IMPROVING MEDIC PASTURES IN PASTURE-WHEAT ROTATIONS IN THE MALLEE DISTRICT OF NORTH-WESTERN VICTORIA.

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by

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A thesis submitted to the University of Adelaide
in fulfilment of the requirements for
the degree of Master of Agricultural Science

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July, 1994

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ABSTRACT

The thesis examines how pasture management techniques improve the productivity of annual medic-based pastures and the following wheat crop in a ley-farming system in the Victorian Mallee. The effects of the environment in determining the long-term persistence of the pasture is an important factor in the study.

A field experiment involving the sowing of a mixture of Harbinger AR (early maturity) medic and Paraggio (mid-season maturity) medic was established at the Mallee Research Station, Walpeup, Victoria, in 1991. In Year 1 of the three-year study, the medic establishment phase, herbage and seed yields, and pasture composition were affected by sheep grazing pressure and herbicide treatments. Increasing the stocking rate reduced ground cover, herbage production and seed yields. Selective grass control reduced total herbage production over the winter period but increased medic seed yields: however, Pasture topping in the spring with glyphosate reduced the medic seed yield. Winter cleaning with glyphosate reduced winter herbage production and reduced the grass component in the pasture but caused no reduction in seed yields.

In the regenerating medic pasture, plant densities were increased through mechanical pod burial which improved seed soil contact. Differences in the second year pasture phase (Year 2) resulted from the previously-applied herbicide and grazing treatments. Reduced weed competition in Year 1 resulted in increased medic seedling density, cumulative herbage production and seed yields in Year 2.

Growing a mixture of two medic cultivars with early and mid-season maturity benefited seed yields in seasons of both lower-than-average and higher-than-average rain respectively. The seed reserves of each cultivar retained during the pasture-pasture-wheat rotation were

influenced by relative seed yield, seed size and seed permeability which was controlled by both inherent and environmental factors.

Grazing during the growing season and over the summer period was shown to reduce both medic seed yield and the medic seed survival. The seed reserve of the larger-seeded cultivar (Paraggio) declined at a greater rate than the smaller-seeded cultivar (Harbinger AR). Furthermore, a higher stocking rate in both pasture years reduced the grass component and increased the total pasture productivity in Year 2.

The percentage of permeable medic seed varied depending on the cultivar, the herbicide treatment applied in Year 1 and the amount of herbage present at seed maturity. However, permeable seed levels were significantly less following Year 2 with above average rain than Year 1 with below average rain.

All herbicide treatments and the higher stocking rate reduced annual grass component of the medic pasture with a resultant decline in the incidence of *Gaeumannomyces graminis* var *tritici* Walker (Take-all) in the cereal phase of the rotation (Year 3) and with a consequent increase in wheat yield and grain protein.

Results of these studies indicate that management practices, including increased sheep stocking rates and selective grass control herbicide treatments, can make significant improvements in the productivity of annual medic-based pastures. Large fluctuations in the productivity of pastures from year to year are caused by the amount of rain. Stocking rates are determined by the productivity of pastures in dry years and there is likely to be a surplus of pasture in other years. Therefore fodder conservation has a role in sustaining stocking rates.

STATEMENT

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

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ACKNOWLEDGMENTS

I am deeply grateful to Mr E.D. Carter, my supervisor throughout this study, for his sound guidance during the planning of the experimental work and his comments and editing of drafts during the preparation of the thesis. Dr T. Bretag and Dr G. McDonald, who also reviewed drafts of this thesis and Mr M. Hannah, who assisted with biometric planning and analysis, deserve sincere thanks.

Many people assisted with field work, the collection and collation of data and the preparation of the thesis: Linton Hahnel, Gwen Cooke and my children Joanne and Damian, in particular, provided significant technical assistance during the project which is deeply appreciated.

I would like to thank staff at the Waite and Roseworthy campuses of the University of Adelaide for their friendship and assistance during the periods of my visits.

The granting of funds by the Grains Research and Development Corporation for this research project is gratefully acknowledged. Permission to undertake the postgraduate study by the Department of Agriculture, Victoria and the support from Mr. G. Stratford, Manager, Mallee Research Station is appreciated.

I would also like to thank Val for her consideration, support and assistance given freely during the period of this study.

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CHAPTER 1

INTRODUCTION

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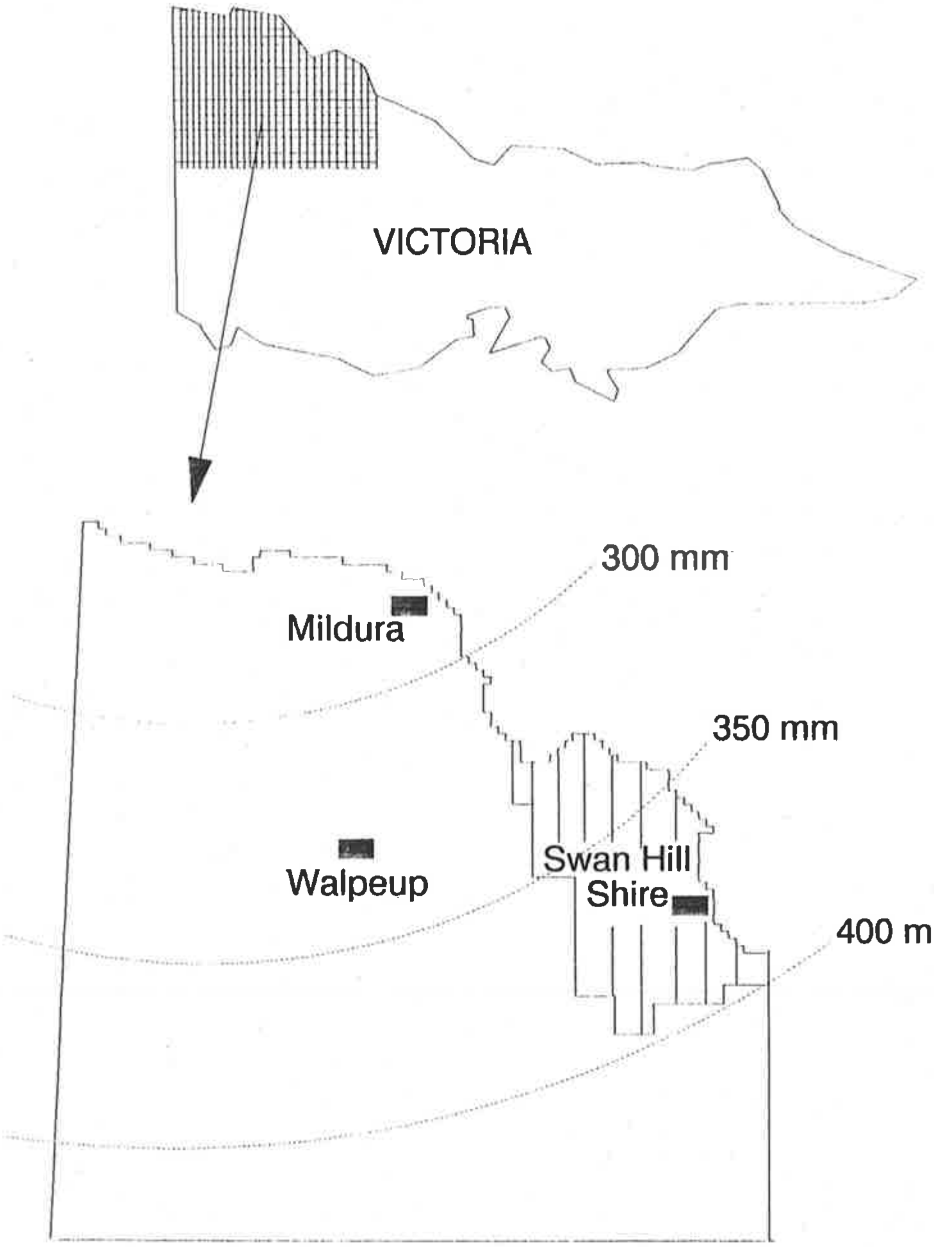
1.1 Annual Pastures in the Victorian Mallee

The deliberate use of self-regenerating annual legumes has provided significant benefits through the ley farming system (annual legume-cereal rotations) in southern Australia. This legume-cereal rotation started in the 1930's, developed in the 1940's and became well established in the 1950's (Carter 1975). Prior to this period the cereal lands had only been cropped to cereals with fallow-cereal rotations. Soil fertility was depleted, soil structure had deteriorated and soil erosion was common. The development of the ley farming system introduced a pasture phase and productivity was enhanced through reduction in the fallow, expanded use of superphosphate, increased areas of barley (and relatively less wheat). In part, the reduction in wheat growing was due to the economic depression of the 1930's. The ley farming system gave increased yields of cereals and greatly increased livestock numbers, better protection of soil and a far more stable farm income. Trumble and Donald (1938) recommended annual medics (*Medicago* spp.) for the low rainfall zones (250 - 350 mm) with shorter growing periods where soils generally have an alkaline reaction. Further studies have confirmed the recommendation (Day and Michelmore 1952; Donald 1960; Rossiter 1966; Donald 1970a, 1970b; Carter 1975, 1978). In the Mallee regions of southern Australia the annual medics were distinguished by their value as pasture plants and as a means of improving soil fertility. (Andrew 1958; Mann 1959; Vercoe and Pearce 1960; Anon 1963; Amor 1965; Elliot 1967; Wells 1970; Mathison 1973b; Bromfield and Simpson 1974; White *et al.* 1978).

The Mallee region of north-west Victoria (see Plan 1.1) lies within the semi-arid zone of



Plan 1.1 Location of the Mallee district of Victoria. Annual rainfall isohyets (·······) are shown.

south-eastern Australia and is characterised by low and variable rainfall. Some species of annual medic, mainly *M. minima* (L.) Bartal, became naturalised and spread throughout the region during the period of initial settlement, the 1880's through to the 1920's. This spread was enhanced by objectionable pods with long spines which adhered to wool. Barrel medic (*M. tribuloides (truncatula)* Desr) was first recorded in Victoria in 1907 (Ewart 1930). However, it spread very slowly through the Mallee during the 1920's, probably being brought from South Australia (McCann 1955).

Despite the natural spread of annual medics in the Mallee there appeared to be scope for further introductions. "South Australian" barrel medic (*M. truncatula* Gaertn later named cv. Hannaford) was commercially harvested in South Australia in 1938 and sown at the Mallee Research Station, Walpeup in the same year (Webb 1943). From these initial studies Hannaford was recommended for its herbage production and for reducing soil drift, (Hore 1945). Its ability to survive a period of drought was emphasised by Sims and McCann (1948). McCann (1955) noted improvements in wheat yield and grain quality and the greater pasture growth increased returns from wool and fat lambs. He considered the sowing of introduced species was justified by the increased sheep-carrying capacity irrespective of cereal productivity.

Barrel medic 'Strain 173' (*M. truncatula* cv. Jemalong) was selected from material collected in the Forbes district of New South Wales in 1939. It was recommended for the Mallee because it was superior to Hannaford in its production of early feed (Anon 1963). *Medicago littoralis* Rhode cv. Harbinger was released for the light sandy soils of the Mallee in 1959. It displayed excellent early herbage production and regeneration (Mann 1959; Anon 1963; Amor 1966a). The development and registration of the aphid-resistant *Medicago truncatula* cv. Paraggio (Oram 1982) coincided with an increased interest in improved pastures in mixed cereal-livestock farming enterprises in the semi-arid Mallee zone.

Following the development and introduction of improved medic cultivars agronomic research examined the most appropriate management strategies for pastures in the region. Mann and Rooney (1963) stressed the importance of restricting the grazing of medic pastures during and following flowering to maximise seed yields and add to the seed reserve. Amor and Mann (1965) contended that medic regeneration densities of 100 plants per m^2 were sufficient following a cropping phase in a four-year rotation of pasture-pasture-fallow-wheat.

Amor (1966b) found that the fertiliser requirements of medic pastures were met most economically by the application of superphosphate on the cereal crops. Topdressing pastures with superphosphate provided a response in years of higher-than-average rainfall: however as this increased pasture production would generally not be fully utilised there was no incentive to topdress the pasture phase of the rotation. There was generally no significant response to superphosphate in seasons of average or lower-than-average rainfall. He also found that the response to potassium and zinc was inconsistent, and he considered it uneconomic. In the decade from 1953-63 the area sown to annual medics in the Victorian Mallee expanded from 25,000 hectares to 250,000 hectares (Anon 1963).

Donald (1960) envisaged the potential for doubling Australian cereal production if demand warranted and contended that successful ley farming systems would provide the major impetus to ensure that achievement. In the late 1960's through the 1970's and into the 1980's the ley farming system was changing. Smith (1977), reporting on a survey in the mid-north of South Australia, noted that 50% of farmers had not sown medics during the previous decade although they expected medic-dominant pastures in the majority of seasons. Moulden (1973) reported that while annual medics had been remarkably free of insect pests, redlegged earthmite (*Halotydeus destructor* Tucker), sitona weevil (*Sitona discoideus* Gyllenhall) and lucerne flea (*Sminthurus vidiris* Linnaeus) were now seriously threatening their viability. Lucerne aphids including the Bluegreen aphid (*Acyrthosiphon kondoi* Shinji) and the Spotted alfalfa aphid (*Therioaphis trifolii maculata* Monell) were accidentally introduced in the late 1970's and devastated pasture legumes throughout southern Australia, including the Mallee regions (Lodge and Greenup 1980; Allen 1989a, 1989b).

In the Victorian Mallee, rotations were generally being shortened from a pasture-pasture-fallow-wheat rotation to a three course rotation of pasture-fallow-wheat. The increased use, and the effects of, broad-leaved weed herbicides in cereal crops (Wells 1972) was limiting the establishment and production of medics under cereal crops. The development of grain legumes suitable for semi-arid regions provided alternatives to pasture legumes in the cropping rotation (Billing and Bishop 1970; Patton 1970).

There have been a number of studies which demonstrated the poor performance of medic pasture. Michalk and Beale (1976) reported no increase in crop yields following medic pastures with the legume component 5 to 30 % of the total pasture. Scott (1985c) also reported no significant responses in wheat yields over two and three consecutive years of cropping following five and four years respectively of improved medic pasture in central western New South Wales. While this study did not report the medic component prior to the cropping phase, medic plant emergence between 100 and 580 plants per m^2 after both the second and third year of cropping, suggested that the medics at these two sites constituted a high proportion of the pasture prior to cereal cropping.

Field surveys of annual medic seed reserves in South Australia including Adem (1977) and Carter (1981; 1982; 1985) found them to be usually too low to establish a good medic-based pasture. These studies supported Griffiths and Walsgott (1982) who promoted grain legumes for the Mallee region as the best available option to maintain soil fertility and control cereal diseases, Take-all (*Gaeumannomyces graminis* var *tritici* Walker) and the Cereal Cyst Nematode (*Heterodeva avenae* Woll.) which were increasing through the 1970's due to the annual grass species which were dominating pastures.

Carter (1975; 1978) recommended establishing 100 - 200 plants per m^2 (5 to 10 kg/ha of scarified seed) to provide both vigorous competition with weeds and adequate seed production. Research at the Mallee Research Station, Walpeup agreed with his recommendation. Williams and Vallance (1982) showed that sowing *M. truncatula* cv. Jemalong into cereal stubble at 8 kg/ha resulted in more than 100 plants per m^2. At this plant density they competed adequately with grass and broad-leaved weeds. However, the seed yields produced in 1981 (100 kg/ha) were much less than those suggested by Carter (1975; 1978) (up to 700 kg/ha) to ensure persistence through a cropping phase.

On the basis of current research and technology, an improved pasture management strategy was promoted in the Victorian mallee to improve the value and performance of annual medics. The strategy was aimed at increasing the pasture quality, competitiveness, productivity and seed yield of medics and therefore to enhance the regenerating plant densities in subsequent years (Latta 1984). These recommendations included sowing into the cereal stubble at the completion of the cereal phase at 8 kg/ha, potentially more than 200 plants per m^2, using selective herbicides to reduce competition from weeds and limiting grazing during both the flowering period and the summer period to maximise seed yield and maintain the seed reserve.

The selective control of grasses with herbicide provided a pasture management strategy which assisted in the control of the two major cereal root diseases in the region, Cereal Cyst

Nematode and Take-all, by preventing disease carryover, reducing seed set of grasses and increasing available nitrogen. This practice also improved pasture quality and minimised grass contamination of the grazing animal (Perry *et al.* 1980; McLeod and MacNish 1989; Roget and Inwood 1991; Little *et al.* 1993).

The loss in cereal grain yield associated with *Heterodera avenae* (Cereal cyst nematode) was measured by Rovira *et al.* (1981) at ten sites in South Australia. Yield increases between 0 and 100% were achieved with the use of a soil fumigant. Roget and Rovira (1991) recorded a 29% yield increase in wheat as a result of the control of *Gaeumannomyces graminis* (Take-all) in the year prior to the cereal.

1.2 The current status of pastures in the Mallee

Although extensive sowings of annual medics have occurred throughout the Mallee regions of southern Australia during the past decade, as documented through seed production figures and sales (Anon, 1992), it is evident that seed yields are seldom adequate to sustain optimum density levels of regenerating medics (Latta and Quigley 1993).

To evaluate the levels of medic seed reserves available on Walpeup district farms a survey was carried out over the 1986/87 summer period on five properties involving eight paddocks (Latta, unpublished data). Samples were taken from four paddocks at the completion of a first year pasture phase and four paddocks at the completion of the cereal phase. Every paddock was being managed in a pasture-long fallow-cereal rotation. The medic species *M. truncatula, M. littoralis* and *M. minima* were present in seven, six and five samples respectively of the eight sampled paddocks.

The mean seed reserve (0-5 cm) at the completion of the pasture phase was 396 kg/ha (range of 192-630 kg/ha) and following the cereal crop only 21 kg/ha (range of 4-34 kg/ha). In 1986, rainfall during the May to October period was above-average in all months apart from June (306 mm compared to a long term mean of 220 mm for the six-month period). The seed reserve in the cereal stubble paddocks was the residue from seed production in 1984 when the rainfall between May and October was 158 mm. Seasonal variations in rainfall had a significant impact on the survey data. However, agronomic influences or management practices which permit medic seed reserves to be limited to less than 50 kg/ha at the commencement of the pasture phase requires evaluation and improvement.

Carter (1982) considered that a 200 kg/ha seed reserve in the top 5 cm of soil was required at the commencement of a pasture phase. This would convert to 200 to 400 plants per m^2 depending on the seed size and the percentage of soft seed.

To estimate the current annual medic plant density status in the Mallee a survey in the Swan Hill shire (see Plan 1.1) was undertaken in 1991 (Walters *et al.* unpublished data). There were 129 pasture paddocks surveyed on five east-west transects. The transects covered a range of soil types, mallee sands in the north, sandy loams through to clay loams in the south of the shire. Average rainfall varies from 300 mm in the north to 350 mm in the south. Annual medic was found in 74% of the 129 paddocks surveyed. However, the average density was 87 medic plants per m^2 and only 18% of paddocks had plant densities greater than 100 per m^2. Redlegged earthmite was present in 74% of paddocks, the same percentage of paddocks as where medics were found. Sitona weevil was found on 40% of paddocks and lucerne fleas on 33%. Less than 20% of the surveyed paddocks had densities of medics which could make a worthwhile contribution to farm productivity. The remaining 80%, had productivity restricted by previous management or environmental factors.

1.3 Objectives of the Thesis

As a contribution to solving the issue of inadequate medic production and persistence the objectives of this thesis are to investigate the impact that current pasture management practices are having on the productivity and persistence of annual medic-based pasture in the Victorian Mallee by determining; The effects of commercial herbicide applications and grazing animals on medic pasture botanical composition, production, and medic seed yields. The incidence of soil borne cereal root diseases, grain yield and protein over a three year pasture-pasture-cereal rotation. The adaptability of the recommended medic cultivars to the semi-arid environment to be assessed in relation to the maintenance of the seed reserve under grazing, permeable seed levels and the ability to maintain necessary plant densities.

Finally, the thesis aims to provide recommendations for best-option strategies to improve medic pasture performance and resultant cereal productivity in the semi-arid zone of south-east Australia.

CHAPTER 2

REVIEW OF LITERATURE

2.1 Cereal production and annual medic pastures

2.1.1. General

The dependence of cereal production on annual medic pasture has been the basis of sustainable (Mallee) agriculture in north-west Victoria (Elliot and Jardine 1972). Legume pastures grown in rotation with cereals can provide a biological disease break from pests and diseases (Rovira 1980). Superphosphate applied for the cereal phase can increase productivity in the subsequent medic phase (Amor 1966b). Cultivation buries the medic seed pod which may improve the regenerating environment for the seed (Fulwood and Carter 1989). Weed control within the cereal crop can reduce weed competition in the following medic phase (Reeves 1987). While each of these agronomic practices can improve medic productivity they also have the potential to limit seed production and reduce ensuing plant densities.

2.1.2. Rotations

The success of a cereal-medic pasture rotation is controlled by the amount of medic seed available to regenerate at the commencement of the pasture phase. The emerging plant density regulates the early herbage production, weed competition and subsequent seed yield (Williams and Vallance 1982). The effect of three common Mallee rotations on the maintenance of the medic seed reserve was studied by Latta (1992). The experiment was not grazed, weed competition and insect pests were controlled with chemicals, therefore the maintenance of seed was solely in response to the effect of the cropping rotation and the seasonal rainfall. The medic seed reserves were reduced by approximately 50% in each non-medic phase of a rotation. Based on the studies of Carter (1981) the medic seed reserve was considered adequate when 200 kg/ha was available at the commencement of the pasture phase.

