stocking rates for the year 1987 at MES.

		L.S.R.	M.S.R	H.S.R	Cultivar means
Sown at 10 kg/ha in 1986					
Nungarin	AG	2.13	2.28	1.83	2.08
	BG	2.53	2.03	1.53	2.03
Dalkeith	AG	2.43	2.18	2.20	2.27
	BG	2.55	1.98	2.33	2.28
Trikkala	AG	2.33	2.28	1.65	2.08
	BG	1.37	1.58	1.45	1.46
Junee	AG	2.13	2.50	2.33	2.32
	BG	1.55	1.65	1.10	1.43
Clare	AG	1.98	2.53	1.88	2.13
	BG	1.63	1.23	1.70	1.52
Mixture	AG	2.20	2.45	2.08	2.24
	BG	2.25	1.58	1.43	1.75
Stocking Rate	:AG	2.20	2.37	1.99	
means	:BG	1.98	1.67	1.59	
Sown at 200 kg/ha in 1986					
Nungarin	AG	2.30	2.33	2.18	2.27
	BG	2.70	2.25	2.10	2.35
Dalkeith	AG	2.40	2.03	1.90	2.11
	BG	2.30	2.93	2.20	2.48
Trikkala	AG	2.20	1.98	2.10	2.10
	BG	1.40	1.28	1.15	1.28
Junee	AG	3.13	2.65	2.43	2.73
	BG	0.93	0.56	1.48	0.99
Clare	AG	2.40	3.10	2.43	2.64
	BG	0.60	0.73	1.18	0.83
Mixture	AG	2.15	1.98	2.18	2.10
	BG	1.10	1.23	1.25	1.19
Stocking Rate	:AG	2.43	2.34	2.19 n.s.	
means	:BG	1.50	1.49	1.56 n.s.	

Table B.27: The mean seed weight (mg) from Above-ground (AG), Below-ground (BG) and Total (T) burrs at two sowing rates and three stocking rates for the year 1987 at MES.

		L.S.R	M.S.R	H.S.R	Cultivar means
Sown at 10 kg/ha in 1986					
Nungarin	AG	4.35	4.63	3.83	4.27
	BG	6.18	6.99	6.65	6.60
Dalkeith	AG	6.31	5.81	4.73	5.61
	BG	9.46	9.26	8.53	9.08
Trikkala	AG	5.46	5.99	5.05	5.50
	BG	7.31	6.79	6.68	6.92
Junee	AG	4.47	4.26	3.90	4.21
	BG	6.38	6.63	5.51	6.17
Clare	AG	6.29	6.67	4.83	5.93
	BG	10.53	10.85	6.55	9.31
Mixture	AG	5.28	7.06	4.92	5.75
	BG	9.12	7.59	7.97	8.23
stocking Rate	:AG	5.36	5.74	4.54	
means	:BG	8.16	8.02	6.98	

Sown at 200 kg/ha in 1986					
Nungarin	AG	6.45	4.47	3.67	4.86
	BG	6.57	6.44	6.24	6.42
Dalkeith	AG	7.26	5.65	4.61	5.84
	BG	8.70	9.18	8.29	8.72
Trikkala	AG	7.30	6.25	6.19	6.58
	BG	7.95	7.80	7.66	7.80
Junee	AG	5.11	3.90	4.37	4.46
	BG	5.78	3.02	5.91	4.90
Clare	AG	6.81	6.33	5.93	6.35
	BG	9.32	9.76	9.19	9.42
Mixture	AG	6.15	5.63	4.64	5.47
	BG	6.51	7.75	5.40	6.55
Stocking Rate	:AG	6.51	5.37	4.90	n.s.
means	:BG	7.47	7.33	7.11	n.s.