The loss of medic seed reserve during the cropping phase is a result of inherent seed impermeability which controls the percentage of medic seed available for germination following autumn rains. A proportion, normally around 10%, will lose its hard-seededness in response to diurnal temperature fluctuations (Taylor 1972). This maintains the longevity (persistence) of the medic seed reserve. For example Carter (1987) found that seed of three medic cultivars had persisted for 13 years both in pods and in sheep faeces, although the majority emerged in the first six years. The medic seed which has lost its hard-seededness germinates in the cereal phases of the rotation and the plants are destroyed by either tillage/sowing operations or herbicides used to control broad-leaved weeds. This reduces the seed reserve available for germination at subsequent pasture phases.

South Australian studies (Carter *et al.* 1982; Adem 1977) showed a 33 and 30% medic seed loss respectively over one non-pasture growing season. Crosby (1989) reported a loss greater than 50% during the cereal phase from a survey of medic seed reserves at 23 sites in two year medic pasture-wheat rotations in the mid-north of South Australia.

Crawford and Nankivell (1989) studied the persistence of medic seed reserves in three rotations (pasture-barley, pasture-fallow-wheat-barley and continuous pasture) with no medic seed production after year one in any rotation. The seed reserve of *Medicago truncatula* cv. Jemalong was reduced by at least 50% in the two cropping rotations in the second year but only by 20% in the continuous pasture rotation. The pasture-fallow-wheat-barley rotation lost another 50% seed reserve in the third year but the seed reserve under the pasture-barley rotation was reduced by only 20% when the rotation reverted to the pasture phase. The longevity of the seed reserve was not increased by the continuous pasture rotation but the seed numbers were maintained at a higher level for the first three years.

In southern Queensland, Heida and Jones (1988) measured seed reserves of *M. truncatula* in two cropping rotations; two years of pasture followed by two years of cereal and three years of pasture followed by one year of cereal. At the completion of the rotations, that with two years of cereal retained only 30% of the medic seed reserve of that with one-year of cereal. The authors concluded that the seed reserve in the pasture-pasture-cereal-cereal rotation was not maintained at an adequate level to regenerate at the required densities.

When Carter (1985) surveyed farms in three separate districts of South Australia he found that only one paddock out of 34 cereal stubble paddocks had adequate medic seed reserves (more than 200 kg/ha), three had marginal levels of seed (100-200 kg/ha) and 20 were extremely poor (less than 20 kg/ha). While it is difficult to attribute a specific component of these deficiencies to unsuitable rotations the survey did show that adequate seed reserves were the exception and not generally achieved without attention to detail by the farm operator.

2.1.3. Tillage

Fallowing by mechanical cultivation is widely practised in Mallee farming systems. Tillage during the growing season destroys the medic plant population and eliminates production. It may also bury the medic seed at a depth whereby emergence is reduced. Fulwood and Carter (1989) showed a direct relationship between cultivation methods, depth of tillage and the decreasing emergence of pasture legume seedlings as the seeds were deposited at increased depths down the soil profile. The percentage of emerging seedlings decreased with an increasing percentage of seeds below 5 cm. The larger-seeded *M. scutellata* cv. Sava emerged at higher percentages from a greater depth in comparison with *M. truncatula* cv.

Paraggio.

Carter *et al.* (1988) found in comparisons between cultivation with a scarifier in preparation for sowing wheat and the direct drilling of wheat, that emergence of the medic following the wheat phase was improved with the direct drilling treatment. They suggested that the scarifier had buried substantial quantities of seed too deep for seedling emergence on the heavy-textured red-brown earth of the Waite Agricultural Research Institute, Adelaide. In a survey of three commercial paddocks in South Australia, Quigley *et al.* (1987) reported a significant percentage of annual medic seed below 5 cm at one of the three sites. They concluded that deep tillage practices may be part of the cause of pasture decline.

Cultivation in the Mallee is normally carried out by a scarifier and the results from these studies (Carter *et al.* 1988; Quigley *et al.* 1987) suggest that some medic seed may be being buried deeper than from which satisfactory emergence will occur. Shallow tillage can bury the medic seed and pod at a depth which may improve germination and emergence at a subsequent pasture phase in the rotation by ensuring the pod/seed-soil moisture contact. Khan *et al.* (1989) demonstrated the importance of some soil disturbance when establishing annual pastures. Improvements in establishment and pasture production occurred with increased disturbance and improved seed-soil contact for moisture exchange and germination. Revell (1989) also showed increases in emergence and subsequent plant density after shallow cultivation, to a maximum depth of 2.5 cm, prior to the autumn rains.

2.1.4. Fertilisers

Current recommendations for fertiliser use on medic pastures in the Victorian mallee are based on the studies by Amor (1966b) at the Mallee Research Station, Walpeup. He studied the responses to top dressing superphosphate (phosphorus) on medic-based pastures. In years of higher-than-average rainfall he reported an increase in medic herbage production in response to phosphorus. However, he concluded that the extra herbage production would not normally be utilised due to the excess feed availability. The application of phosphorus at 9 to 12 kg/ha, on the preceding cereal crop, however, would provide adequate levels for the following one to three years of pasture and was more economic. He recorded a limited response to zinc and potassium when applied to pastures but considered it to be uneconomical.

In the higher-rainfall zone of Kangaroo Island, Carter and Day (1970) reported a positive response in dry matter production from fertilising sub-clover based pastures. However, they also concluded that there was no economic justification for applying high levels of superphosphate to annual pastures unless the increased pasture production was utilised by increasing the stocking rate.

Scott (1973; 1985a) at Condobolin, New South Wales supported Amor's findings. He found that topdressing fertiliser on medic pastures achieved only marginal, erratic responses although phosphorus increased dry matter production when placed in the soil profile at 10 - 15 cm. He found no response in the field to sulphur but suggested a potential deficiency in the future because of the wide use of high-analysis fertilisers with a minimal sulphur component.

It is quite likely that the availability of phosphorus partially controls the medic component of pastures. Rudd (1972) recorded increasing medic herbage production and the resulting medic component correlated with increasing phosphorus applications on loamy mallee soils. He considered that annual medics had similar phosphorus requirements to *Trifolium subterranean* which Ozanne *et al.* (1969) showed had an increased requirement for phosphorus over broad-leaved weeds (*Arctotheca calendula* and *Erodium spp.*) and grass (*Vulpia spp.*). The requirement difference was significant enough to influence the botanical composition of a pasture in either the absence or availability of phosphorus.

Robson (1969) considered sulphur deficiency to be widespread in Australia and may be related to an increasing soil pH. Gilbert and Robson (1984a; 1984b) studied the effects of sulphur on temperate pasture species. They found that medics had a higher requirement than annual grasses and subterranean clovers to achieve 90% of potential maximum growth.

Current practices in the Victorian Mallee of applying 10 to 15 kg/ha of phosphorus in each cereal phase of a three year pasture-pasture/fallow-cereal rotation is probably maintaining adequate phosphorus levels for medic production without maximising productivity in seasons of higher-than-average rainfall. The extensive use of high analysis fertilisers with minimal quantities of sulphur may be limiting productivity on the high pH soils. Trace elements such as zinc has not provided a significant response.

2.1.5. Herbicides

The use of broad-spectrum herbicides for the control of broad-leaved weeds in cereal crops normally eradicates annual medics within the crop. Young *et al.* (1992) evaluated a range of post-emergent broad-leaved herbicides which are registered as having minimal impact on medics. They measured medic dry matter production and seed yields in response to the herbicides. The least damaging herbicide was 2,4-DB, whilst MCPA-amine severely damaged plants in comparison to the control. There was some damage measured with the use of all herbicides evaluated.

Persistence of herbicide residues after cropping has been blamed for poor pasture re-establishment after cropping. To date there is little evidence to support this hypothesis, although the failure of medics to regenerate after applications of chlorsulfuron to a highly alkaline soil (>pH 8.5) in a drought year has been substantiated verbally (Reeves 1987). The extensive use of sulfonyl urea broad-spectrum herbicides in the Mallee district may be expected to be having some influence on medic plant regeneration and production in years of lower-than-average rain.

2.1.6. Cereal residue

Quigley (1988) quantified the deleterious effects that cereal straw residues have on the emergence and productivity of annual medic pastures. He measured a decline in seedling emergence as crop residue exceeded 3 t/ha. He considered this was due mainly to the insulating effect which reduced diurnal temperature fluctuations and retarded the breakdown of hard-seededness. Barley crops rather than wheat crops appeared to present greater problems for regeneration.

Crop residues would have a negative effect on medic productivity in the Mallee as reported by Quigley (1988). However, the predominance of wheat crops and generally lower grain yields and associated residues may lessen the problem.

2.2. The grazing animal

In 1988 the Victorian Mallee region carried approximately 500,000 sheep on 500,000 hectares of pasture land (Australian Wool Corporation 1989). More than half of these sheep were breeding ewes. The estimated stocking rate for the region was calculated at 1.5 DSE/ha.

In a temperate Mediterranean climate, seasonal fluctuations in pasture growth are the main limitation to animal production (Christian 1987). Annual medics in ley pastures may benefit livestock production and in some cases livestock can improve the annual medic component

(Stern 1969; Dunlop *et al.* 1984). This can provide a symbiotic relationship with cereal production when an increased grazing pressure coupled with high levels of phosphorus can increase available nitrogen for the subsequent cereal crop (Simpson *et al.* 1974).

At Condobolin, New South Wales, Brownlee (1973a; 1973b) showed an increase in carrying capacity from 1.36 DSE/ha to 3.1 DSE/ha on medic based pastures compared to volunteer, unimproved pastures. The medic component increased (from 65% to 87%) as a result of the set stocking over a period of three years. Dunlop *et al.* (1984) showed an increase in clover content in response to an increased stocking rate. Michalk and Beale (1976) found no improvement in animal production when annual medics provided less than 30% of total pasture availability. Parkin (1966) found that pure medic pastures provided the capacity to significantly increase stocking rate with minimal concern for animal health. The oestrogenic activity of annual medic was shown to be less than Yarloop and Dwalganup and similar to Mt. Barker subterranean clover (Millington *et al.* 1964).

Cocks (1988) suggested that the success of pasture ley farming is closely linked to the high-quality feed available in the form of medic pods and seed over the summer months. The benefit of medic pods as a dry fodder residue was reported by Vercoe and Pearce (1960) who measured dry matter digestibility of pods at 30% and the crude protein level of pods to be 18.2%. Later, Denny *et al.* (1979) measured annual medic pods as having 23.8% crude protein and 24.3% digestibility while medic hay had 19% crude protein and 65% digestibility.

While medic-based pastures can provide benefits to the livestock industries, livestock can reduce the productivity of the medic. It is well documented by Mathison (1973b), Taylor and Rossiter (1974), Carter (1981; 1987; 1988), Carter *et al.* (1982) and Heida and Jones (1988) that the grazing of annual medic pastures over the summer-autumn period will result in a significant decrease in seed reserves, and should therefore be minimised. Data from Carter (1981) show that 56 days grazing with 10 merino wethers on 0.18 ha (equivalent to 17 DSE/ha) reduced viable seed numbers from 23,712/m² to 2,652/m². This decline equated with consumption of 1 t/ha of medic seed. This data showed the potential for excessive consumption of medic pods/seeds on hard-setting soils. Tow and Hodgkins (1982) showed a similar trend with significant reductions in seed reserve due to the delay in removal of stock from medic pastures over spring and summer.

The level of viable legume seed which remains following ingestion by sheep has also been studied. Carter (1980) and Carter *et al.* (1989) found a relationship between the seed size and the seed survival following ingestion: the larger the seed size the lower the percentage of viable seed following ingestion. Chewing rather than the digestive process was responsible for this decline (Squella and Carter 1992). Carter *et al.* (1989) found that survival of most medic seed was less than 5% following passage through sheep and frequently less than 2%. Denny *et al.* (1979) reported that less than 1% of barrel medic seeds survived ingestion. Vercoe and Pearce (1960) found that a maximum of 3% ingested *M.truncatula* seed was recovered from sheep faeces.

Livestock can cause damage to the growing medic plant and the soil structure. Carter (1977) noted that an increased stocking rate reduced the soil water holding capacity through soil compaction. Carter (1978) reported that the amount of plant and soil damage was directly related to feed availability, lower levels of pasture availability resulted in an increase in the grazing and walking time. Rossiter (1966) reported that only 50% of pasture production was being utilised by animals and 24% was destroyed by trampling and environmental variables. Stern (1969) produced similar figures. Willoughby (1959) found that less than one third of liveweight gain potential was being achieved by livestock from the available pasture production. Carter and Sivalingham (1977) reported that damage in pastures was caused by treading on low density pastures with a significant resultant loss in plant density, pasture yield and subsequent regeneration. They found that annual grasses or a mixture of grasses and legumes were generally more tolerant to treading than annual legumes. Although the study used sub-clovers the results showed that grass as a monoculture or as a mixture with a legume protected the soil structure, pasture productivity and plant density. However, the conservative stocking rates in the Mallee region may reduce the impact of livestock damage to medic pastures.

The grazing preferences of livestock may also influence the productivity and composition of the medic pasture. Arnold *et al.* (1966) found no selective grazing by sheep between grass (several species) and subterranean clover during the growing season. However, Broom and Arnold (1986) showed a grazing preference for annual ryegrass and/or subterranean clovers in preference to broad-leaved weeds throughout the growing season. Brown (1976) showed that the annual grass component increased when grazing was deferred over autumn and the annual legume component increased with continuous grazing. These last results indicated that grass was being selectively grazed over the autumn period. Carter and Lake (1985) reported a change in the pasture composition in response to stocking rates. A low stocking rate increased the *Hordeum leporinum* domination, medium stocking rate led to domination by *Arctotheca calendula* and high stocking rate resulted in domination by *Poa annua* and *Trifolium glomeratum*.

Apart from the loss of seed by sheep grazing during summer-autumn, some reduction in medic seed reserves has also been measured as a result of grazing throughout the growing season. Thorn (1989) showed a 52 kg/ha decrease in seed production for each extra wether/ha carried over the growing season. However, grazing over the winter period reduces the production of species with a prostrate growth habit only marginally, unless they are very early maturing and are flowering over the winter period.

Thorn and Revell (1987) categorised the seed reduction in three medic cultivars with different maturity and growth habit under three grazing treatments: No grazing, 16 DSE/ha stocked 33 days after sowing for 60 days then removed (moderate grazing) and 16 DSE/ha stocked 33 days after sowing for 165 days then removed (heavy grazing). The seed production of Harbinger from the no grazing treatment was 325 kg/ha and was decreased by 37% and 91% by moderate and heavy grazing respectively, Paraggio from 558 kg/ha by 31% and 97% and Jemalong from 322 kg/ha by 11% and 93%. Harbinger has the earliest maturity and the greatest seed loss, Jemalong has the most prostrate growth habit of the three cultivars and therefore had the least seed loss under moderate grazing. Chaichi and Carter (1993) also reported a decrease in medic seed production as a result of both increasing time of grazing and increasing the stocking rate during the period of seed pod maturation. They measured a medic seed loss of 313 kg/ha (351 kg/ha to 38 kg/ha after a 6 week grazing period with 60 sheep/ha).

Curll and Jones (1989) recommended that grazing be managed whereby established plants are able to recover and where appropriate set seed and establish seedlings. Carter (1986) stressed the need for grazing management to protect seed production in an establishing pasture. He recommended that grazing be restricted during the period of flowering and seed set to maximise seed production.

There has been no reported research in the Mallee to confirm the relevance of the above studies to the region. It could be considered that the conservative stocking rates which are practised may reduce both the beneficial and negative aspects of sheep grazing on the productivity of annual medic pasture.

2.3. Competition among plants

Plant competition within a community occurs for available light, water and nutrients (Donald 1963). Cocks (1988) considered sowing rates of the order of 20 to 40 kg/ha (approximately 400-800 viable seeds/m^2) as being most suitable in a 400 mm rainfall area. There is substantial documentation including Donald (1951), Silsbury and Fukai (1977), Silsbury *et al.* (1979) and Williams and Vallance (1982) that increasing plant density significantly increases early herbage production, however, seasonal factors provide the stimulus to maximise seed production (Donald 1954).

On red brown soils at the Waite Institute, Adelaide, Adem (1977) sowed medics at rates of 1 to 1000 kg/ha, he achieved a positive response in herbage production at three and seven weeks after emergence of 10,000 plants/m^2 in comparison to lower densities. At 11 weeks 580 plants/m^2 maintained a productivity benefit over lower plant densities. There were no further herbage production benefits in plant densities greater than 400 plants/m^2 during that growing season. Plant densities declined through thinning to approximately 100 to 200/m^2 during the spring and there were no differences in seed yield although the trend was towards an increased seed yield at the lowest plant densities which were the lowest initial sowing rates. 668 mm of rain occurred in 1975, the year of the study (long term average 629). 100 mm in March provided an excellent 'seasonal break'. May, July, September and October had above average rain. April, June and August had less than average rain.

From the Victorian Mallee, Amor (1965) reported that seasonal variations in rain meant medic plant densities which varied between 150 and 1,000 plants/m^2 may be most suitable to maximise seed yields. Latta and Quigley (1993) counted plant densities up to 1500 plants/m^2 under experimental conditions at Walpeup from seed reserves of approximately 1 tonne/ha. However, this seed reserve would not be considered achievable under commercial constraints. They also measured establishment densities of *M. truncatula* cv. Paraggio in a commercial field. It established at 1213 and 230 plants/m^2 in 1988 and 1990 from a seed resource of 4561 and 2421 seeds/m^2 respectively (approximately 200 and 100 kg/ha) and about 25% (1988) and 10% (1990) of the seed reserve. The 1213 medic plants/m^2 which emerged in 1988 dried off prematurely following less than 50% of average rainfall during July and August (30 mm compared to 60 mm) although September received 150% of the long term average. The seed reserve was reduced from 4561 to 3295 seeds/m^2 which was a similar number to the emerged plants/m^2 (1213). In 1990 the medic regenerated and established at 230 plants/m^2. The seed resource was increased by 50% (2421 to 3503 seeds/m^2) from approximately 100 to 150 kg/ha. The rainfall in 1990 during September and October was less than 50% of average (15 and 9 mm). However, the three winter months were about 30% above the mean annual rain for Walpeup. The study showed the benefits in seed production resulting from plant densities of 200 to 300/m^2 and adequate winter rain in the semi-arid zone irrespective of spring rain (Latta and Quigley 1993).

Williams and Allden (1976) showed the direct relationship between increased plant densities and improved animal production. However, a low sowing rate followed by limited grazing would result in satisfactory seed production. Difficulty arises in matching stocking rate to seasonal fluctuations and limitations and Christian (1987) considered that the effect of these fluctuations on pasture production constitute the major limitations in animal production. This is especially the case in the semi-arid regions of south east Australia which have a variable date for the opening and closing of the growing season and high drought risk during the growing season (Cornish 1985a).

In the field annual medics are not competing solely with the same species but with annual plants which are often naturalised and well adapted to prosper in the environment. Carter (1985; 1987; 1988) reported that low medic seed reserves were limiting plant densities, competition and therefore ultimately seed production. Previously, Amor and Mann (1965) had reported that medic plant numbers regenerating in the Mallee within a pasture-cereal ley system were generally less than 100 plants/m^2.

Competition from annual grass and broad-leaved weeds in a mixed pasture reduces seed production of legumes. Mixtures of pasture species are seldom in equilibrium. Management practices influence the composition of mixtures by altering species competitiveness. Establishment methods and times of defoliation are examples of strategies which can alter the balance (Sheaffer 1989). Fisher and Thornton (1989) stated that growth rate was an important factor in the control of plant relations in pastures. Grass dominance is inevitable unless it is at some competitive or demographic disadvantage (e.g. by severe grazing), or is grazed preferentially. An agriculturally-desirable legume content may be viewed as an attempt to sustain a non equilibrium condition. Thorn and Perry (1987) found that broad-leaved weeds tended to fill the niche left available by the removal of annual grasses. The legume component was not increased significantly.

The chemical and physical manipulation of pastures to reduce non-legume components provides an opportunity to regulate the pasture composition and maximise seed production. Dunlop and Thorn (1984) reported some reduction in total pasture production as a result of grass removal but the annual medic herbage and seed yield increased. Venn (1984) recorded no total herbage loss with the removal of annual grasses when the plant densities of medic were greater than 800 plants/m^2. However, Venn (1989) reported that selective herbicide control of annual ryegrass in an annual medic pasture resulted in an increase in the capeweed component and a decrease in annual ryegrass but no change in the medic. Thorn and Perry (1983; 1987) recorded a 30% and a 8% decrease respectively in total herbage production in October when grasses were removed from an annual pasture. However, extra legume and broad-leaved weeds compensated in the subsequent pasture year for the grass removal and the legume seed production increased.

The use of non-selective "knock down" herbicides has been shown to limit the density of annual grasses in the following year. Leys *et al.* (1991) achieved an 84% reduction in regenerating plant densities of *Vulpia bromoides* following spraytopping applications. The effect on the legume pasture as a result of the non-selective herbicide applications was not reported.

2.4. Cultivars

Cultivar development has endeavoured to increase the medic component of annual pastures through improving environmental adaptability, vigour, competitiveness and subsequent seed yield (Crawford *et al.* 1989). Reed *et al* (1989) discussed the need for high seed yield and hard-seededness in a medic cultivar to ensure persistence under conditions of low or zero seed set, which occur in the cropping phase or as a result of cultivation in a pasture ley system. Carter (1988) stressed the importance of persistence and the availability of adequate numbers of permeable seed at the commencement of a pasture phase, in preference to the promotion of cultivars based on their potential productivity. Clements (1989) questioned the long-term value of cultivars hastily developed in response to insect infestations. He set criteria for the success of a medic cultivar, viz.: seedling vigour, winter herbage dry matter production, suitable flowering and seed maturation timing for the environment, adequate seed production, acceptable pod spininess, appropriate hard-seededness and resistance to pests and diseases.

Amor (1966a) reported medic cultivar performance in the Victorian Mallee in evaluation trials from 1960 to 1964. He showed that *M. littoralis* cv. Harbinger outperformed three cultivars of *M. truncatula* viz. cvv. Hannaford, Jemalong and Cyprus. Harbinger had significantly higher winter herbage production than the other cultivars in three years out of five. Plant densities were not reported: therefore the results cannot be attributed solely to inherently greater growth rates. However, the initial sowing rates were based on equal weight/area of seed and the lighter seeded Harbinger may have established a greater plant density (more seeds sown/area). The measured seed yields of Harbinger were also higher in every year which may have maintained higher plant densities in subsequent years.

To replace aphid-susceptible medic cultivars in north-west Victoria an evaluation of new aphid resistant lines was commenced in 1980. As a result of these studies *Medicago truncatula* cvv. Paraggio and Parabinga were recommended as replacements for Jemalong barrel medic: these were shown to have better seed yield and early herbage production than Jemalong (Amor *et al*. 1986). Harbinger was replaced by an aphid-resistant Harbinger backcross, Harbinger AR (Oram 1990). It was recommended for the lighter soils of the Victorian Mallee in 1990.

McComb and Andrews (1974) considered that increasing the percentage of permeable seed, at the break of the season, would increase the densities of regenerating plants from an environmentally-controlled seed reserve. To ensure the survival of permeable medic seeds until the autumn rainfall event, Crawford *et al.* (1989) suggested 100% of seed should remain impermeable until April, then 30% of the seed reserve should become permeable (soft) when the probability of a false break was less likely.

M. truncatula cv. Paraggio was registered in 1982 on the basis of its resistance to the aphids (Oram 1982). However, Paraggio also had inherently higher percentages of permeable seed

(30%) at the seasonal break than the previously recommended cultivar, Jemalong (10%). It also had higher levels of soft seed over the summer period which could cause increased seed losses from the reserve as a result of summer rains (Crawford *et al.* 1989). However, Crawford and Nankivell (1989) argued that there was a niche for cultivars with less hard-seededness at the seasonal break to increase the plant density, competitiveness and productivity of the medic-based pasture.

Latta and Quigley (1993) studied the persistence of Paraggio in the Mallee environment and found that while permeable seed levels were significantly higher than alternative *M. truncatula* and *M. littoralis* cultivars, adequate seed reserves were maintained over three years with no seed production. This was considered a satisfactory period of time and would ensure the success of Paraggio in the majority of Mallee farming systems.

Cornish (1985a) showed the need for medic flowering at Condobolin to occur before the end of August due to the variable date of the opening and closing of the growing season and the high risk of drought. The theoretical optimum flowering time at Condobolin was 90 days following an early May sowing and 78 days following an early June sowing (Cornish 1985b). He concluded that cultivars with a range of flowering times could be successful although early types were likely to be the most persistent. The Walpeup growing season and total rainfall is similar to Condobolin and the theoretical optimum flowering time would be similar at both sites. Harbinger flowered at Walpeup after 81 days following a mid-April sowing and Paraggio after 114 days (Hochman 1987). This should reduce to less than 70 days for Harbinger (Harbinger AR has been measured as 1 to 3 days later flowering than Harbinger) and approximately 100 days for Paraggio following a May sowing as suggested by Cornish (1985b). These two cultivars provide a maturity range which should best utilise the majority of seasonal variables in the Mallee environment when sown as a mixture (Cornish 1985b).

Andrew (1962) reported the benefits of larger seeded cultivars of *M. tribuloides (truncatula)*, in terms of increased growth during the early vegetative phase of large seeded pasture legumes when compared to small size seeds. This can reflect on final legume herbage yields and increased seed production in a mixed sward when competitiveness is a factor. Williams (1963) reported that the emergent force of annual legume pastures was directly related to the size of the seed. Carter and Challis (1987) also showed that large seeds and the resultant vigorous seedlings improved seed yield after an early autumn emergence. Taylor (1971) supported this evidence in *Trifolium subterraneum* by showing that the larger seeds produced increased plant weight at emergence. The smaller seeds were able to increase relative plant growth to compensate during the growing period, but the competitive factor limited the opportunity for the compensating growth.

The Mallee region requires cultivars to suit predetermined rotations. The cultivar must have adequate seed available at the commencement of a pasture phase. It should be tolerant of low-cost broad spectrum herbicides, endemic pests, water deficiency, low P levels and the grazing animal.

2.5. Pasture Predators

Redlegged earthmite are considered the most significant medic pasture insect pest in the Victorian mallee. They have been noted to cause establishment failures and production losses in established medic pastures. The sitona weevil is also considered to be having an increased impact on medic establishment on the heavier soil types. It has been suggested that reductions in the area of clean mechanical fallowing in recent years has expanded the problem due to less interruptions of the insect life cycles through cultivation.

Moulden (1973) reported that redlegged earthmite, sitona weevil and lucerne flea were seriously threatening the viability of annual medics. He suggested that success in establishment was governed by the absence of insect pests. Carter (1986) confirmed the continuing productivity losses associated with these insect pests.

Studies by Allen (1989a; 1989b; 1990) have shown that the bluegreen aphid, lucerne flea, redlegged earthmite and sitona weevil can reduce plant numbers when they occur at and before emergence and restrict plant vigour and herbage production when they occur throughout the growing season. Seed yield losses in medic pastures due to redlegged earthmite have been measured at up to 80% and bluegreen aphid 30 - 50%. Larvae of sitona weevil damage nodules but plants appear to compensate for the damage in terms of the amount of nitrogen fixed. Insecticides are the most common control method although cost precludes wide use in dryland pastures, such as those found in the Mallee region.

In a study at Albany, Western Australia, Nicholas and Hardy (1976) showed a 50% increase in pasture herbage production due to the control of redlegged earthmite with an insecticide in May. With no control, earthmite populations increased to $50/m^2$ in June, $500-1000/m^2$ in July. Lodge and Greenup (1980) reported 50% losses in spring herbage production in a range of medic cultivars susceptible to the spotted alfalfa aphid and bluegreen aphid in northern New South Wales. Seed yields were reduced by 5 - 25% depending upon numbers of aphids present at time of flowering and the flowering date of the cultivar. The pea aphid *Acyrthisophon pisum* (Harris) has been shown to cause damage to medics. Damage varied between species and cultivars within species (Ridland and Berg 1981).

Johns and Greenup (1976) reported a loss of pasture seed including *Medicago sativa* due to the theft by ants in the establishment year when seed was surface spread.

2.6. Environment

Annual medics are most specifically adapted to the neutral to alkaline soil regions of the 250-400 mm rainfall zones of southern Australia. As the genus is native to a wide range of Mediterranean-type environments there are species which are most suited to the various ecological zones within southern Australia (Mathison 1973a; Adem 1977). Legume persistence is becoming more difficult to manage in the Australian environment and new species are required to utilise changing environmental and edaphic conditions (Hochman and Helyar 1989).

Annual medics should be responsive to both photo-period and temperature in order to maximise seed set (Aitken 1955; Clarkson and Russell 1975). This results in seed production occurring in the most favourable period of the year (relating to moisture availability) and shortens the required growth period in the case of late seasonal breaks or sowings.

The high temperatures and dry summers normally experienced in the Victorian Mallee assist with medic persistence. In studies by Quinlivan (1971a; 1971b), reported that diurnal temperature fluctuations between 15^{0}C and 60^{0}C during the summer-autumn period would be the principal mechanism causing the softening of impermeable medic seeds in the mallee regions. The fluctuating temperatures increased the percentage of seed permeability while constant high temperatures had less effect. Increasing constant temperatures from 15^{0}C to 60^{0}C increased seed permeability only marginally. He showed that the effects of decreasing soil moisture levels during summer was shown to determine seed impermeability. Recent work by Taylor and Ewing (1992) have also shown the importance of moisture levels during seed maturation in determining the percentage of permeable medic seed.

Lodge *et al.* (1990) reported similar results in the decline of hard-seededness levels in annual legumes, including medics, over a range of temperature fluctuations; 60 to 25°C, 40 to 10°C, a range of constant temperatures and fluctuations within that range. Both the increase in the maximum temperature and the degree of variation of the temperature increased the seed permeability. Quigley (1988) reported that increased concentrations of cereal straw and plant residue was consistently associated with reductions in medic plant emergence due to an insulating effect and therefore a reduction in the temperature fluctuation.

The high temperatures and temperature fluctuations prevalent in the Victorian Mallee during summer provide relatively high levels of soft seed by late summer. The probability of significant summer-autumn rainfall which would cause a 'false break' is also high (refer rain data Figure 3.1). Hence, losses of medic seed reserves as a result of these rainfall events may be significant. During the period 1914 to 1945 there were 12 seasons at Condobolin, New South Wales and 7 seasons at Merredin, Western Australia, in which rainfall events caused a false break. In the Victorian Mallee 40% of the rain falls outside the growing season (May to October) compared to 57% at Condobolin and 35% at Merredin. Imbibition without emergence was estimated to occur in 56% of years at Condobolin and 50% of years at Merredin. At Walpeup it could be assumed that some imbibition without emergence would occur in at least 50% of years (Cornish 1985a). Carter and Challis (1989) could account for approximately 80% of medic seed sown in pods in 1976 by 1985. Emerged seedlings were counted on a yearly basis. No further significant emergence occurred from 1985 to 1989 although some viable seed remained leading to the assumption that a significant amount of seed had imbibed and died.

In Adelaide, South Australia, Crawford and Nankivell (1989) showed in 1981 that 50% of permeable barrel medic seed germinated on 2 March when retained on the surface but 100%

of permeable seed which was buried germinated on that date. In 1982, 25% germinated on 22 March when on the surface and approximately 60% when buried. The difference in germination percentages were ascribed to better seed/soil contact and therefore moisture exchange as a result of the seed burial as described by Revell (1989).

In a study of the permeable medic seed levels over the summer autumn period at the Mallee Research Station, Walpeup, Latta and Quigley (1993) recorded up to 20% soft seed of Paraggio during the summer period. This would provide the potential to reduce the seed reserve by that amount if significant rains fell. Hagon (1974), in a study at Tamworth, NSW, could not account for between 12 and 26 % of *M. truncatula* seed present at the start of a summer in the following autumn. While the long term average incidence of November to April rain is much greater at Tamworth than Walpeup, 380 mm compared to 136 mm, the probability of significant rain at Walpeup during those months provides the potential for a significant seed loss. Saoub *et al.* (1992) reported a 21% seed loss due to false breaks.

2.7. Establishment

Successful establishment of medics provides the basis for the future success of the annual medic pasture. Gramshaw and Cameron (1988), Gramshaw *et al.* (1989) discussed the key to successful legume establishment and persistence. Cultivar selection, seed quality, seed treatments, sowing rate, seedbed preparation, reduction of competing plants and grazing are all management strategies which can enhance the probability of successful establishment. Carter (1987) addressed the limiting factors associated with establishment techniques and provided the recipe for success for the range of environmental and edaphic conditions in southern Australia. Current deficiencies in establishment are associated with low-cost techniques for the less favourable rainfall districts where extensive pasture sowing in ley farming systems is practised (Gramshaw and Gilbert 1989).

The recommended practise for establishing annual medics in the Mallee was by undersowing at 2 kg/ha in the cereal crop preceding the pasture phase (Amor and Mann 1965). However, in one instance they recorded only 6.5 plants/m^2 of medic in the pasture phase in the year following establishment in a cereal crop. This may have been due to high percentages of hard seed with crop residue retarding the breakdown of hard seeds. Amor and Mann (1966) showed the importance of shallow seed burial; 10% establishment of sown seeds when left on surface, 61% when sown at 2.5 cm and 40% when sown at 5 cm. They supported undersowing in the cereal crop by arguing that there was little return in the establishment year if the annual medics were sown into a cereal stubble whereas undersowing in the cereal crop would enable an adequate seed reserve to be available for germination in the subsequent pasture phase.

In south-eastern Western Australia, Poole and Gartrell (1970) reported reductions in cereal grain yields and medic seed production when the medics were undersown. Cyprus barrel medic and Harbinger strand medic sown at 3 kg/ha and 9 kg/ha had their seed production reduced by approximately 75% at 3 kg/ha and 50% at 9 kg/ha when undersown in wheat as compared to being sown as a monoculture. Wheat yields were reduced by 14% and 20% when the medics were undersown at 3 and 9 kg/ha respectively.

In central New South Wales, Brownlee and Scott (1974) showed a negative response in cereal grain yields when sowing rates of annual medic were greater than 4 kg/ha. Scott and Brownlee (1974) recommended that annual medic be sown at 4 kg/ha (increased from 1 to 2 kg/ha) and cereal sowing reduced from 40 kg/ha to 11 kg/ha to provide a competitive 250 plants/m^2 of medic in the subsequent pasture. However, Scott (1985b) found that undersown medics, irrespective of the sowing rate or method, reduced cereal grain yield and the medic seed yield was only providing 2 -3 kg/ha of germinable seed in the subsequent pasture phase.

Gillespie *et al.* (1983) recommended against undersowing pastures in a cereal crop if the cereal is the priority crop, as grain yield would not be maximised. In discussing the benefits of establishing annual pastures post or prior to the seasonal break (wet or dry) they suggested that it was a decision between some loss in plant emergence with dry sowing and reductions in the workload at the seasonal break. Carter (1974) recommended establishing medics into the cereal stubble at 100 - 200 plants/m^2 (5 to 10 kg/ha sowing rate) to maximise competitiveness, production and resulting seed yield.

Carter (1986; 1987; 1988) promoted successful establishment strategies and listed the best available management practices to ensure success. The list included, the control of sowing depth, seedbed preparation, sowing implements, the role of cover crops and undersowing strategies. He stressed the importance of controlling and limiting grazing as a means of maximising seed production in the establishment year. Thorn (1989) stated that the aim of establishment of an annual legume pasture should be to maximise seed set by regulating the following variables: insect pests, species, disease, rotation, weeds, fertiliser and grazing.

Williams and Allden (1976) showed a direct relationship between higher plant densities and increased animal production, but they considered there was no value in establishing a dense pasture unless early production was required. Limited grazing would result in satisfactory seed production from low-density plant establishment. However, often there must be a compromise between the cost of seed and the control of weeds.

2.8. Fodder conservation

Launders (1971) promoted the use of medics as a high-quality conserved livestock fodder. However, Carter *et al.* (1988) found that medic seed production was reduced by approximately 50% as a result of cutting for hay at early flowering. In their study the mowing was carried out at 8 cm, which they suggested was significantly higher than would be the case on most farms, therefore normal seed losses may be much higher. It was found that losses were increased in the taller more erect growing cultivars such as *Medicago scutellata* cv. Sava, than the more prostrate cultivars such as Jemalong barrel medic.

2.9. Plant diseases

The occurrence and effect of pathological and foliar diseases on annual medic production and performance has not been widely reported for the sandy soils of the semi-arid zone. Personal observation are that in years of exceptionally high rainfall damage due to *Phoma medicaginis*, *Fusarium avenaceum*, *Pythium irregulare*, *Pythium ultimum* and *Rhizoctonia solani* can occur (Irwin 1989; Reed *et al.* 1989).

Bretag and Kollmorgan (1986) studied the incidence of root diseases in medics on self-mulching grey clays of the Wimmera. They found there were different levels of resistance within the *Medicago* genus and within *Medicago* spp..

In a South Australian study, increases in medic production were measured following the use of fungicides, at seven of eight selected sites (Pankhurst *et al.* 1991). At one site soil disturbance was found to give production improvement possibly through the control of rhizoctonia root rot.

2.10. Nitrogen fixation

The infectiveness and effectiveness of previously-introduced and now naturalised *Rhizobium* strains has been accepted as satisfactory on the alkaline soils of the Victorian Mallee. Amor and Mann (1966) reported no response to inoculation with appropriate bacterial inoculant, on the heavy loam flats or the sandy rises of the Mallee. The Victorian Department of Agriculture does not promote inoculating medic seed with the *Rhizobium meliloti* strain unless sowing into land with no history or presence of medics.

Research by Brockwell and Hely (1961; 1966) in the central and northern regions of New South Wales found a great diversity of *Rhizobium* strains with differing effectiveness on various *Medicago* spp. However, these studies were carried out on neutral to acid soils. In a Californian study, high numbers of improved *Rhizobium* strains were seen as important to compete against ineffective *Rhizobium* native strains (Jones *et al.* 1978).

2.11 Conclusion

This brief review of the literature has defined the limitations which restrict the productivity and benefits of annual medics in pasture-cereal rotations. However, there are deficiencies in current knowledge relating to the Mallee zone of south-eastern Australia and includes:

1) The impact of chemical grass control techniques in conjunction with the grazing animal on the composition and productivity of a medic-based pasture. The subsequent wheat yield and grain protein content which result from the grass control strategies.

2) The effects of the grass herbicide treatments interacting with grazing livestock on the persistence of the currently-recommended medic cultivars in a pasture-pasture-wheat rotation.

CHAPTER 3

THE EFFECTS OF PASTURE MANAGEMENT TECHNIQUES ON THE PRODUCTION OF AN ANNUAL MEDIC-BASED PASTURE-PASTURE-WHEAT ROTATION

3.1 Introduction

The experiment described in this chapter of the thesis aims to: 1. Study the productivity, over three seasons, of an annual pasture based on two medic cultivars (Harbinger AR and Paraggio) in the establishment and regeneration years and subsequent cereal crop with four herbicide and three sheep stocking rate treatments imposed in the pasture years; 2. Evaluate the effectiveness of the imposed treatments through the measurement of (i) pre-sowing medic seed reserves in Year 1, (ii) the density of emerged medic plants, (iii) herbage production, (iv) pasture botanical composition, (v) medic seed yields and (vi) the productivity of the grazing animal at the different stocking levels during the 2-year pasture phase; 3. Examine response in a wheat crop of the pasture management treatments through (i) the incidence of cereal root diseases (ii) the wheat grain yield and (iii) the grain protein.

Reliable low-cost methods of establishment are required in less-than-favourable rainfall districts where extensive pasture sowing and ley farming is practised (Gramshaw and Gilbert 1989). One such area is the Mallee region of south-eastern Australia where historically, the establishment of medics in the Victorian Mallee meant sowing with the cereal crop at 1 - 2 kg/ha (Amor and Mann 1966). Changing farming practises in response to the downturn in livestock industries in the late 1960's and through the 1970's resulted in the shortening of the pasture phase in the rotation and the increased use of herbicides. Williams and Vallance (1982), at Walpeup, studied the performance of medics sown into a cereal stubble and showed there was no improvement in spring herbage production, weed competitiveness or seed yield once more than 100 plants per m^2 were established. This converted to approximately 4 kg/ha of seed becoming established. As a result of this study, sowing into the cereal stubble at 8 kg/ha is recommended (this assumes at least 50% of seed sown becomes established). Recommended sowing time is the second half of April, whether or not the opening rains have fallen, as there is little plant competition due to the weed control associated with cereal growing. Burial of the seed is essential to give maximum seed-soil-moisture contact.

The foundation of a sustainable annual medic pasture in a ley-farming system is the seed yield obtained in the year of establishment. This provides the resource for subsequent plant densities and this determines the medic productivity, competitiveness and recurring seed yields. Carter (1981) indicated that seed reserves of about 200 kg/ha are required to ensure the productivity of medics in crop-pasture rotations. This figure may be higher than can be consistently produced or is required in medic pastures in the Mallee. Two experimental studies at Walpeup (Amor 1966a; Latta and Quigley 1993) without the limiting effects of insect pests, grazing animals or non-selective herbicides, measured medic seed yields between 200 and 600 kg/ha. In a commercial paddock at Walpeup, seed reserves increased by approximately 200 kg/ha in the establishment year. However, in a survey of paddocks of regenerating medic pastures they found that medic seed reserves only increased by between 0 and 100 kg/ha per year (Latta and Quigley 1993). The seed reserve necessary to sustain self-regenerating medic pastures in the Mallee region requires investigation.

The germinating environment can determine the medic plant density. Sedgely (1963) showed the speed of seed germination and the percentage of seedling survival was increased by improving the degree of contact between seed and soil moisture. Andrew (1958) reported that improved seed pod/soil contact increased established plant density. Khan *et al.* (1989) and

Revell (1989) demonstrated the benefit of some soil disturbance for improved germination and emergence density. The plant density most beneficial in the Mallee environment to optimise early production has not been accurately defined. Densities from 150 to 4,000 plants per m^2 have been published as advantageous in certain environmental conditions (Amor 1965; Carter 1981; and Abd El-Moneim and Cocks 1986). This thesis study at Walpeup aims to provide supportive data.