Table B.28: Germination tests on seed in above-ground burrs (arcsine transformed), % soft (S), % hard (H) and % dormant (D) for the year 1987 at MES.
(Natural percentage values are shown in brackets)

		L.S.R	M.S.R	H.S.R	Cultivar means
10 kg/ha in 1986					
Nungarin	S	12.1	16.8	17.4	15.4 (8.3)
	H	95.2	87.5	82.2	88.3 (77.7)
	D	0.0	1.5	8.7	3.4 (5.7)
Dalkeith	S	9.6	9.1	5.8	8.2 (2.7)
	H	96.0	92.7	87.1	91.9 (89.3)
	D	0.0	4.6	11.6	5.4 (8.0)
Trikkala	S	10.0	5.9	19.1	11.7 (5.6)
	H	87.0	90.4	72.1	83.2 (81.6)
	D	8.7	8.2	16.9	11.2 (12.8)
Junee	S	7.6	11.1	11.8	10.2 (4.0)
	H	79.3	90.9	87.9	86.0 (84.0)
	D	18.2	5.2	6.5	9.9 (12.0)
Clare	S	12.2	24.8	18.2	18.4 (11.3)
	H	67.7	77.3	82.4	75.8 (74.0)
	D	27.6	3.9	7.3	12.9 (14.7)
Mixture	S	7.7	16.3	15.0	13.0 (6.7)
	H	86.2	88.8	87.5	87.5 (84.1)
	D	10.3	2.2	4.9	5.8 (9.2)
Stocking Rate means	:S	9.9	14.0	14.5	
	:H	85.2	87.9	83.2	
	:D	10.8	4.3	9.3	
200 kg/ha in 1986					
Nungarin	S	12.3	7.2	11.3	10.3 (3.8)
	H	95.2	97.8	86.5	93.2 (92.1)
	D	0.0	0.0	9.0	3.0 (4.1)
Dalkeith	S	12.8	4.8	10.8	9.5 (3.8)
	H	93.9	98.6	94.0	95.5 (95.3)
	D	0.9	0.0	0.0	0.3 (0.9)
Trikkala	S	10.9	13.6	13.3	12.6 (5.5)
	H	90.5	94.3	90.2	91.7 (88.3)
	D	4.3	0.0	4.1	2.8 (6.2)
Junee	S	9.9	10.7	9.5	10.1 (3.7)
	H	95.5	91.4	88.4	91.8 (88.5)
	D	1.2	4.6	7.9	4.6 (7.8)
Clare	S	18.0	21.3	23.6	21.0 (15.0)
	H	70.8	79.1	35.2	61.7 (59.2)
	D	18.6	6.1	45.1	23.3 (25.8)
Mixture	S	15.7	16.8	19.1	17.2 (9.6)
	H	87.5	90.0	83.2	87.2 (85.5)
	D	4.8	0.0	4.8	3.2 (4.9)
Stocking Rate means	:S	13.3	12.4	14.6	
	:H	88.9	92.0	79.6	
	:D	5.0	1.8	11.8	

Table B.29: Germination tests of seed in below-ground burrs (arcsine transformed), % soft (S), % hard (H) and % dormant (D) for the year 1987 at MES.
(Natural percentage values are shown in brackets)

		L.S.R	M.S.R	H.S.R	Cultivar means
10 kg/ha in 1986					
Nungarin	S	6.3	2.0	7.6	5.3 (1.8)
	H	91.3	67.9	79.3	79.5 (77.1)
	D	6.3	31.6	18.3	18.8 (21.1)
Dalkeith	S	8.0	7.7	8.6	8.1 (2.8)
	H	88.8	73.3	71.6	77.9 (74.8)
	D	8.1	24.1	25.8	19.3 (22.4)
Trikkala	S	15.2	4.8	8.6	9.5 (4.5)
	H	72.6	75.3	58.5	68.8 (69.5)
	D	22.6	23.3	34.2	26.7 (26.0)
Junee	S	10.6	10.9	7.9	9.8 (3.9)
	H	90.6	80.2	58.3	76.4 (75.9)
	D	6.8	15.9	36.5	19.7 (20.2)
Clare	S	7.6	6.0	4.8	6.1 (2.1)
	H	70.3	59.1	72.4	67.3 (67.6)
	D	28.3	38.5	25.2	30.7 (30.3)
Mixture	S	10.8	9.0	2.7	7.6 (3.0)
	H	96.9	76.5	93.8	89.1 (86.8)
	D	2.1	20.8	0.8	7.9 (10.2)
Stocking Rate	:S	9.8	6.7	6.7	
means	:H	85.1	72.0	72.3	
	:D	12.4	25.7	23.5	
200 kg/ha in 1986					
Nungarin	S	3.9	7.3	14.2	8.4 (3.4)
	H	84.7	83.4	81.2	83.1 (79.4)
	D	8.3	9.4	17.9	11.8 (17.2)
Dalkeith	S	9.3	7.9	12.8	10.0 (3.8)
	H	81.4	97.3	86.7	88.5 (84.5)
	D	12.9	0.8	9.5	7.7 (11.7)
Trikkala	S	10.8	4.0	7.5	7.4 (4.0)
	H	58.7	29.7	75.7	54.7 (58.6)
	D	38.0	68.4	17.5	41.3 (37.4)
Junee	S	9.1	3.0	1.8	4.6 (1.6)
	H	51.3	78.0	60.3	63.2 (68.7)
	D	48.3	20.9	36.5	35.2 (29.7)
Clare	S	5.3	7.8	8.0	7.0 (2.2)
	H	61.2	73.6	71.3	68.7 (70.1)
	D	35.9	24.5	26.9	29.1 (27.7)
Mixture	S	7.6	7.6	3.5	6.2 (2.1)
	H	97.0	94.7	90.1	93.9 (87.1)
	D	23.5	3.1	7.5	11.3 (10.8)
Stocking Rate	:S	7.7	6.3	7.9	
means	:H	72.4	76.1	77.5	
	:D	27.8	21.2	19.3	