The effect of grazing sheep on the pasture herbage production, composition and subsequent seed yield is largely unknown for the Mallee region. Studies by Brownlee (1973b) and Dunlop *et al.* (1984) have shown increases in the legume pasture component as a result of a higher stocking rate, and Brown (1976) reported preferential grazing of annual grasses early in the season. Chaichi and Carter (1993) reported a decrease in medic seed production as a result of both increasing time of grazing and increasing the stocking rate during the period of seed-pod maturation. They measured a medic seed loss from 351 kg/ha (no grazing) to 38 kg/ha (6 week grazing period with 60 sheep/ha). Thorn (1989) found grazing over the winter period reduced the seed yield of medics only marginally in species with a prostrate growth habit, unless they are very early maturing and are flowering over the winter period. These apparently-inconsistent studies require clarification in the Mallee environment.

The relative production of grass-free, legume-based pasture in comparison to pastures with an annual grass component has not been studied in the Victorian Mallee. Dunlop and Thorn (1984), Venn (1984), Thorn and Perry (1987), Stephenson (1993) and Stephenson and Mitchell (1993) all reported some reductions in annual pasture herbage and/or livestock production for 1 or 2 years when annual grasses were controlled. However, subsequent legume seed yields were improved. Parkin (1966) contended that basically pure medic pastures have the capacity to significantly increase current stocking rates with only minimal concern for animal health. The comparative performance of grass-free and mixed grass-medic pastures needs evaluation in the semi-arid alkaline-soil environment of the Victorian Mallee.

The interrelationships between medic pastures and the resultant cereal productivity has been an ongoing study. Studies by Elliot and Jardine (1972) and White *et al.* (1978) reported the benefits in cereal production as a result of medic pastures grown in rotation with a cereal. However, the extensive occurrence of soil borne cereal root diseases in the semi-arid zone of south-eastern Australia, due to the annual grass component in the pasture phase of the rotation, has reduced the viability of the ley-pasture farming system (Rovira 1980; Griffiths and Walsgott 1982). Studies on the effects of pasture management practices on cereal root diseases and their impact on cereal production have been carried out by Thorn and Perry (1983), MacLeod and MacNish (1989) and Stephenson (1993). While results have varied, it has been generally accepted that grass-free legume pastures improve cereal yield and quality, through the increase in available soil nitrogen and the reduction in cereal root diseases. These results require substantiation in the Mallee environment.

This thesis study aims to establish the effects and interaction of plant density, sheep grazing and grass-free pastures on the productivity of an annual medic-based pasture and a wheat crop in a pasture-pasture-wheat rotation.

This chapter (Chapter 3) studies the production of the medic-based pasture in 1991 and 1992 followed by the production of the wheat crop in 1993. The following chapter (Chapter 4) concentrates on the dynamics of medic seed survival over the 3-year period.

3.2 Materials and Methods.

3.2.1. Site Description

The field experiment commenced in 1991 at the Mallee Research Station, Walpeup, Victoria, (Long. 142^0 E, Lat. 38.8^0 S, Alt. 50 m). Soil at the site has been described generally as a gradational calcareous earth (Gc.1.22, Northcote 1979), and in more detail, as a mid-mallee sandy loam making up the majority of the site with a mid-mallee sandy loam, calcareous phase abutting into portions of the site (Newell 1960).

A soil sample (composite of 100 sub-samples 0-10 cm) was collected from the site prior to the establishment of the experiment. It was analysed by the Department of Agriculture, Victoria, Soil Chemistry Laboratories. The results from that analysis were:

pH (water)	7.7
pH ($CaCl_2$)	7.2
Phosphorus (P) - Olsen method	5.4 μg/g
Potassium (K) - Skene method	493 μg/g
Available Sulphur (S)	1.5 μg/g
Total Nitrogen (N)	0.072 %
Oxidisable Organic Carbon (C)	1.22 %
Organic Matter	2.3 %

Monthly rainfall, minimum and maximum temperature from January 1991 to March 1994 (the period of the study) and the long-term averages (1911 - 1993) are presented in Figure 3.1.

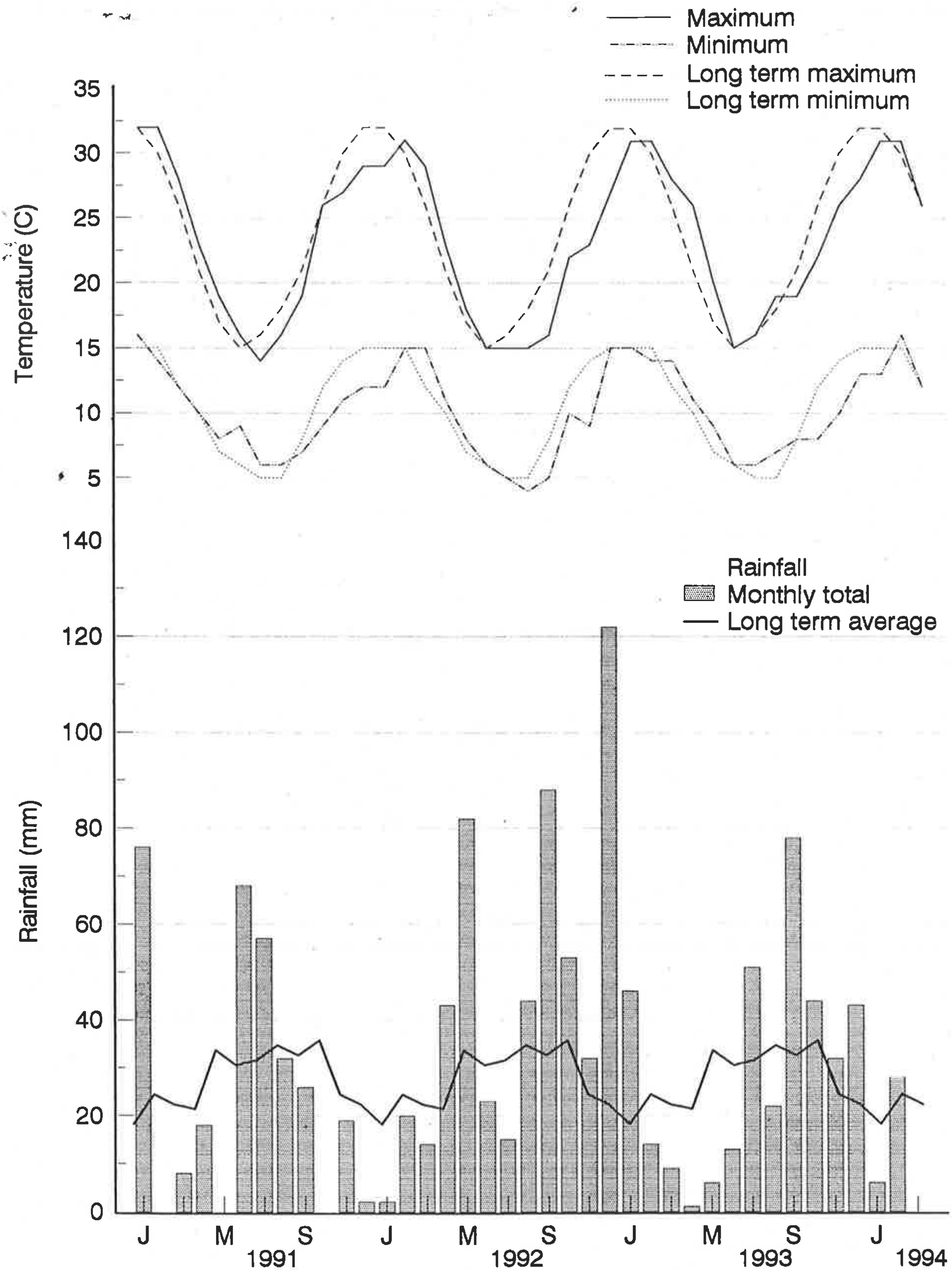


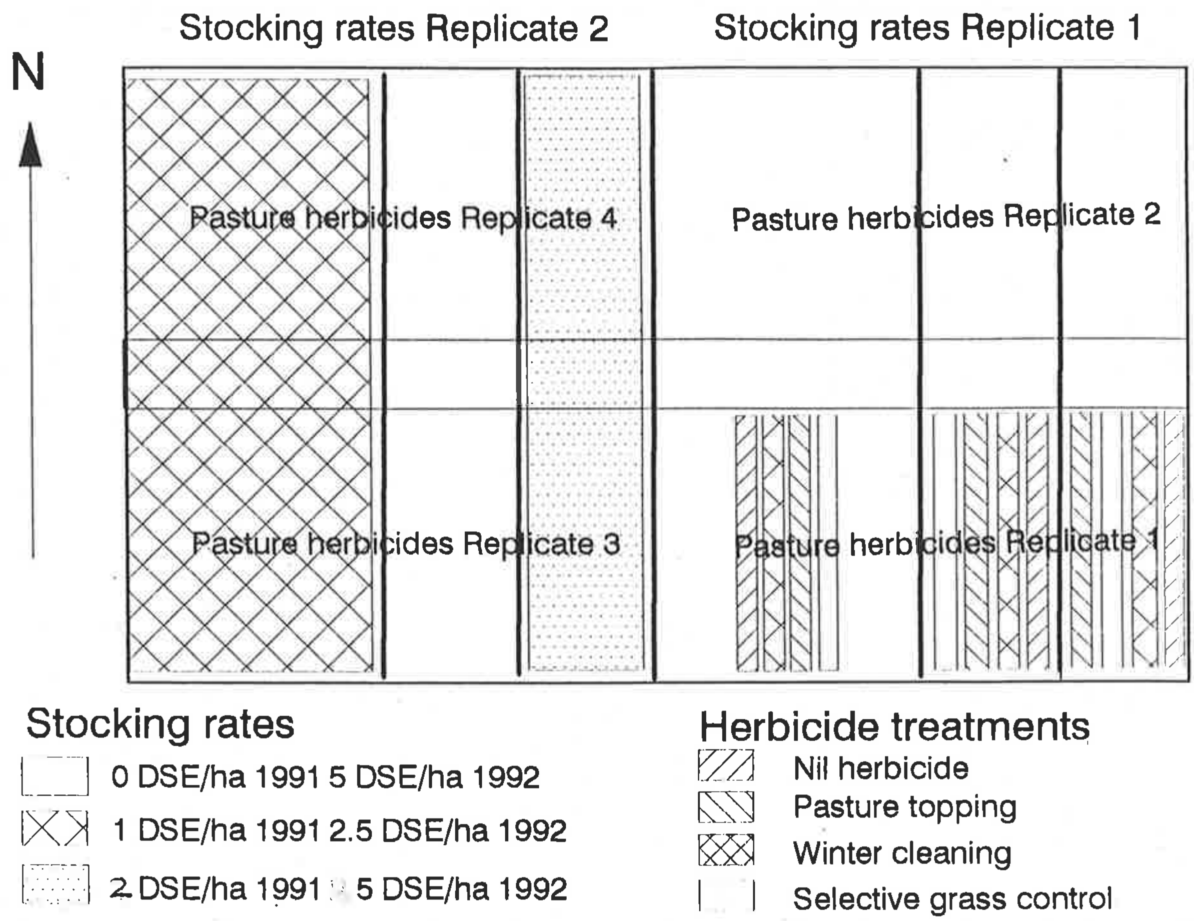
Figure 3.1. Temperature and rainfall data for the Mallee Research Station, Walpeup, for the period of the study and the long-term averages (1911-1993).

3.2.2. Experiment design and treatment details

The experiment area of 10 ha was established on a cereal stubble paddock. The area was fenced into 6 paddocks to carry 3 stocking rates replicated twice and randomised within each replicate. In 1991 the stocking rates for the 6 month period, July to December, were calculated as 0, 1 and 2 dry sheep equivalent/ha (hereafter DSE/ha). The 6 paddocks of 1.25, 2.5 and 1.25 ha (replicated twice) were stocked with 0, 10 and 10 wethers respectively for 1 week in each month July through to November. In 1992 10, 10 and 10 wethers were stocked on the 1.25, 2.5 and 1.25 ha paddocks for 140 days (all the months of June, August, October, November and December). This stocking rate was calculated as an annual rate of 5, 2.5 and 5 DSE/ha. In both years the DSE/ha calculations (45 kg = 1 DSE) incorporated the variations in body-weights. In June through to December in 1991 and during July 1992 when the sheep were not on the experiment they were stocked on companion paddocks at the same 1 and 2 DSE/ha in 1991 and 5, 2.5 and 5 DSE/ha in 1992 stocking rates.

The wethers used to graze the experiment in Year 1 (1991) were selected from a flock of 96 on the basis of having the lowest variation from the mean flock live and wool weights. The remaining 56 wethers in the flock were divided into 2 groups of 28 and grazed in separate companion paddocks at 1 and 2 DSE/ha, the same rate at which the experimental wethers were stocked on the experimental plots. These wethers were to provide replacement stock in the case of any deaths; however, none were required. Following their removal from the experiment in November 1991 all wethers were carried in one flock at the same stocking rate until the same sheep were returned to original paddocks in June, 1992. A further 20 wethers were selected from the replacement flock to stock previous 0 DSE/ha paddocks at 5 DSE/ha.

In 1991, within each stocking rate paddock, three herbicide treatments were imposed and a control included. Details of the split plot design are shown in Plan 3.1.



Plan 3.1. 10 hectare experimental site including three stocking rates replicated twice and four pasture herbicide treatments superimposed on the stocking rate treatments.

The pasture herbicide treatments were replicated twice in each stocking rate paddock, a total of four replicates. The plot sizes of the herbicide treatments were 12 m x 70 m, an area of 0.084 ha. Herbicide treatments were applied at commercially-registered rates and at the recommended times during the growing season. The products, rates and dates of application and the objectives of the treatments were:

1. Nil herbicide treatment.
2. Pasture topping with Roundup(R), Monsanto Australia, glyphosate 360 g/l a.i. @ 330 ml/ha at grass anthesis, on 26 September, to inhibit the seed set of annual grasses.
3. Winter cleaning with Roundup(R), Monsanto Australia, glyphosate 360 g/l a.i. @ 330 ml/ha, on 31 July, to retard the development of annual grasses.
4. Selective grass herbicide, Fusilade(R) I.C.I Australia, fluazifop 212 g/l a.i. @ 500 ml/ha on 1 August, to control annual grasses.

The herbicides were applied with a 10 m spray boom through Hardie 4110-12 nozzles at 3 kPa/cm^2 delivering 114 l/ha at the volume median diameter of 131 microns. Spraying was carried out on sunny days with wind speed estimated as less than 3 km, reducing the possibility of drift to companion plots. Fluazifop was applied on 2 m wide buffer zones between companion plots to lower probability of plots becoming infected by grass seeds carried from plot to plot during the summer by wind or sheep.

3.2.3. Pasture establishment and management

The pasture mixture of *Medicago truncatula* cv. Paraggio and *Medicago littoralis* cv. Harbinger AR was sown at 7 kg/ha to establish more than 100 medic plants per m^2. This is approximately 50% of the sown seed numbers which are shown in Table 3.1. Williams and Vallance (1982) recorded the establishment of only 32% of the total medic seed sown in an experiment at Walpeup in 1981.

Table 3.1. The number of seeds sown/m^2 of each pasture component.

Components	Botanical name	Sowing rates (kg/ha)	Seeds sown numbers/m^2
Paraggio barrel medic	*M. truncatula*	4	100
Harbinger AR strand medic	*M. littoralis*	3	116

The annual medic seed was certified with a minimum guaranteed germination of 80%.

The pasture seed was sown into a wheat (*Triticum aestivum* cv. Meering) stubble on 22 April 1991. The previous wheat crop was sown on 26 May 1990 at 50 kg/ha with 50 kg/ha of Pivot Double Super, containing 15.8% phosphorus, 4% sulphur and 2.5% zinc. The growing crop was treated with diclofopmethyl 375 g/l a.i. @ 800 ml/ha and bromoxynil 200 g/l a.i. @ 1000 ml/ha to control *L. rigidum* and broad-leaved weeds respectively. Grain yield of 2 t/ha was harvested in December 1990. The wheat stubble was slashed on 14 January 1991 to assist with cereal residue breakdown. Sheep grazed the stubble at approximately 2 DSE/ha following the grain harvest until the pasture was sown. Soil conditions when the pasture was sown were dry, and it was 40 days prior to the seasonal break on 2 June. Seed was dropped on the soil surface through a pasture small seed box attached to the rear of a conventional tyned drill (3.5 m wide). The seeder was tilted forward to allow the front row of tynes to disturb and lightly ridge the soil. A piece of weldmesh (4 m wide by 3 m in length, 150 mm x 100 mm mesh size, 12 mm mild steel rod) trailed behind the seeder to level the ridges and lightly cover the majority of seed. Excessive cereal straw which accumulated under the seeder was removed from the weldmesh outside the experimental area. After sowing, the site retained an even covering estimated at less than 1 t/ha of cereal residue.

Soil disturbance with a "Phoenix Prickle Chain" was carried out on 5 March 1992. The "Prickle Chain" is a rotating chain with spikes which are dragged rotating at a 45° angle across the soil surface. It is designed to cultivate soil to a depth of up to 25 mm; however, dry loam soils can restrict penetration. The experiment was prickle chained following 20 mm of rain in February, but prior to any significant rain in March, and the break in the season, following 43 mm of rain on 6 April.

3.2.4 Pasture measurements and data collection

To improve the plot coverage of pasture data collections each pasture herbicide treatment was split into five strata. Each pasture measurement collected was composed of one, two or four samples taken from within each stratum. The samples from each strata were bulked into single plot samples prior to any statistical analysis of results.

Seed reserves: To establish the amount of medic seed reserves present over the site, prior to the experiment commencing, 20 soil cores (40 cm^2) were taken to a depth of 5 cm at 15 sites selected in a grid pattern. Seed pods and naked seed were removed from some of the soil and vegetable matter through a 0.7 mm sieve. The pods were threshed by hand and the seed was separated from remaining soil and vegetable matter with trichloroethylene by the method described by Carter *et al.* (1977).

Emergence counts: Collected on the 1 - 3 July 1991, four weeks after 40 mm of rainfall during the first week in June. The number of annual medic, grass and broad-leaved weeds were counted in four 0.1 m^2 quadrats from each of the five strata within each pasture herbicide treatment plot, i.e. 20 counts of 0.1 m^2 collected from each plot, 160 counts were taken from each stocking rate treatment (see Plan 3.1 for clarification).

In 1992 medic, grass and broad-leaved weed populations within ten quadrats of 0.1 m^2 were counted on the 20 April (two from within each stratum) to determine the density of emerged plants following 43 mm of rainfall in early April. A second count was taken on 13 May to record a second plant emergence resulting from substantial rain on 8 and 9 May.

Herbage production: Following the seasonal break on 2 June 1991, four harvests to assess herbage production were taken over the growing season: at 6 weeks (18 July), 12 weeks (30 August), 16 weeks (28 September) and 19 weeks (14 October). Pasture availability and total pasture production were determined by the open and closed quadrat method of M^{c}Intyre (1946). For an example of this method see Carter and Day (1970). Five grazing exclosures measuring 1 m^2 were placed on each pasture herbicide treatment plot prior to the introduction of sheep. One exclosure (closed quadrat) was placed within each stratum within each plot. Each exclosure was relocated randomly within that stratum after each pasture sampling. One quadrat of 0.2 m^2 was cut to ground level from both the closed and companion open quadrat area. Herbage samples from both quadrat cuts were sorted into their three pasture components, viz. medic, grass or broad-leaved weeds, then dried and weighed.

For example the cumulative herbage production at 12 weeks was as follows:

Cumulative herbage production at 12 weeks = a + (b - c), where:

a = ungrazed herbage production at 6 weeks

b = ungrazed herbage production from 6 weeks to 12 weeks

c = grazed herbage production at 6 weeks.

The ungrazed (0 DSE/ha) plots were not caged and five 0.2 m^2 quadrats were sampled in each plot with the sequential herbage yields at each sampling occasion giving the cumulative yield. In 1992 herbage production samplings were taken at five times over the growing season commencing on 3 June, 4 weeks after the seasonal break. Four further samplings were taken at 9 weeks (6 July), 13 weeks (3 August), 18 weeks (7 September) and 24 weeks (19 October) after the seasonal break. The cumulative herbage production was calculated as for 1991. The sampling method was the same as described for 1991, five samples from each plot (one from each stratum) were bulked for data analysis.

Botanical composition: The comparative proportions of each pasture component were measured twice during both the 1991 and 1992 growing seasons by the Levy Point Quadrat sampling method (Levy and Madden 1933). These included the winter production period and the spring production period (16 August and 9 October in 1991 and 11 June and 7 September in 1992). A ten-pin frame was used at each of ten measurement sites per pasture herbicide treatment plot; two per stratum, 80 per stocking rate plot. Results were reported as the percentage overlapping cover of the medic and grass component. The broad-leaved weed component (which is not reported) makes up the remainder of the 100% pasture component.

Medic seed production: Sampling to assess medic seed production was carried out in December, in both 1991 and 1992. Samples were collected from one 0.2 m^2 quadrat in each stratum, making five samples in each pasture herbicide treatment plot. Medic seed pods were collected by hand, cleaned and sorted into *Medicago* species (*M.truncatula* and *M.littoralis*). The pods were then weighed, counted and threshed. The seed was cleaned, weighed and calculated as kg/ha.

Medic seed-pod burial: An experiment to study the effect of soil disturbance on medic seedling emergence and productivity of a regenerated medic pasture was established in 1992. It was sited in a medic-based pasture paddock and fenced to exclude livestock. The medic pasture was established at the same time by the same method and with the same medic cultivars and rates in 1991 as described in the main experiment. Medic seed yield in the establishment year (1991) was not measured but would have been similar to the 131 kg/ha average 1991 medic seed production for the main experiment.