APPENDIX C

Table C.1: The bodyweights of sheep in the summer-autumn grazing experiment at the Waite Institute, 1987.

Sheep number	Weight on 2.2.87 (kg/head)	Weight on 13.4.87 (kg/head)	Weight loss (kg/head)
1	56.0	50.5	5.5
2	53.0	48.0	5.0
3	59.0	56.0	3.0
4	60.0	54.0	6.0
5	60.0	46.5	13.5
6	67.0	54.5	12.5
7	64.0	52.0	12.0
8	63.0	57.0	6.0
9	63.0	56.5	6.5
10	62.0	57.0	5.0
Mean	60.7	53.2	7.5

Table C.2: The bodyweights of sheep in the pen feeding experiment at the Waite Institute, 1988.

Sheep number	Weight on 31.1.88 (kg/ha)	Weight on 18.3.88 (kg/ha)	Weight change (kg/head)
1	53.7	56.7	+3.0
2	55.9	55.9	0.0
3	59.5	60.9	+1.4
4	54.5	57.0	+2.5
5	56.7	58.7	+2.0
6	59.0	60.3	+1.3
7	56.1	55.5	- 0.6
8	58.3	58.9	+0.6
Mean	56.7	58.0	+1.3

Table C.3: Weight of dry faeces (g) needed to equate with 100g fresh faeces in the raised-bed experiment at the Waite Institute, 1987-88.

	Date of sample in 1987									
Sheep number	5.2	12.2	19.2	26.2	5.3	12.3	19.3	26.3	2.4	9.4
1	57.0	56.6	49.3	65.3	56.2	56.6	51.8	52.2	52.3	52.8
2	48.9	52.8	49.8	51.7	54.8	53.8	52.4	49.8	52.1	48.1
3	54.1	51.9	50.9	56.8	54.5	45.3	52.4	53.4	50.3	55.5
4	52.7	53.3	47.6	53.9	55.9	47.7	55.1	55.7	53.7	52.7
5	53.3	52.0	50.7	53.6	54.0	44.5	52.3	52.2	54.2	54.7
6	55.1	52.7	53.1	54.3	39.6	53.3	49.8	44.8	54.2	53.0
7	52.8	50.2	48.1	53.1	52.8	38.3	57.0	49.9	54.1	52.9
8	52.4	56.8	47.6	56.6	56.9	55.2	54.9	52.7	51.8	53.8
9	52.2	51.6	44.4	51.9	50.4	48.8	53.4	49.7	52.0	52.0
10	51.1	46.7	42.0	49.4	52.1	45.7	50.1	50.8	41.8	43.2

Table C.4: The burr samples from field transects used in the raised-bed experiment at the Waite Institute, 1987-88.