Two treatments (plus and minus soil disturbance) were replicated four times with 20 m x 4 m plots. Soil disturbance with a "Phoenix Prickle Chain" was carried out on 5 March 1992 following 20 mm of rain in February, but prior to any significant rain in March, and the break in the season when 43 mm fell on 6 April. Emerging plant densities were counted on 13 May. Medic herbage production was measured on 10 July and 16 October 1992. Emergence counts and herbage samples were collected from 5 x 0.2 m^2 quadrats in each plot.

3.2.5 Livestock measurements

Sheep and wool weights: In 1991 the body weight of all the wethers was recorded approximately every 28 days from July to November. The weighing coincided with their removal from the experiment after 1 week grazing each month. They were stocked on companion plots at a similar stocking rate for the remaining three weeks of each month then all sheep were run together from November 1991 to June 1992. In 1992 body weights were recorded approximately every 28 days commencing immediately prior to their return to the experiment on 3 June. They were retained on plots throughout all of June and August and from October through to the end of January. During July and September they were run on companion paddocks at their relative stocking rates but from January they were run in the same flock. Wool weights were recorded at shearing in April in both 1992 and 1993.

3.2.6. Cereal establishment and management

The pasture stubble was initially cultivated with a scarifier on 2 February 1993 following 40 mm of rain over the period 26 January to 2 February. A second cultivation was completed on 14 June 1993. Plots were grazed for short periods during March and April 1993 to control *Chondrilla juncea* (skeleton weed). Wheat (*Triticum aestivum* cv. Meering) was sown on 1 July 1993 into a moist seed-bed following 5 mm of rain. It was sown at 50 kg/ha with 50 kg/ha of Pivot Double Super, containing 15.8% phosphorus, 4% sulphur and 2.5% zinc. Rain measuring 24 mm fell on the 7 and 8 July, initiating a germination of annual grasses and broad-leaved weeds. On 12 July the site was sprayed with 1 l/ha of Sprayseed(R) (125 g/l paraquat and 75 g/l diquat) to control weeds prior to the emergence of the wheat. The growing crop was treated with diclofopmethyl 375 g/l a.i. @ 800 ml/ha and bromoxynil 200 gm/L a.i. @ 1000 ml/ha to control *L. rigidum* and broad-leaved weeds on 12 August 1993.

3.2.7. Cereal measurements and data collection

(i) *Plant establishment* counts were made on the 6 August 1993. The number of wheat, annual ryegrass, barley grass, brome grass and broad-leaved weeds were counted in two 0.2 m^2 quadrats from each of the five strata within each pasture herbicide treatment plot, i.e. 10 counts of 0.2 m^2 collected from each plot, 80 counts were taken from each stocking rate treatment (see Plan 3.1 for clarification).

(ii) *Cereal disease* analysis for the percentage of seminal roots infected with *Heterodera avenae* (Cereal cyst nematode) and *Gaeumannomyces graminis* (Take-all) was carried out by D. K. Roget, C.S.I.R.O. Division of Soils, Adelaide. Twenty wheat plants from each herbicide treatment were randomly collected on the 19 September 1993, 160 plants for each stocking rate, refrigerated and transported to Adelaide for analysis.

(iii) *Grain yield and protein* data were collected at the harvest of the experiment on 29 and 30 December 1993. Plots were harvested with a 2m wide self-propelled Kingaroy plot harvester. Two 2m strips were harvested from each 10 m wide herbicide treatment plot (harvested area = 4 m x 70 m per plot) and weighed. Sub-samples were collected from the harvested sample and sent to the Cereal Chemist, Victorian Institute for Dryland Agriculture to measure grain protein by Near Infra-red Reflectance.

3.2.8. Data analysis

Analysis of variance were conducted at each time of measurement on all data parameters using Genstat 5 Release 1.3 (DOS/386) Implemented by Marketing Risk Management Copyright 1988, Lawes Agricultural Trust (Rothamsted Experimental Station). The blocking structure was complex, and this was taken into account in the analysis. Since there were only six main plots for stocking rate, error degrees of freedom were low for testing this term. To conserve as many degrees of freedom as possible, the sum of squares for stocking rate blocks are pooled with the corresponding error term, giving three degrees of freedom, instead of two. The blocking structure was then pasture plots within pasture blocks (consisting of four plots) within stocking rate main plots. To analyse measurements covering periods during the studies this blocking structure was further split for time.

Plate 3.1 Method of pasture establishment.

Plate 3.2 Establishing the pasture in April 1991.

Plate 3.3 A view of experiment and companion paddocks.

Plate 3.4 Low stocking rate treatment with large component of annual grass.

Plate 3.5 Herbicide application to experiment in 1991.

Plate 3.6 Wethers grazing experiment.

Plate 3.7 Measuring sheep live weights.

Plate 3.8 Method of sampling cumulative herbage production (1991).

Plate 3.9 Pasture growth in 1991.

Plate 3.10 Pasture growth in 1992: also showing grazing exclosure cage.

Plate 3.11 Levy point quadrat sampling pasture components.

Plate 3.12 Collecting medic pods from $0.2m^2$ quadrat.

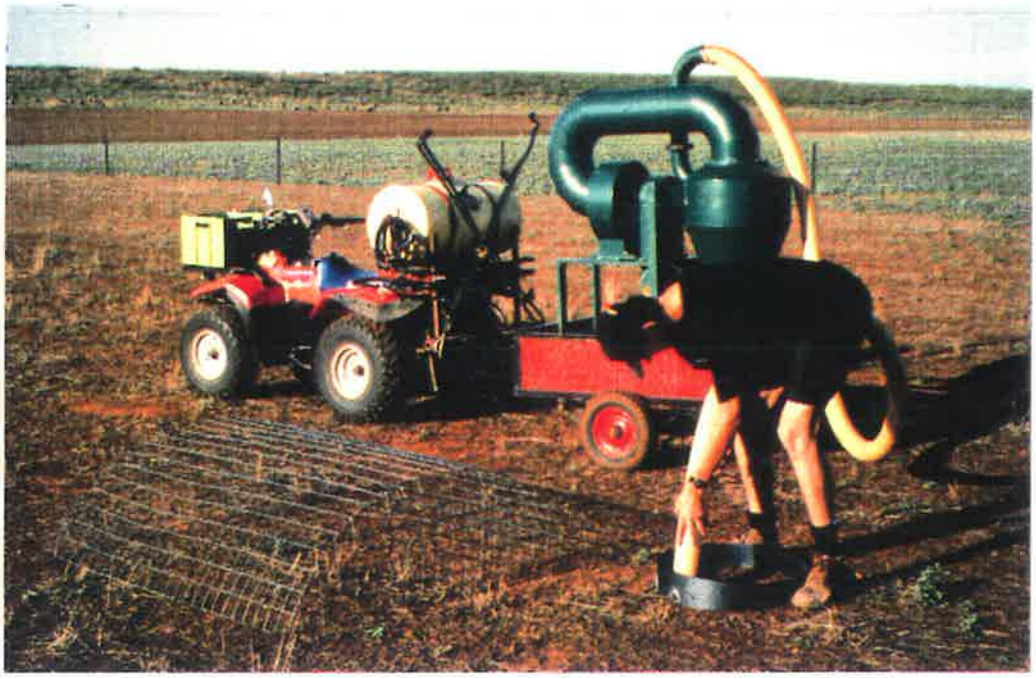


Plate 3.13 Sampling medic pods from grazed and livestock exclosure areas.

Plate 3.14 Pasture residue (>3 tDM/ha) in December 1992.

Plate 3.15 Separating medic seedpods through sieves.

Plate 3.16 Threshing medic pod to obtain seed yield.

3.3. Results

3.3.1. Volunteer annual medic seed reserves

On 21 March 1991 there were an average of 188 ($\pm$ s.e.183) seeds per m^2 of *Medicago* spp.. These seeds comprised approximately equal proportions of *M.truncatula* cv. Jemalong, *M.littoralis* cv. Harbinger and *M.minima* seeds. Species were identified by seed pods: however, seeds free from pods were not identified which did not allow exact figures for species to be reported. The percentages of viable seed were not measured due to the mechanical threshing of the seed pods.

3.3.2. Emergence 1991

Table 3.2 shows the densities of the sown and volunteer plant species counted on 1 to 3 July, 1991, four weeks after the seasonal break on 2 June. The emergence counts were made before the commencement of grazing or the application of herbicides.

Table 3.2 Emergence of medic, broad-leaved weeds and three grass species (data shows plants/m^2 in July 1991).

Stocking rate	Medic	Broad-leaved weeds	Barley grass	Rye grass	Volunteer cereal
0 dse/ha	145	12	14	43	18
1 dse/ha	128	10	44	69	26
2 dse/ha	119	15	29	32	23
Signif. of diff.	ns	ns	ns	ns	ns
Herbicide treatment					
Control	133	12	31	50	19
Pasture topping	130	14	26	42	25
Winter Cleaning	133	10	24	55	25
Selective grass control	127	12	35	45	22
l.s.d.(P=0.05)	ns	3	ns	ns	5

The differences in the plant densities of the pasture components were the broad-leaved weeds and volunteer cereals when data was analysed within the herbicide treatments.

3.3.3. Herbage production 1991

The cumulative herbage production of the medic, grass and total (the sum of medic, grass and broad-leaved weeds) produced over the growing season is presented in Figure 3.2. Data points represent four sampling times, at 6, 12, 16 and 19 weeks from the seasonal break on 2 June, 1991. The cumulative medic and total herbage increased at each sampling time. However, the cumulative grass herbage did not increase after 16 weeks.

The highest stocking rate (2 DSE/ha) reduced total herbage production in comparison to 1 DSE/ha at 12 and 16 weeks but production was similar at 19 weeks (Fig. 3.3). No grazing induced a lower total yield at 16 weeks in comparison to 1 DSE/ha. Grass production was reduced by 2 DSE/ha at 12 weeks and 2 and 0 DSE/ha at 16 and 19 weeks in comparison to 1 DSE/ha.

Selective grass control increased medic and reduced grass production when compared to all other treatments at 16 and 19 weeks; however, total herbage production was less than the Nil treatment at 16 weeks (Fig. 3.4). The Winter cleaning treatment produced less grass and total herbage than Nil at the 12, 16 and 19 week samplings and less medic after 16 weeks.

Medic herbage production was higher following the Selective grass control treatment than the Winter cleaning treatment at 16 weeks at all stocking rates (Fig. 3.5). At 2 DSE/ha, 19 weeks cumulative medic production following Selective grass control was higher than all other herbicide treatments. Also at 19 weeks 1 DSE/ha following Selective grass control produced more medic herbage than the Nil herbicide treatment.

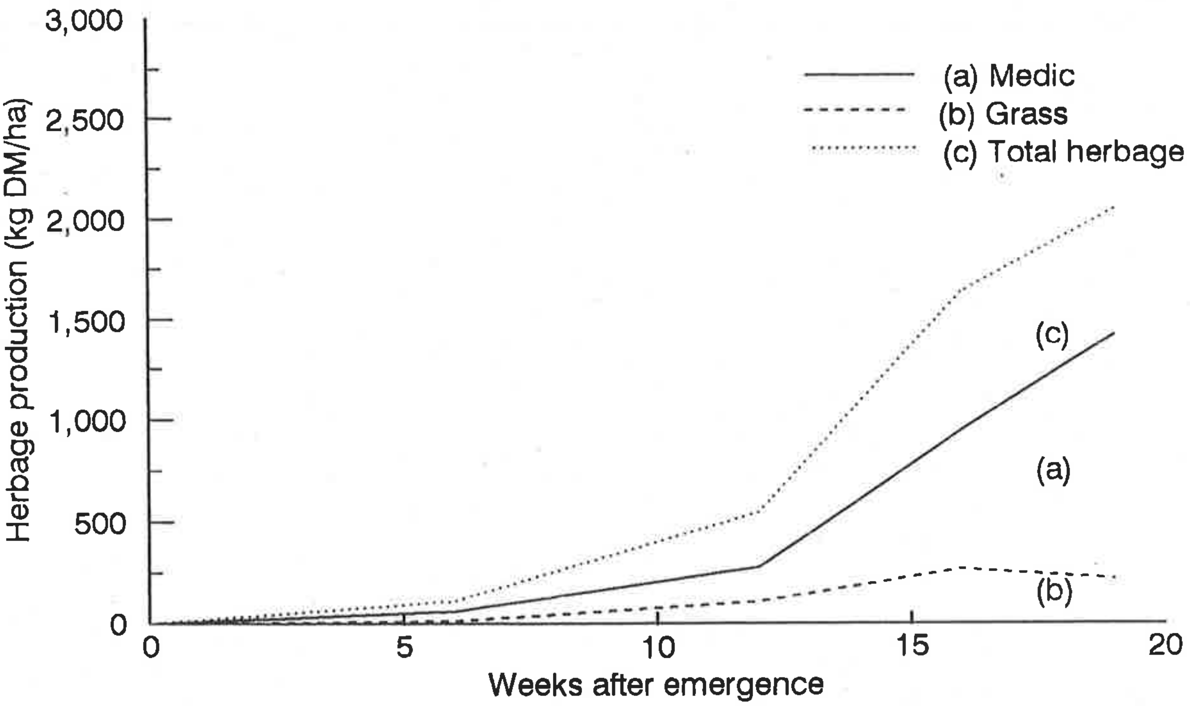


Figure 3.2. Cumulative medic, grass and total herbage at 6, 12, 16 and 19 weeks from 2 June, 1991 and presented as the means of 3 stocking rates and 4 herbicide treatments.

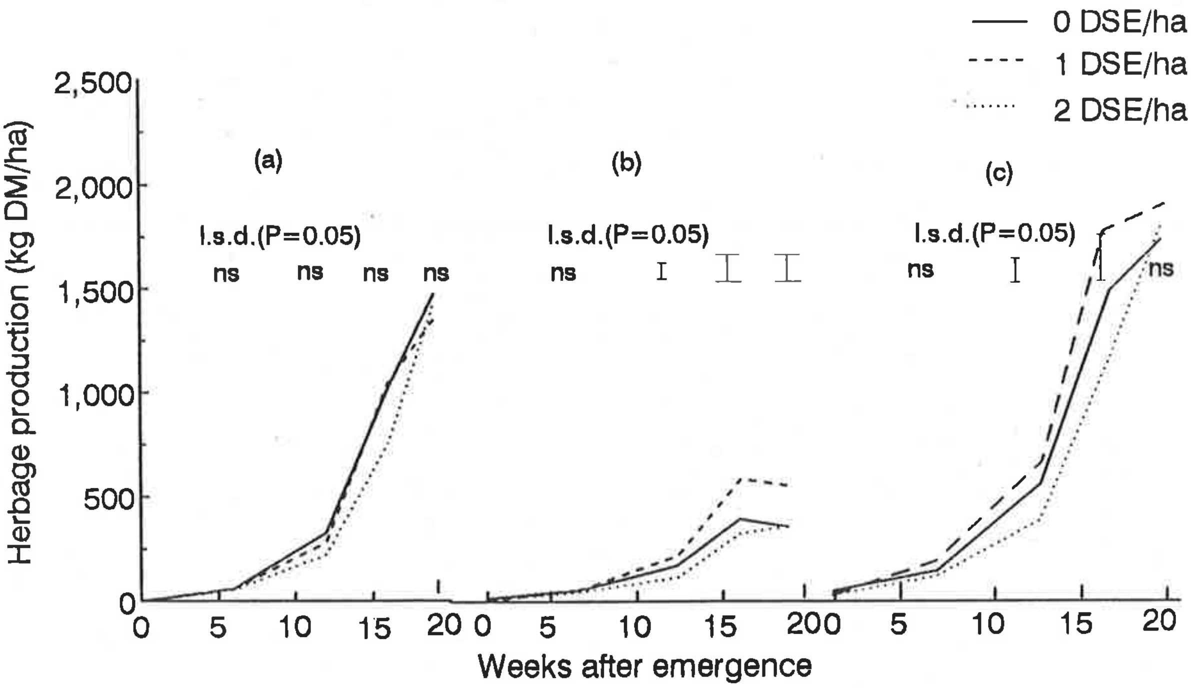


Figure 3.3. Cumulative medic (a), grass (b) and total (c) herbage production at 6,12,16 and 19 weeks from 2 June, 1991 in response to three stocking rates.

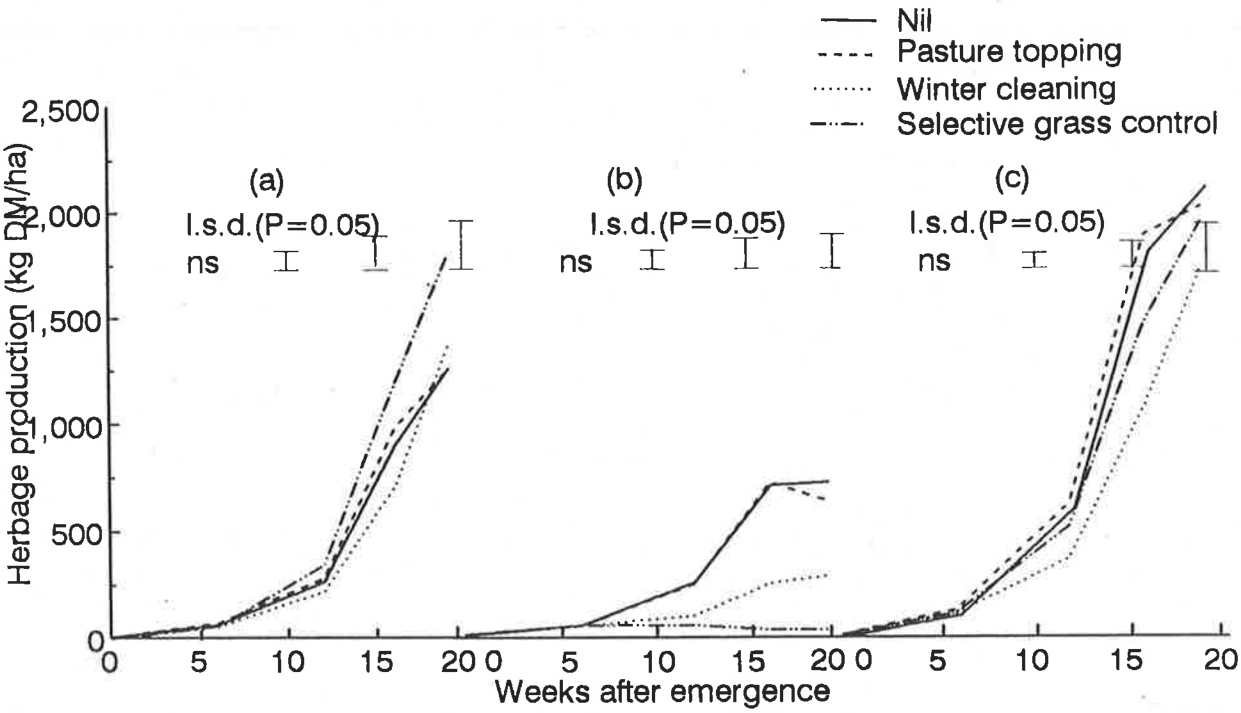


Figure 3.4. Cumulative medic (a), grass (b), and total (c) herbage production at 6, 12, 16 and 19 weeks from 2 June in response to four herbicide treatments.

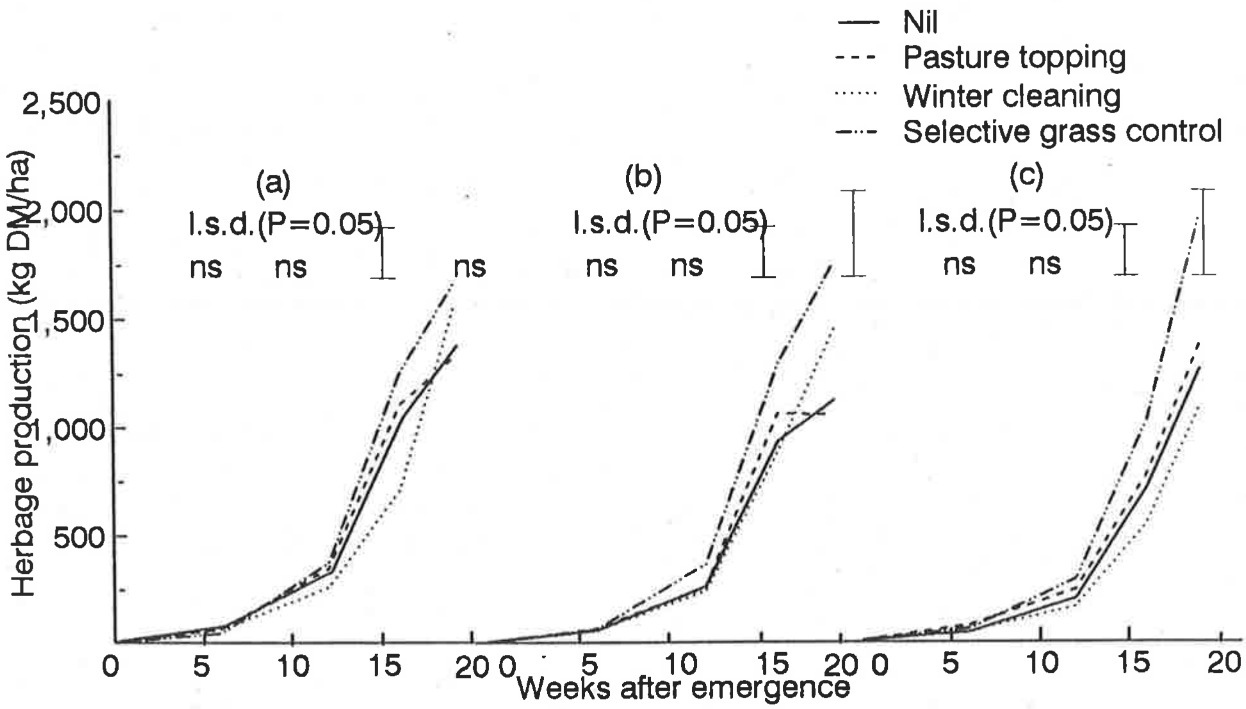


Figure 3.5. Cumulative medic herbage production at 6, 12, 16 and 19 weeks from 2 June with herbicide treatments imposed interacting with 0 (a), 1 (b), and 2 (c) DSE/ha stocking rates.