	Date of sample in 1987										
Replicate	30.1	9.2	16.2	23.2	2.3	9.3	16.3	23.3	30.3	6.4	13.4
1	1.6	2.7	1.3	1.2	1.7	2.4	1.6	1.2	3.2	1.1	1.1
2	3.2	2.2	1.5	1.1	1.3	1.4	3.4	2.4	3.2	1.1,2	1.2
3	2.6	1.8	1.2	1.8	1.6	1.2	1.8	2.5	1.8	1.3	1.2
4	2.3	3.2	2.5	2.1	3.3	1.5	1.7	2.7	3.1	1.3,5,6	1.3
5	1.3	1.1	1.6	1.4	2.3	1.1	1.4	1.3	3.1	1.4	1.3
6	3.3	1.7	1.7	2.5	2.2	3.3	2.3	2.8	1.1	1.4	1.7
7	2.2	1.6	2.7	2.2	1.5	1.7	1.2	1.8	2.4	2.3	2.2
8	1.2	1.2	3.2	2.8	1.5	1.3	2.2	2.2	2.1	2.8	2.2
9	2.8	2.8	2.2	3.2	1.4	2.5	1.5	2.3	2.3	3.1	2.2
10	1.5	1.3	1.4	1.5	1.1	1.8	2.6	3.2	1.7	3.3	2.8
Burrs*	34	37	43	40	50	50	47	43	56	78	68

*Number of burrs needed to give approximately 100 seeds.

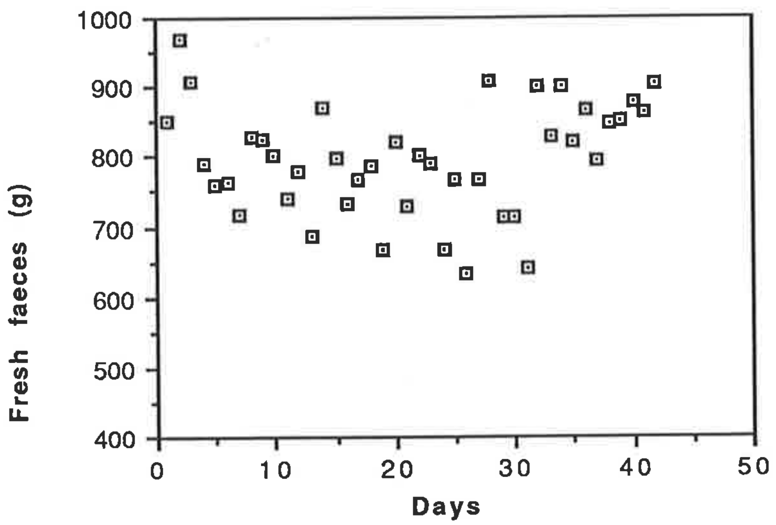
Table C.5: Daily total seed number in faecal output of each sheep in the period of 70 days.