3.3.4. Botanical composition 1991

The percentages of medic and grass in the total pasture components are presented in Table 3.3. They show the interaction effects of the imposed herbicide and stocking rate treatments at two times during the growing period, 16 August and 9 October. These dates are associated with the commencement of the flowering period, 16 August, and the completion of the growing season, 9 October, in 1991.

Table 3.3. The percentage of medic and grass measured at two times, 16 August and 9 October, 1991

Stocking rate	Herbicide treatment	Medic (% cover)		Grass (% cover)	
		16 Aug.	9 Oct.	16 Aug.	9 Oct.
0 DSE/ha	Nil	40	54	47	30
	Pasture topping	43	53	39	30
	Winter cleaning	44	62	38	23
	Selective grass control	51	75	37	0
1 DSE/ha	Nil	30	46	54	36
	Pasture topping	34	49	53	36
	Winter cleaning	36	57	55	26
	Selective grass control	43	80	45	0
2 DSE/ha	Nil	46	54	46	28
	Pasture topping	45	57	48	31
	Winter cleaning	46	63	48	20
	Selective grass control	48	76	41	0
l.s.d.(P=0.05) Sr x Herb*		ns	14	ns	13
l.s.d.(P=0.05) within each Sr		ns	12	ns	12

* Sr (Stocking rate) x Herb (Herbicide treatment).

The effect of stocking rate did not alter the percentages of medic or grass (P=0.05) at either sampling time, although trends suggested higher medic and lower grass percentages at 0 and 2 DSE/ha compared to 1 DSE/ha. The Selective grass control treatment increased the medic and reduced the grass component percentages in comparison to all other herbicide treatments.

3.3.5. Medic seed production 1991

The interrelationship of stocking rates and herbicide treatments on medic seed yields are presented in Figure 3.6. The Pasture topping treatment had lower seed yields than all other treatments at all stocking rates. Seed yields as a result of Selective grass control were higher than all other treatments at all three stocking rates.

3.3.6. Sheep and wool weights 1991

Figure 3.7 presents sheep live weights from 14 June 1991 until 9 January 1992. Sheep live weights were greater at 1 DSE/ha during July and September in response to the greater quantity of feed available at the lower stocking rate (refer Fig. 3.3(c)).

Table 3.4. Wool production per head (kg) and per hectare (kg/ha) at two stocking rates

	Wool weight per head	Wool weight per hectare
1 DSE/ha	6.3	6.3
2 DSE/ha	6.1	12.2
l.s.d.(P=0.05)	ns	3.2

There was no difference in wool weight per head between the two treatments which resulted in a doubling of wool production per hectare (Table 3.4). As the sheep were taken off the experiment in November and stocked at the same rate until they were shorn in April this may have had some impact on the result.

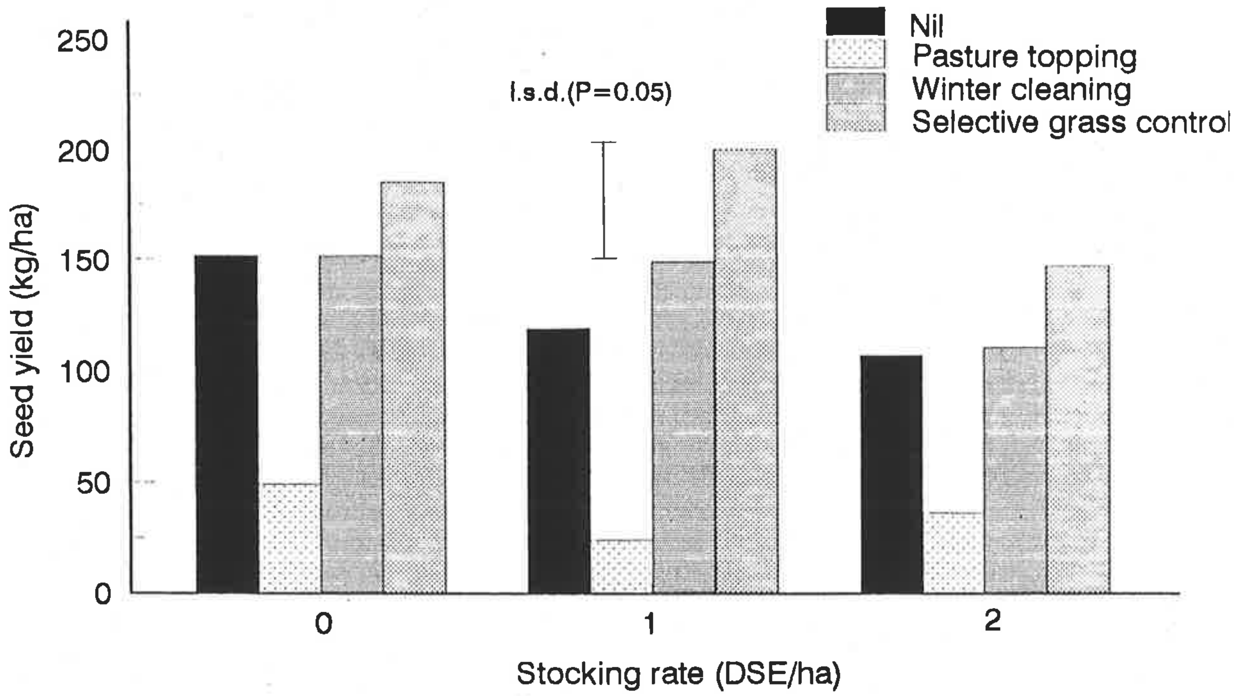


Figure 3.6. Medic seed yield (kg/ha) in 1991 in response to three stocking rates and four herbicide treatments.

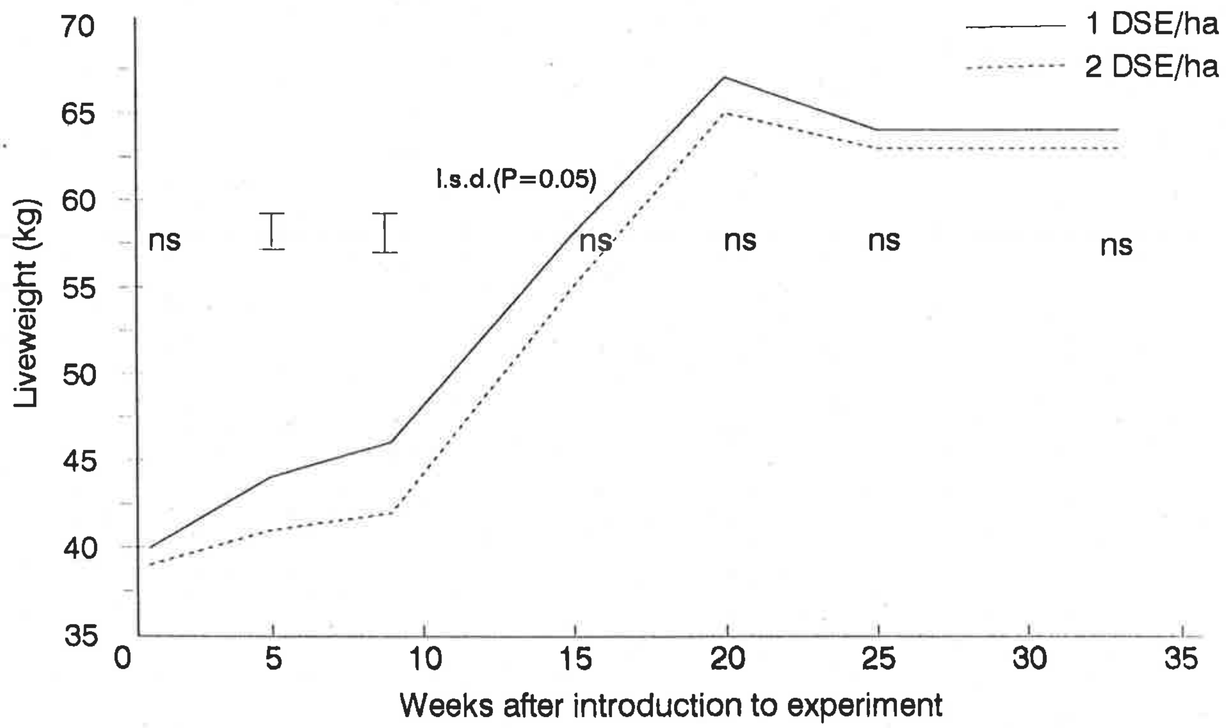


Figure 3.7. Sheep weights (kg) from 14 June 1991 to 9 January 1992 at two stocking rates.

3.3.7 Emergence 1992

The densities of medic and annual grasses were counted on 20 April soon after emergence. Following a further emergence a second count was taken on 13 May, 1992 and the two sets of emergence data were totalled and presented in Figure 3.8.

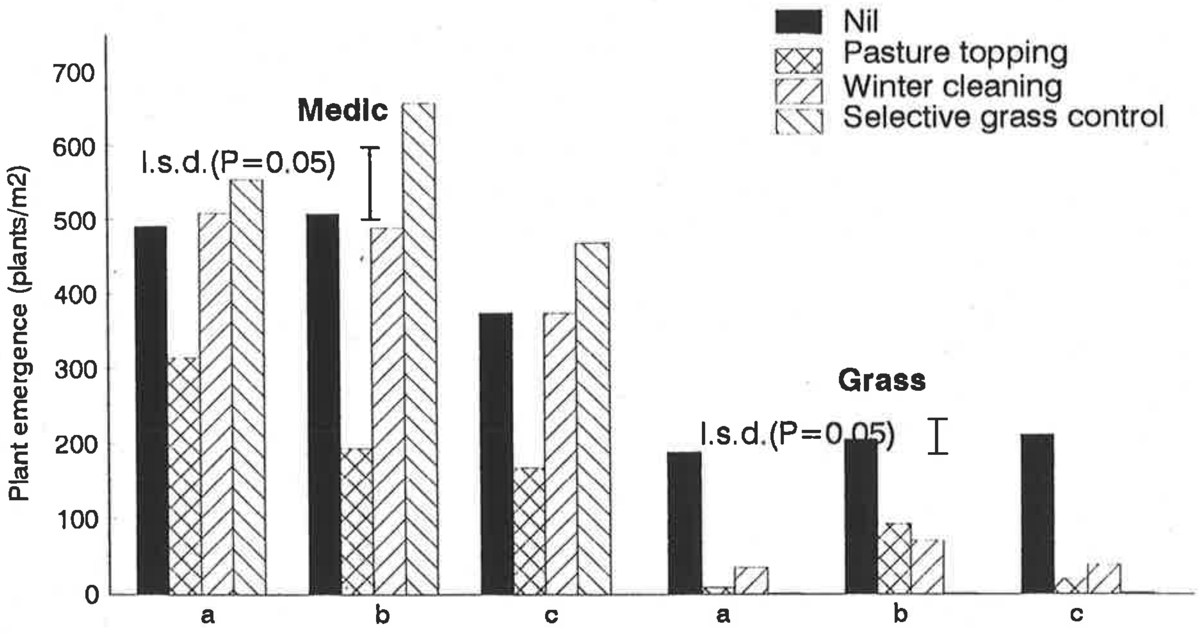


Figure 3.8. Plant densities of medic and grass which emerged in 1992 in response to 0 (a), 1 (b) and 2 (c) DSE/ha stocking rates and the interrelationships with four pasture herbicide treatments also applied in 1991.

The densities of medic which emerged in response to herbicide and stocking rate treatments in 1991 reflected the seed yields presented in Figure 3.6. Pasture topping and the 2 DSE/ha stocking rate reduced 1991 seed yields and subsequent emerging medic plant densities in 1992 (Fig. 3.8). The density of annual grasses which emerged were reduced by the 1991 Pasture topping and Winter cleaning treatments compared to the Nil treatment. Selective grass control eliminated the grasses. The two glyphosate herbicide treatments (Pasture topping and Winter cleaning) interacting with the 0 and 2 DSE/ha stocking rate treatments reduced the plant densities of grass in comparison to the 1 DSE/ha treatment.

3.3.8 Soil disturbance 1992

Table 3.5. Plant emergence, winter and spring herbage production of annual medic in response to soil disturbance with a 'prickle chain'

	Emergence (plants/m^2)	Winter herbage production (kg DM/ha)	Spring herbage production (kg DM/ha)
	13.5.92	10.7.92	16.10.92
Control	389	448	2085
Prickle Chain	619	591	2392
l.s.d.(P=0.05)	92	74	ns

The soil disturbance treatment increased the plant emergence and winter herbage production of the medic (Table 3.5). Medic spring herbage production was similar in both treatments.

3.3.9. Herbage production 1992

The cumulative herbage production of the the medic, grass and total (the sum of medic, grass and broad-leaved weeds) produced over the growing season is presented in Figure 3.9. The medic production increased at a greater rate than the grass after the 18 week sampling.

The total cumulative herbage production was increased by the high stocking rate (2 DSE/ha in 1991 and 5 DSE/ha in 1992) in comparison to the low stocking rate (1 DSE/ha in 1991 and 2.5 DSE/ha in 1992) (Fig.3.10).

Comparing the 1991 applied herbicide treatments (Fig. 3.11); Selective grass control showed higher medic, lower grass and similar or higher total herbage production in compared to all other treatments. Compared to the Nil herbicide treatment, Winter cleaning reduced the grass and increased the medic and total production and Pasture topping increased total production after the 9 week sampling. The total cumulative herbage production includes broad-leaved weeds as well as the medic and grass components in Figures 3.9, 3.10 and 3.11.

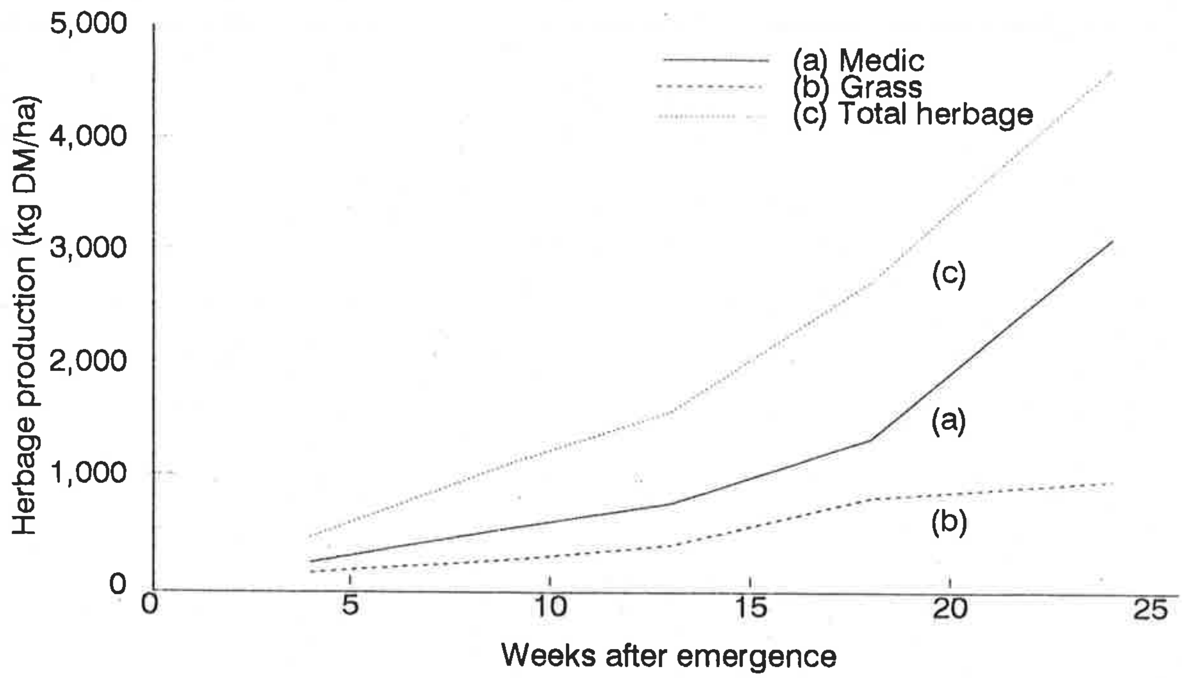


Figure 3.9. Cumulative medic, grass and total herbage at 4, 9, 13, 18 and 24 weeks from 8 May, 1992 and presented as the means of 3 stocking rates and 4 herbicide treatments.

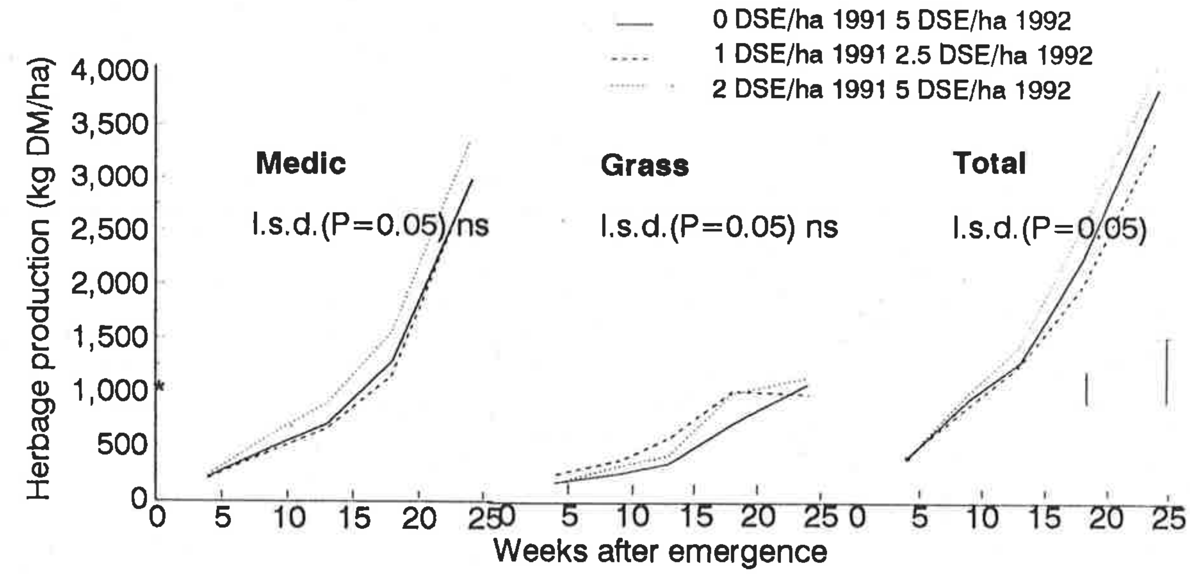


Figure 3.10. Cumulative medic, grass and total herbage production at 4,9,13,18 and 24 weeks from 8 May, 1992 in response to three stocking rates.

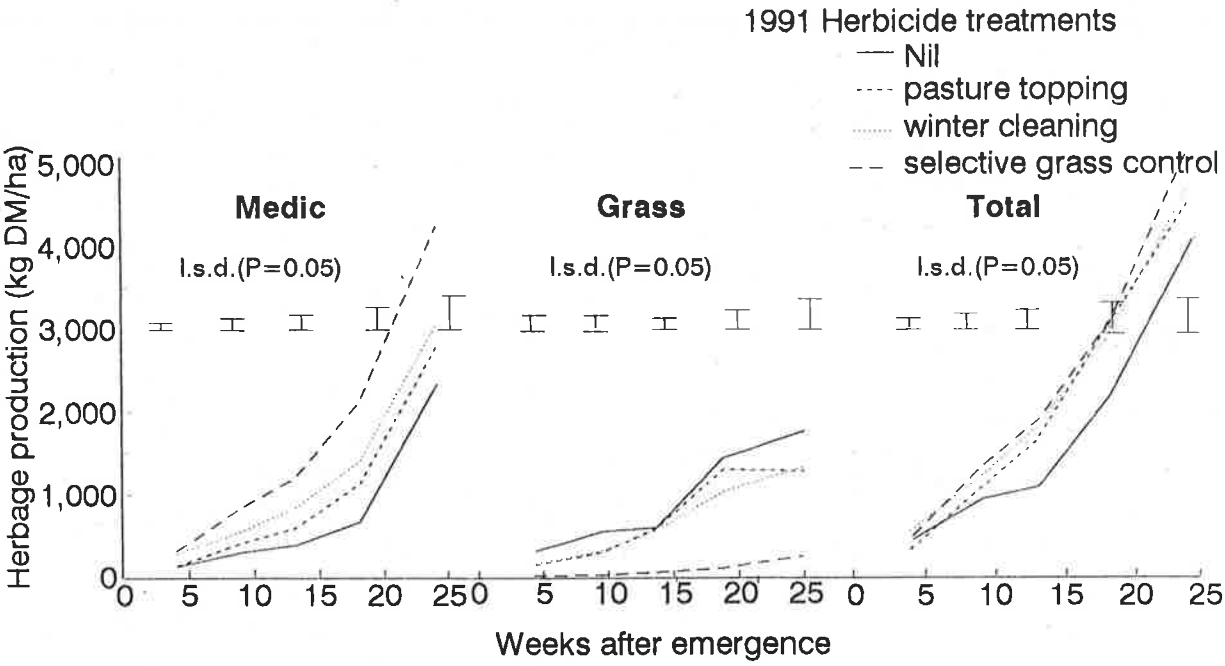


Figure 3.11. Cumulative medic, grass and total herbage production at 4, 9, 13, 18 and 24 weeks from 8 May, 1992 in response to four herbicide treatments applied in 1991.

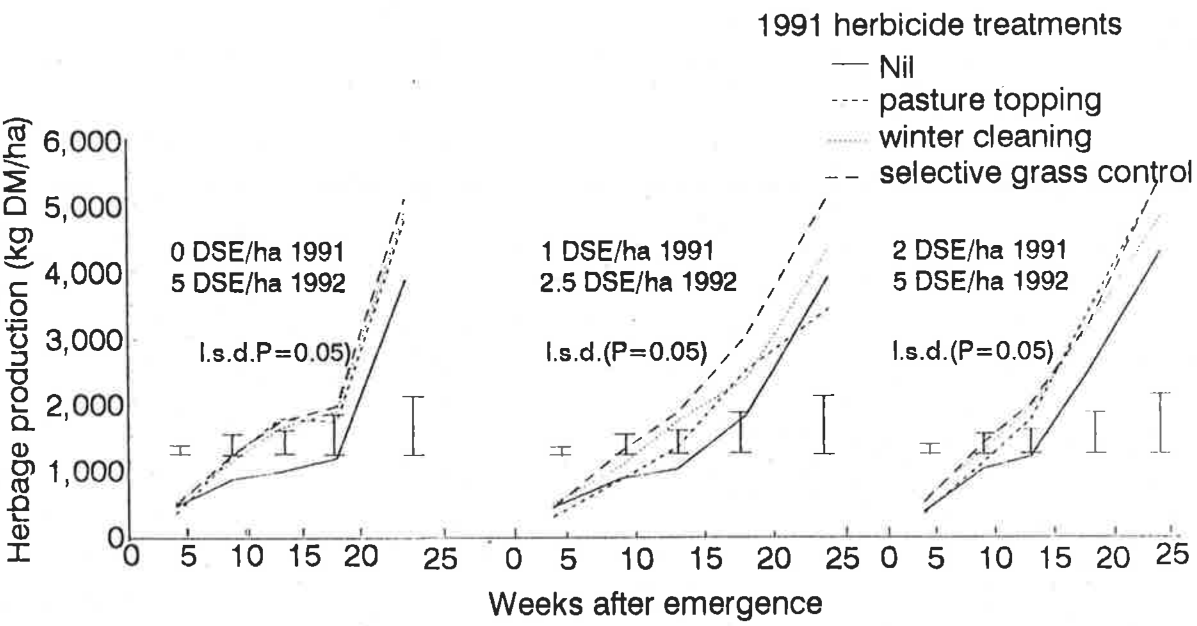


Figure 3.12. Cumulative medic production at 4, 9, 13, 18 and 24 weeks from 8 May, 1992 in response to herbicide treatments in 1991 interacting with stocking rates applied in 1991 and 1992.

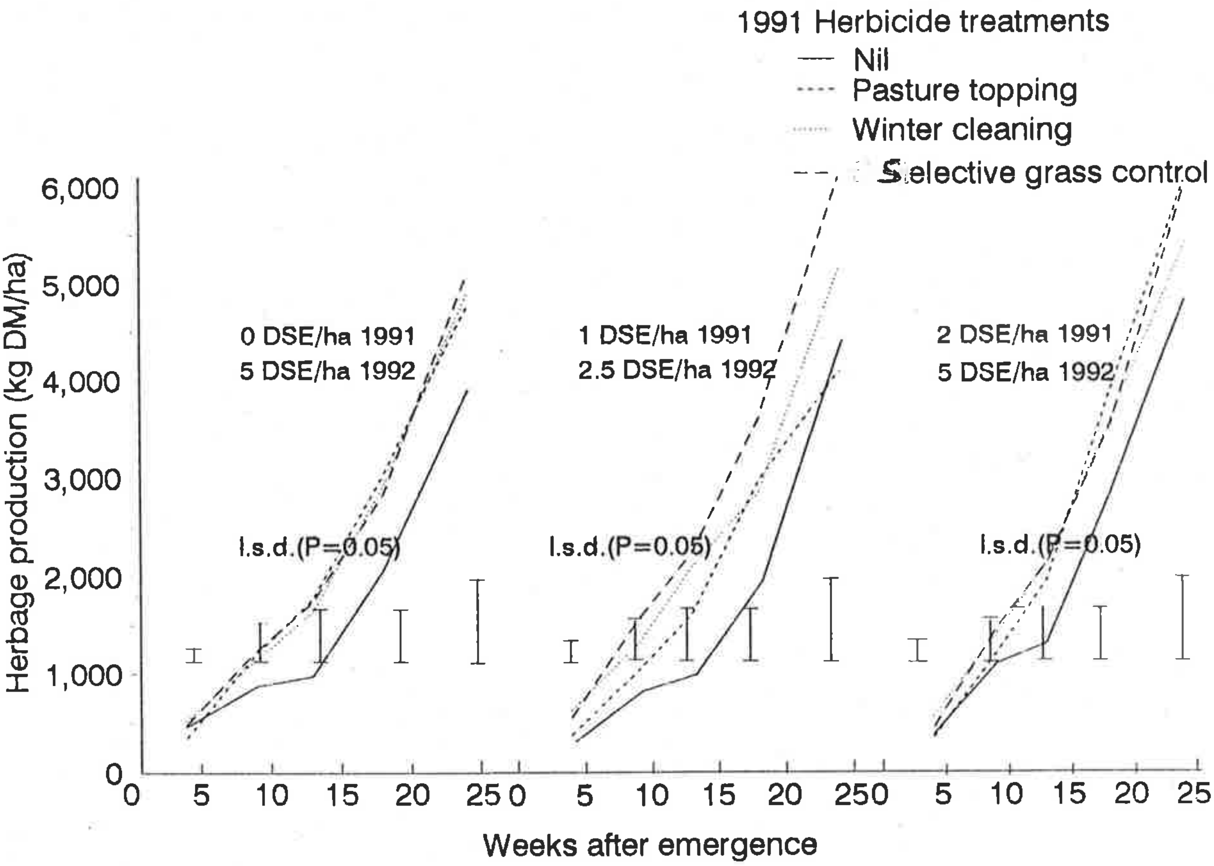


Figure 3.13. Total cumulative herbage production grazed at 5 DSE/ha, 2.5 DSE/ha and 5 DSE/ha at five sampling times 4, 9, 13, 18 and 24 weeks from 8 May 1992. Interrelationships between current stocking rates and the previously-imposed three stocking rates and four herbicide treatments from 1991 are included.

Compared to the Nil herbicide treatment Figures 3.12 and 3.13 show that the Selective grass control treatment, applied in 1991, increased the cumulative medic (Fig.3.12) and total (Fig.3.13) herbage production at all stocking rates. Pasture topping and Winter cleaning either increased or produced similar medic and total herbage to Nil. Medic production was generally increased by the two years high stocking rate (2 and 5 DSE/ha). Total herbage production was generally reduced by the O and 5 DSE/ha in 1991 and 1992 respectively.

3.3.10. Botanical composition 1992

The percentages of medic and grass of the total pasture components are presented in Table 3.6. They show the interaction effects of the imposed herbicide and stocking rate treatments sampled at two times during the growing season with a Levy Point Quadrat. The percentage of broad-leaved weeds, are not reported, but they make up the remainder of the 100% total.

Table 3.6. The percentage of medic and grass sampled at two times in 1992

Stocking rate	Herbicide treatment	Medic (% ground cover)		Grass (% ground cover)	
1992	1991	12 June	7 Sept.	12 June	7 Sept.
5 DSE/ha	Nil	30	38	57	55
	Pasture topping	35	43	28	37
	Winter cleaning	45	54	33	40
	Selective grass control	62	73	4	7
2.5 DSE/ha	Nil	28	36	65	56
	Pasture topping	19	33	64	57
	Winter cleaning	38	49	46	41
	Selective grass control	64	75	8	9
5 DSE/ha	Nil	24	38	66	53
	Pasture topping	30	42	42	40
	Winter cleaning	48	53	32	29
	Selective grass control	60	72	5	6
l.s.d.(P=0.05) Sr x Herb		17	16	16	17
l.s.d.(P=0.05) within each Sr		9	11	12	12

On 12 June both stocking rate treatments of 5 DSE/ha had a lower component of grass compared to 2.5 DSE/ha when herbicide was applied; there was no effect of stocking rate on the component of grass or medic when no herbicide was applied. Selective grass control applied in 1991 maintained the grass percentage below 10% and the medic percentage above all other pasture treatments at both sampling times: along with a higher percentage of broad-leaved weeds. Between 12 June and 7 September the percentage of medic had generally increased, grass had remained constant and the broad-leaved weeds reduced.

3.3.11. Medic seed production 1992

In comparison to the the Nil herbicide treatment the medic seed yields were increased in response to Selective grass control at all stocking rates and Winter cleaning after the two years of high stocking rates (2 and 5 DSE/ha in 1991 and 1992 respectively, Fig 3.14). Seed yields and rain were higher in 1992 than 1991 (Figs.3.6 and 3.1 respectively).

3.3.12. Sheep and wool weights 1992

The wethers grazed at 2.5 DSE/ha in 1992 had a higher mean live-weight after 4 and 8 weeks in comparison to the other two stocking rates (Fig.3.15). This difference was maintained over the 0 DSE in 1991, 5 DSE/ha in 1992 stocking rate at every weighing time. However, the 2 DSE/ha in 1991, 5 DSE/ha in 1992 stocking rate maintained similar weights to the lower stocking rate until the final weighing after 40 weeks (2 February). The 2 and 5 DSE/ha stocking rate had higher mean live-weights after 16 weeks (3 September) in comparison to the 0 and 5 DSE/ha stocking rate treatment.

Table 3.7. Wool production per head (kg) and per hectare (kg/ha) at three stocking rates

DSE/ha		Wool weight	
1991	1992	(kg/head)	(kg/ha)
0	5	6.8	34
1	2.5	7.4	18.5
2	5	7.3	36.5
l.s.d.(P=0.05)		0.4	5

The wool production (kg/head) measured from wethers stocked at both the high and the low rates for the two year period were similar (Table 3.7). However, the wool production (kg/head) from the two year nil and high stocking rate treatment was lower. The wool production per hectare was obviously almost doubled as a result of doubling the stocking rate.

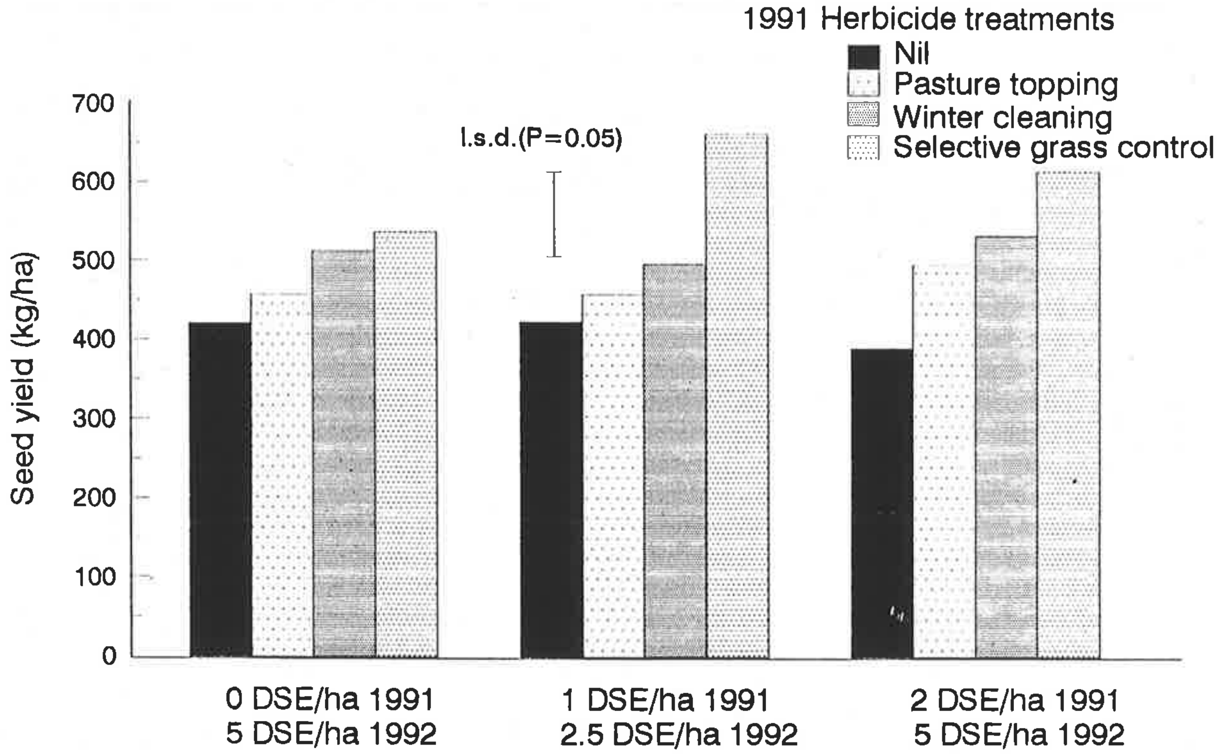


Figure 3.14. Medic seed yield (kg/ha) in response to two stocking rates in 1992 and three stocking rates and four herbicide treatments imposed in 1991.

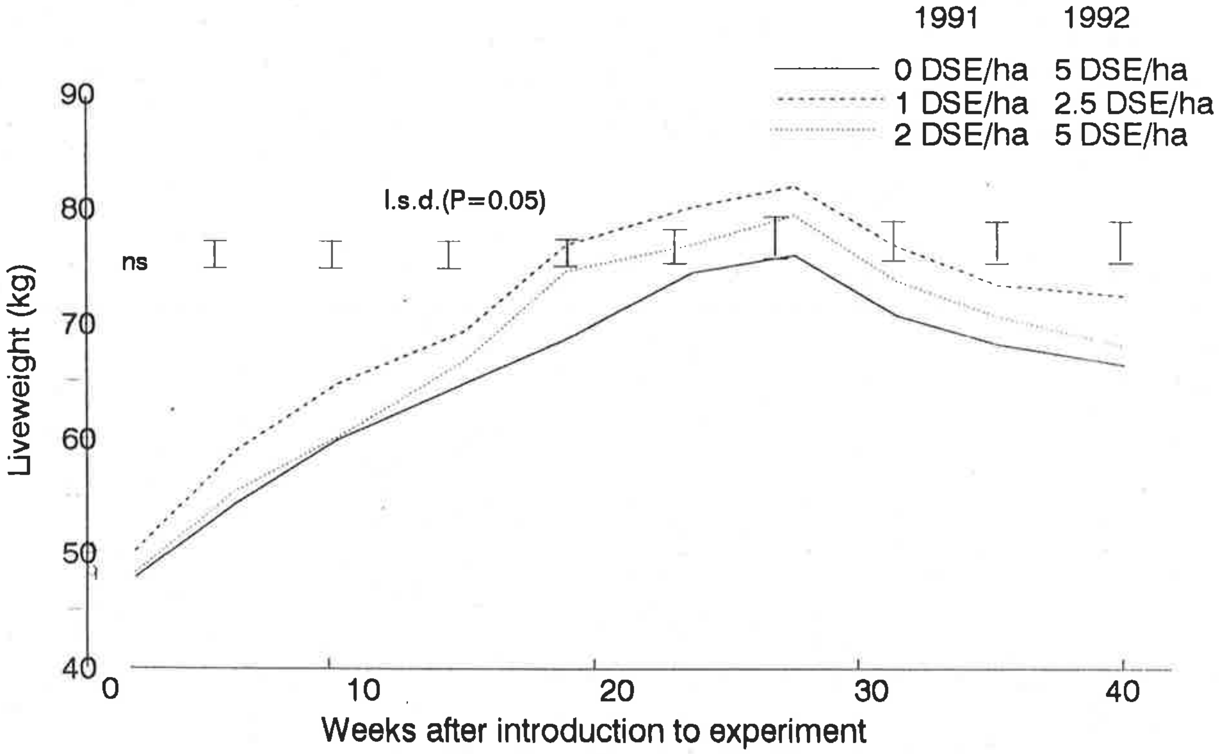


Figure 3.15 Sheep weights (kg) from 3 June 1992 to 30 January 1993 at three stocking rates.

3.3.13 Wheat production 1993

(i) *Plant establishment* of the sown wheat (*Triticum aestivum* cv. Meering) and two groups of volunteer annual grasses, Group 1 *Hordeum leporinum* (Barley grass) and *Bromus diandrus* (Brome grass) and Group 2 *Lolium rigidum* (Annual ryegrass) were counted on 3 and 6 August 1993. The effect of previously-applied herbicide treatments and stocking rates on plant establishment densities are presented in Table 3.8.

Table 3.8. Establishment densities (plants/m^2) of wheat and volunteer annual grasses in 1993 cereal phase of rotation

Stocking rate (DSE/ha) 1991	1992	Herbicide treatment 1991	Wheat	Barley grass Brome grass (plants/m^2)	Ryegrass	Total grass
		Nil	74	81	136	217
		Pasture topping	67	64	68	132
0	5	Winter cleaning	73	28	169	197
		Sel. grass cont.	79	5	12	17
		Nil	73	118	230	348
		Pasture topping	76	216	145	361
1	2·5	Winter cleaning	70	132	241	373
		Sel. grass cont.	86	13	67	80
		Nil	66	155	59	214
		Pasture topping	74	119	41	160
2	5	Winter cleaning	69	81	47	128
		Sel. grass cont.	74	12	7	19
l.s.d.(P=0.05) Sr x Herb			11	56	103	109
l.s.d.(P=0.05) within each Sr			11	62	75	93

Densities of wheat plants were generally higher and volunteer annual grasses lower in response to the 1991 Selective grass control treatment than all other treatments (Table 3.8). The two high stocking rate treatments imposed in 1992 (5 DSE/ha) reduced the grass numbers in the Pasture topping and Winter cleaning herbicide treatments compared to Nil.

(ii) *Cereal diseases* In 1993 *Heterodera avenae* (Cereal cyst nematode) and *Gaeumannomyces graminis* (Take-all) levels were measured on wheat roots. There were no measurable levels of Cereal cyst nematode. The percentage of seminal roots infected with Take-all, the annual grass densities in 1992 and 1993 are presented in relation to the effects of the 1991 and 1992 stocking rates (Table 3.9) and the herbicide treatments applied in 1991 (Table 3.10).

Table 3.9. The annual grasses (plants/m^2) in 1992 and 1993 and the incidence of Take-all (% of infected seminal roots) in the 1993 wheat crop

Stocking rate (DSE/ha) 1991	1992	Grass 1992 (plants/m^2)	Grass 1993 (plants/m^2)	Take-all 1993 (% infection)
0	5	58	281	10
1	2.5	93	581	6
2	5	68	260	6
l.s.d.(P=0.05)		ns	228	ns

Table 3.10. The annual grasses (plants/m^2) in 1992 and 1993 and the incidence of Take-all (% of infected seminal roots) in the 1993 wheat crop

Herbicide treatments 1991	Grass 1992 (plants/m^2)	Grass 1993 (plants/m^2)	Take-all 1993 (% infection)
Nil	202	519	17
Pasture topping	41	435	4
Winter cleaning	48	465	2
Selective grass control	1	77	5
l.s.d.(P=0.05)	48	107	10

The percentage of seminal roots infected with *Gaeumannomyces graminis* (Take-all) in the 1993 wheat crop were a reflection of the grass plant numbers in 1992. The three stocking rates (Table 3.9) caused no differences while the three herbicide treatments (Table 3.10) reduced the grass populations. The 1993 grass densities had no impact on Take-all infection in the wheat. Infection levels above 10% are considered a moderate infection and could be expected to cause a reduction in wheat yield.

(iii) *Grain yield and protein content* of the wheat plots was harvested on 29 and 30 December 1993, grain yields measured and representative sub-samples were taken for protein determination. The effects of the herbicide treatments applied in 1991, and the stocking rates in 1991 and 1992, on grain yield and protein are presented in Table 3.11.

Table 3.11. Wheat grain yield (t/ha) and grain protein (%) in 1993

Stocking rate (DSE/ha) 1991	1992	Herbicide treatment 1991	Grain yield 1993	Grain protein 1993
		Nil	2.1	11.5
		Pasture topping	2.3	12.0
0	5	Winter cleaning	2.3	11.3
		Selective grass control	2.7	12.6
		Nil	1.5	11.5
		Pasture topping	1.6	11.0
1	2	Winter cleaning	1.5	11.8
		Selective grass control	2.3	12.8
		Nil	1.9	11.8
		Pasture topping	2.1	11.7
2	5	Winter cleaning	2.2	12.4
		Selective grass control	2.8	13.7
l.s.d.(P=0.05) Sr x Herb			0.4	1.8
l.s.d.(P=0.05) within each Sr			0.3	0.8

Grain yield was increased with selective grass control and the higher (5 DSE/ha) stocking rate in 1992. Selective grass control increased grain protein percentage within each stocking rate.