	date	sheep 1	sheep 2	sheep 3	sheep 4	sheep 5	sheep 6	sheep 7	sheep 8	sheep 9	sheep 10	total seed#/flock
1	1	•	0	0	•	12	•	•	0	•	16	28
2	2	0	0	0	16	59	5	0	0	233	14	327
3	3	161	0	52	15	258	96	0	0	480	86	1148
4	4	93	0	103	21	166	144	8	9	249	105	898
5	5	79	20	108	5	82	136	30	24	250	214	948
6	6	143	11	260	8	260	183	18	54	330	125	1392
7	7	162	7	612	77	722	207	60	116	617	364	2944
8	8	221	58	900	98	1098	570	70	37	789	651	4492
9	9	184	154	847	122	1200	809	152	165	1572	614	5819
10	10	366	157	559	62	501	874	83	392	1111	724	4829
11	11	605	74	776	92	463	417	25	231	753	772	4208
12	12	728	32	1191	79	1565	1009	189	82	133	576	5584
13	13	608	127	832	156	1906	1031	179	87	77	801	5804
14	14	768	238	613	140	1264	910	434	51	238	909	5565
15	15	1293	321	697	292	1131	887	407	38	357	1228	6651
16	16	1874	392	965	210	1304	1109	235	64	862	1142	8157
17	17	2179	330	1815	298	1543	722	310	231	1109	1429	9966
18	18	1704	582	2152	461	1689	554	409	345	916	1878	10690
19	19	961	326	693	279	1118	67	307	230	2071	851	6903
20	20	1036	211	647	•	965	450	316	150	451	781	5007
21	21	1386	384	962	239	1745	809	349	255	916	565	7610
22	22	923	266	985	309	2188	709	600	265	309	847	7401
23	23	1332	229	1284	362	1554	807	406	206	260	1231	7671
24	24	1635	374	1166	277	845	748	363	292	422	1130	7252
25	25	3125	179	1258	480	1500	527	388	346	424	930	9157
26	26	2569	344	2129	274	1767	873	694	251	643	1024	10568
27	27	1299	421	1306	289	1776	1315	728	355	945	1434	9868
28	28	1005	204	1043	143	1519	989	371	173	316	1007	6770
29	29	1304	204	979	210	2808	908	345	413	440	1202	8813
30	30	2071	143	1957	396	3119	1175	509	442	584	1226	11622
31	31	2415	169	1577	298	2560	1328	389	471	1565	1328	12100
32	32	1977	89	1468	622	2364	1015	641	296	1237	1363	11072
33	33	2549	49	1185	410	2593	610	524	353	319	1667	10259
34	34	•	•	•	•	•	•	520	•	•	1258	1778
35	35	1620	113	1166	375	1464	498	738	393	421	1274	8062
36	36	868	365	1413	393	1527	638	241	249	679	1827	8200
37	37	1122	192	1059	308	1242	309	527	544	3217	1221	9741
38	38	1027	244	1033	396	972	254	717	217	1172	980	7012
39	39	1005	275	1175	271	969	232	•	134	1167	587	5815
40	40	960	313	1408	517	2313	236	57	136	2999	893	9832
41	41	1387	235	1143	496	1392	383	176	107	3812	974	10105
42	42	1020	533	1364	675	1549	397	230	56	2629	1494	9947
43	43	1215	425	1083	429	2446	285	407	345	2047	1074	9756
44	44	1328	526	1323	516	2685	715	404	726	2113	1023	11359
45	45	1353	357	3144	767	3923	740	251	818	2783	1379	15515
46	46	1958	463	1968	548	2179	897	317	1052	3545	1689	14933
47	47	1898	227	2084	752	1628	739	540	1162	2039	947	12016
48	48	1304	309	1313	505	1649	687	461	723	2030	659	9640
49	49	1252	232	1338	342	1116	527	383	500	1118	659	7467
50	50	1125	119	953	337	1100	324	477	321	693	654	6103
51	51	585	92	968	385	1462	199	444	297	691	558	5681
52	52	574	252	647	478	968	302	336	203	1613	671	6044
53	53	636	239	1028	433	909	158	325	144	716	469	5057
54	54	932	255	897	410	663	212	198	117	773	721	5178
55	55	702	134	1172	249	500	182	247	131	1993	676	5986
56	56	388	85	822	235	670	134	291	126	5374	410	8535
57	57	159	79	533	123	362	114	204	99	1629	363	3665
58	58	165	10	356	81	291	49	173	92	575	290	2082
59	59	162	43	376	102	446	43	210	125	1487	103	3097
60	60	184	9	522	58	407	62	256	65	1397	194	3154
61	61	261	31	328	82	239	41	58	52	1124	103	2319
62	62	565	9	332	90	184	33	37	50	1071	118	2489
63	63	511	24	324	117	359	32	312	86	429	216	2410
64	64	498	46	314	180	432	50	169	70	720	160	2639
65	65	332	23	357	209	409	49	152	31	1315	140	3017
66	66	245	19	340	121	314	31	11	88	372	147	1688
67	67	549	33	384	133	125	50	22	78	152	293	1819
68	68	440	28	397	97	116	77	64	44	855	228	2346
69	69	433	27	455	56	108	61	11	76	213	252	1692
70	70	601	30	669	130	115	111	42	112	460	352	2622

NB: Missing values on day 34 due to scoured sheep. Other missing values are due to loss of bag.

Table C.6: The total seed and the number of viable seed (soft+hard) found in the faeces of pen-fed sheep at the Waite Institute, 1988.

Total seed output	Sheep number							
	1	2	3	4	5	6	7	8
Cultivar								
Nungarin	253	143	268	84	228	82	207	299
Dalkeith	472	231	118	6	64	122	448	79
Trikkala	124	175	136	20	44	246	185	181
Junee	343	265	339	20	128	145	258	358
Clare	140	46	36	12	28	102	359	107
Total viable seed output								
Nungarin	188	95	216	57	178	50	178	236
Dalkeith	376	191	106	2	60	104	382	61
Trikkala	105	123	107	17	36	211	126	145
Junee	272	229	295	29	90	101	209	241
Clare	72	26	30	3	12	71	327	79



Appendix C: Fig. 1 Mean fresh weight of faeces from penned sheep

8
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8. BIBLIOGRAPHY

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