3.4. Discussion

Self-regenerating pastures in the pasture ley system need to provide adequate feed for livestock. The proportion of annual medic in the pasture should be maximised not only to ensure good pasture quality and medic seed yields, but also to limit the grass component so that the likelihood of a carry-over of soil-borne root diseases to subsequent cereal crops is reduced (Roget and Inwood 1991) and the soil nitrogen fertility is maintained or increased.

The level of productivity of the annual medic-based pasture in the semi-arid wheat-belt region is largely controlled by the availability of soft seed (Taylor and Ewing 1992) and rain (Jones and Carter 1989). At the Mallee Research Station, Walpeup, in 1991, the first year of this study, 170 mm of rain fell in the normal growing period, May to October, with 122 mm falling in June and July. In 1992, 310 mm fell during the same growing period (May to October). The long-term average at Walpeup for that period is 200 mm (Figure 3.1.). Therefore the study on pasture productivity was carried out under both lower- and higher-than-average rainfall conditions.

The Walpeup experiment was sown 6 weeks before the seasonal break which occurred in June 1991, and satisfactory establishment was obtained with a mean plant population of 131 plants/m^2. This was within the plant density range of 100 - 200 plants/m^2 shown by Williams and Vallance (1982) to be able to maximise seed yield and provide some competition with volunteer pasture species. The established medic density corresponds to 50% of the 200 seeds/m^2 medic seed sown becoming established plus 10 to 20% germination and establishment of the 188 seeds/m^2 of volunteer annual medics measured in the initial seed reserves which would normally be permeable at the seasonal break (Latta and Quigley 1993).

An average of almost 100 plants/m^2 of volunteer and sown grasses, and less than 20 plants/m^2 of broad-leaved weeds, were counted at establishment. The grass did not reduce medic herbage production in the establishment and seedling stages, as suggested by Bellotti *et al.* (1992), as the cumulative medic herbage production was not lower at 12 weeks (Fig. 3.4 (a)) in the Nil treatment in comparison to the Selective Grass Control treatment where the grass component had been eradicated.

The study showed that when grass was removed during the pasture establishment phase, by a selective grass herbicide, the reduction of almost 50% in total plant numbers produced insignificant reductions in early herbage production. This was caused by medic production increasing by 20 to 30% (Fig 3.4) and higher production from the broad-leaved weeds as a result of the removal of the grass component, supporting the study of Thorn and Perry (1987). The high stocking rate (2 DSE/ha) and the use of glyphosate as a winter cleaning grass control strategy reduced the cumulative grass and medic herbage production throughout 1991 (Fig.3.3(b) and 3.5(c)).

The percentage of medic and grass ground cover overlap was measured, to investigate the hypothesis that an increased stocking rate will reduce the grass component due to an increase in the broad-leaved (including legume) component (Carter 1968). This study found that the percentage of grass was generally less in both the 0 DSE/ha and 2 DSE/ha stocking rates in comparison to the 1 DSE/ha. The 0 DSE/ha had a lower grass component because of an increased component of broad-leaved weeds due to no grazing and the resultant increased competition. The reduction in the grass component as a result of the 2 DSE/ha is consistent with the study of Carter (1968).

The maximum medic seed yields achieved in this study in 1991 were above 200 kg/ha which were comparable to those reported by Latta and Quigley (1993) where seed reserves in a commercial field following a medic establishment phase increased by 150-200 kg/ha. Minimum seed yields below 50 kg/ha were similar to Bellotti *et al.* (1992) who measured seed yields less than 50 kg/ha as a result of volunteer plant competition. The seed yields from this current study varied in response to plant competition, stocking rates and herbicide treatments applied. However, the lowest seed production occurred after a glyphosate application in September (Pasture topping), which increased flower/seed abortion substantially. The small amount of rain that followed denied the opportunity for the medic to recommence flowering and set further seed.

Below average rain in 1991, in conjunction with Selective grass control, limited the establishing medic pasture to a seed yield of about 200 kg/ha. This amount of seed would be expected to regenerate 400 plants/m^2 in the following year (Carter 1982). The reduction in seed yield, down to approximately 130 kg/ha, due to volunteer plant competition in the Nil treatment and glyphosate damage in the Winter cleaning treatment would restrict subsequent density of medic plants to below 400 plants/m^2. The Pasture topping treatment, with a seed yield less than 50 kg/ha would not be expected to regenerate at a plant density which would provide an adequate medic component.

The results showed that in a season of low rain (1991) the seed yield, and therefore the ongoing productivity of a self-regenerating medic pasture was enhanced by Selective grass control and reduced grazing pressure. However, Pasture topping severely diminished the potential of the pasture legume (medic) to set seed.

Soil disturbance with the prickle chain improved medic herbage production in the winter of the regeneration year. The benefits derived from this practice may be greater in a drier season when rain was less. The results support the studies of Abd El Moneim and Cocks (1986), Khan *et al.* (1989) and Revell (1989).

The total rain for 1992 (536 mm) was much higher than the long-term average (336 mm). More than 40 mm and 80 mm, in April and May respectively, provided an excellent opening to the season (Figure 3.1). An average of 150 kg/ha medic seed reserve was available at the commencement of the season.

The medic densities which emerged in 1992 (Fig. 3.9) closely reflected the order of the seed yields measured in 1991 (Fig. 3.7). The largest number of seedlings established (650 plants/m^2) following Selective grass control on pastures grazed at 1 DSE/ha, while lowest plant establishment (175 plants/m^2) following Pasture topping and being grazed at 2 DSE/ha. These two treatments were comparable to the lowest and highest seed yields in 1991. Annual grasses (Fig.3.9) provided the other major component of the pasture and were a direct reflection of the level of grass control in 1991. The stocking rates imposed in 1991 had no effect on grass numbers in 1992 when no herbicide was applied. The mean number of broad-leaved weeds over all treatments were less than 50 plants/m^2. However, as a result of Selective grass control broad-leaved plant densities were almost 100 plants/m^2. Thorn and Perry (1987) also found that grass removal with a grass-selective herbicide increased the plant density of broad-leaved weeds.

Selective grass control maintained higher cumulative medic production in 1992 as a result of increased plant densities and reduced competition from volunteer grass. These results supported the findings of Adem (1977) and Abd El-Moneim and Cocks (1986), who also showed a response in early pasture production because of increased medic plant densities. The Nil treatment had reduced herbage production during a period of low rain throughout

June and July which was coupled with below-average temperatures and increased frost days (refer Fig. 3.1). The grass was observed to be suffering moisture stress and frost damage which impeded growth during the mid-winter period. The slow down in growth (refer Fig.3. 12) was shown between 9 and 13 weeks after emergence in the Nil treatment which had the highest component of grass (refer Fig. 3.8).

Although the medic seedling densities were less than the 800 plants/m^2 which Venn (1984) considered is required to maximise herbage production in the absence of grass, total herbage production in 1992 (Fig.3.12) showed no negative response to the complete grass removal resulting from the use of a selective grass herbicide in 1991. While there is no evidence that greater medic densities may not have increased early herbage production the presence of about 200 plants/m^2 of annual grass in the Nil treatment generally reduced total herbage production throughout the season. Adding the medic, grass and broad-leaved weeds, total plant densities were: Nil herbicide, 700 plants/m^2; Selective grass control, 655 plants/m^2; Winter cleaning, 551 plants/m^2; and Pasture topping 282 plants/m^2. The early herbage production was negatively associated with increased densities of grass (Nil treatment) and positively associated with increased densities of medic (Selective grass control). Following the Pasture topping in 1991, early herbage production in 1992 was reduced at the first two times of sampling (4 and 9 weeks after emergence) as would have been expected from lower plant densities.

High medic seed yields of 400 kg/ha (Nil treatment) to almost 700 kg/ha (Selective grass control treatment applied in 1991 and the lower stocking rate in 1992 of 2.5 DSE/ha) were measured in 1992. The mean seed yield was close to the 600 kg/ha, described by Cocks (1988) as being suitable to provide livestock fodder over the summer period while retaining an adequate reserve for subsequent pasture phases. But it must be remembered that summer/autumn grazing can decimate seed reserves (Carter 1981). However, in 1992 the effects of the grazing animal on the productivity, composition and seed yields of the medic pasture was small, due to the excellent seasonal conditions. The sheep were initially introduced on the 3 June and grazed from that time until the end of the year at 5 DSE/ha and 2.5 DSE/ha. The stocking rates applied did not reduce the pasture availability significantly, even though they were much higher than the district average (about 2 DSE/ha) and they were stocked at more than twice that rate for the 12 month period (5 DSE/ha). The non-significant differences in sheep live-weights throughout the period July to November (Fig.3.16) also indicate that pasture growth was able to support an exceptionally high stocking rate. The other indication of the limited effect the sheep had on the pasture productivity was the small reductions in seed yields in response to the higher stocking rates (Fig 3.15). Herbicide treatments applied in 1991 had the major effect on seed yield and on the consequent pasture components and competition.

The observation that in 1992 pasture productivity was high despite low levels of soil phosphorus, supports Amor (1966b), who suggested that rain was the major factor controlling medic production. Phosphorus levels at the commencement of the study (mean 5.4 μg Olsen P) are considered deficient: however, herbage yields of up to 7,000 kg/ha were much greater than could be utilised by available livestock and provided an opportunity to conserve fodder.

The grain yield and protein percentages of the 1993 cereal phase of the rotation increased in response to a reduced level of grass at the commencement of the second pasture year, 1992. Grass numbers which emerged in 1992 in response to all herbicide treatments applied in 1991 were below 50 plants/m^2 has been shown to provide adequate control of the carryover of the Take-all fungi (Roget and Inwood pers.comm.). Roget and Rovira (1991) showed the relationship between lower annual grass plant densities during the winter in the year prior to the cereal crop and the lower incidence of cereal root diseases.

The highest grain yield and grain protein percentage was achieved by Selective grass control using fluazifop (Fusilade[R]) in the year of establishment coupled with the 2 years of high stocking rate. The low stocking rate over both years together with the Nil herbicide treatment produced the lowest grain yields and grain protein. The impact of the weed levels within the wheat crop was significant, and the inability to chemically remove volunteer annual grasses (*Bromus* and *Hordeum* spp.) from the wheat crop reduced the yield potential of the Nil, Winter cleaning and Pasture topping treatments.

The productivity of the medic-based pasture-pasture-wheat rotation was enhanced through the use of grass control herbicides in the first year of a 2 year pasture phase which restricted grass emergence (to less than 50 plants/m^2) in the second pasture year. This grass plant density is currently considered a figure where the succession of Take-all is limited and financial benefits are achieved through increased grain yield and quality. The improvement in wheat and livestock production as a result of a productive medic-based pasture irrespective of grass herbicide treatments is difficult to assess. The grain yield over all treatments was more than 2 t/ha compared to a district average of 1.7 t/ha, but in 1993 district yields were generally above average due to high spring rainfall. Grain protein levels above 11% were comparable to the higher district results. Grazing at more than twice the district stocking rate during and immediately following the growing seasons in both pasture years had no negative impact on livestock production and improved the cereal returns through both wheat yield and grain protein. However, the ability to carry the extra livestock is controlled by the fodder deficiency in the autumn period and winter/spring lambing strategies should be given serious consideration to maximise grazing pressure during that period and improve and subsequent pasture and cereal productivity. Fodder conservation provides an option but is often not considered economic, except for drought feeding, due to pasture decline after hay-making and the low current market value of on-farm grain.

CHAPTER 4.

SEED DYNAMICS OF TWO ANNUAL MEDIC CULTIVARS IN A PASTURE-PASTURE-WHEAT ROTATION

4.1 Introduction

Seed production of annual pasture legumes reflects the genetic potential of the plant, the environmental conditions over the growing season (rainfall particularly) and the grazing management imposed on the pasture. The seed reserve and subsequent number of regenerating plants reflects hardseed breakdown due to diurnal temperature fluctuations, cultivation practices and removal of seed by grazing animals. Persistence can be improved through improved genotype and better management strategies over the growing season and the summer period (Jones and Carter 1989).

The selection of medic cultivars on the basis of time to maturity may also affect medic productivity, seed yield and therefore persistence. The flowering time of a cultivar in relation to the length of the growing season determines whether the seed can mature before the soil is too dry for continued growth of the plants. The development of annual medic cultivars adapted to the Mallee region of south-east Australia has been an important component in the evolution and maintenance of the ley farming system. Studies by Amor (1965, 1966a) reported the excellent performance of *M. truncatula* cv. Jemalong and *M. littoralis* cv. Harbinger in the Victorian Mallee. The studies promoted Jemalong for the loamy soils and Harbinger for the sandy soils of the Mallee. These cultivars were widely utilised on Mallee farms until the 1980's. Amor *et al.* (1986) measured improved early herbage production, seed yields and densities of regenerating plants from *M. truncatula* cvv. Paraggio and Parabinga in comparison to Jemalong. Harbinger AR was developed as an aphid-resistant replacement for Harbinger (Oram 1990).

Carter (1981) considered seed reserves of 200 kg/ha in the top 5 cm of soil following a cropping sequence was the critical minimum seed reserve required to maintain the stability of self-generating medic pastures in the ley farming system. With 150 kg/ha being retained at the commencement of the pasture phase and 15 to 20% permeable seed at the seasonal break with a 50% establishment success would result in a regenerating plant density of more than 400 plants/m^2. This was an adequate medic plant density to optimise early herbage production, weed competition and seed production. Latta (1992) found that at Walpeup, in an ungrazed experiment, medic seed reserves were maintained above 200 kg/ha in a pasture-pasture-wheat rotation.

The loss of medic seed, as a result of grazing, will have an effect on subsequent production and persistence due to seed reserves being below the minimum required level to provide both summer fodder and supply an adequate density of regenerating plants. Amor and Mann (1965) noted that grazing medic-based pastures during the growing season at Walpeup, reduced the plant density which regenerated the following year by 32%. Carter (1981) measured a loss in medic seed numbers from 25000 to 3000/m^2 as a result of 56 days grazing during March and April with more than 50 sheep/ha at the Waite Institute, Adelaide.

Minimal amounts of seed is returned to the seed bank after passing through the digestive tract of the grazing sheep. Studies on the seed survival following ingestion have agreed that less than 5% of medic seed passes through sheep and frequently less than 2% (Carter *et al.* 1988). However, there was a direct relationship between seed size and survival after ingestion with smaller seeds having higher survival percentages. They suggested that small, hard-seeded pasture legumes were better suited for survival in self regenerating stocked pastures.

Quinlivan (1971a; 1971b) found that medic seed impermeability (hard-seededness) was induced by decreasing soil moisture levels during seed maturation. Permeability (softening) occurred as a result of diurnal temperature variation, and the proportion of permeable seed increased with increased temperature variation. Taylor and Ewing (1992) extended this work by determining the close relationship between the growing environment and the softening rates of medic seed. Medics grown in a more favourable environment were much slower to soften than those in a drier, shorter season environment. Both studies emphasise the potential differences in the soft seed percentage of a cultivar grown over several years at a common site in response to both growing season and summer/autumn seasonal variables.

Permeable seeds imbibing after summer rain can result in significant losses of seed reserves. Latta and Quigley (1993) compared the persistence of the insect-resistant *M. truncatula* cv. Paraggio released in the 1980's with the earlier released cultivars Jemalong and *M. littoralis* cv. Harbinger. These studies showed that Paraggio had higher levels of soft seed than the older cultivars and seed was being lost as a result of summer rainfall events. Crawford and Nankivell (1989) suggested that the seedcoat impermeability of medic is perhaps as important as seed production capacity in maintaining persistence. Crawford, *et al.* (1989) thought the most desirable seed softening pattern would be to have no permeable seed until late March, then an immediate increase to approximately 30% permeable seed by mid April; this would safeguard against summer rainfall germinating seed which would normally die due to an extended dry, hot period.

The comparative ability of Paraggio and Harbinger AR to produce and then sustain 150 - 200 kg/ha of medic seed to the commencement of a pasture phase requires clarification. Selective and non-selective herbicides and the impact of the grazing animal, on the larger, more-permeable seeded, later-maturing Paraggio and the smaller, harder-seeded, earlier-maturing

Harbinger AR (Oram 1982; 1990) are important to the semi-arid pasture ley farming system practised in the Mallee. This chapter examines and discusses the seed production and persistence of these two cultivars, which are recommended for the Mallee, over the three years of a pasture-pasture-cereal rotation.

4.2 Materials and Methods.

4.2.1 For details on site description, experiment design and treatment details, pasture establishment and management see Chapter 3.2.1.

Monthly rainfalls, and the long term averages (1911-93), together with minimum and maximum temperatures for the period January 1991 to March 1994, are presented in Figure 3.1.

4.2.2 Measurements and data collection

This chapter covers the period from initial seed set (September 1991) through to the final seed reserves available in autumn 1994. It measures the production and retention of the Paraggio and Harbinger AR seed reserves in response to the herbicide treatments, grazing sheep and their inherent seed permeability.

The effect of sheep grazing on seed yield and persistence: Grazing management during the growing period in both pasture years (1991 and 1992) are described in Chapter 3.2.4. To measure the effect of the sheep grazing during the period of seed maturation in 1991, five exclusion cages were placed on each of the grazed herbicide treatment plots during September, October and November. Seed was collected from the soil surface to determine yields on 16 December. One sample of 0.2 m^2 from each of the five stratum were taken from each plot.

Samples were taken from both the caged and companion uncaged areas. The soil and vegetable matter was removed from the sample; the medic pods separated into species, threshed and the seed cleaned and weighed.

In 1991, the stocking rates on the plots over the three-month period, September to November, were 0, 2 and 1 DSE/ha (0 and 10 sheep on 1.25 ha for three weeks, and ten sheep on 2.5 ha for three weeks respectively). However, the average live weight of the wethers was 40% above the 45 kg specified as 1 DSE, and the actual stocking rates were 0, 1.4 or 2.8 DSE/ha during the three month period. Sheep had access to the maturing seed pod in the uncaged areas and had the opportunity to reduce the seed yield.

In 1992, sheep were removed from the experiment on the 3 September. Ten sheep were returned to each plot on 5 October, and from that time, sheep remained continuously on the site until the 30 January 1993. Stocking rates over that period were, 17 DSE/ha and 8.5 DSE/ha, which was equivalent to 6 and 3 DSE/ha for the 12 month period.

One cage within each stratum excluded the grazing sheep from 5 October until 16 December 1992, when the seed was collected from the caged and companion grazed sites. Two further measurements of the remaining medic seed yield were carried out on 30 December and 30 January. Seed pods were collected from 5 x 0.2 m^2 quadrats in each plot.

Plant residues: In 1991, the amount of plant residue was measured at the time of seed collection, 16 December, from 5 x 0.2 m^2 quadrats per plot. Soil was removed by sieving, and the remaining dry pasture residue weighed and calculated as kg/ha.

In 1992/93 pasture residues were measured twice; 1) at the time of sheep introduction (5

October) and 2) at the final seed reserve collection (30 January), from 5 x 0.2 m^2 quadrats per plot. The green herbage sample collected in October was dried at 100°C for 24 hours then weighed. The dry pasture residue collected in January had the soil removed by sieving and the remaining plant residue, including medic seed pods, weighed and calculated as kg/ha.

Permeable seed: In Year 1 (1991/92), medic seed pods were randomly selected at one point within each stratum from each herbicide treatment plot, at 4 times during the summer-autumn period of 1992 (15 January, 3 February, 26 February and 3 April). They were sorted into species, *M. littoralis* and *M. truncatula*, immediately after sampling. Fifty pods of each species were randomly selected and placed in a controlled temperature environment of between 20 and 23°C until final sampling on 3 April. The 50 pods were placed in Petri dishes on cotton wool with 50 ml of water with 5 g/L of thiram (Thiram 800(R); Agchem Pty.Ltd., 800 g/kg a.i.) added for control of fungal growth. They were placed in an incubator, at the Waite Agricultural Res. Inst., Adelaide at 18.5°C ± 1°C. Emerging cotyledons were counted every second day for 10 days. After 10 days 10 pods were selected and allowed to dry and were then dissected by hand to count remaining impermeable seed. The percentage of permeable seed was calculated using the formula;

Permeable seed % = germinated seed / germinated seed + hard seed x 100.

During the summer-autumn period of 1992/93 pods were randomly collected by the same method as in 1991/92 but at 5 times (16 December, 30 December, 30 January, 1 March and 17 April). The method of analysis was similar to Year 1. The total number of seeds in the 50 seed pods from each sampling time were calculated (retained seed in pods + emerged cotyledons) to measure any seed loss during the sampling period.

In 1994, pods were collected as a bulk site sample on 30 March. They were sorted into species, *M. littoralis* and *M. truncatula*, immediately after sampling. Three hundred pods of each species were randomly selected to make-up 6 replicates of 50 pods. Data collection procedure was a repeat of 1991/92 technique.

Seed reserves: The weight of medic seed present through the soil profile (0 - 5 cm) throughout the course of the study was measured at 4 times over the course of the study, 1) prior to the establishment of the experiment in April 1991 and before the opening seasonal rains in 1992, 1993 and 1994 (21 April 1992, 5 July 1993, 18 February 1994). Twenty soil cores (40 cm^2) were taken to a depth of 5 cm at 15 sites selected in a grid pattern (1991), then within each herbicide treatment in 1992, 1993 and 1994 (4 samples within each stratam). The soil from samples was removed through a 0.7 mm sieve and the vegetable residue blown out by an aspirated "Clipper" grain cleaner. The initial separation of the seed pods of the two species was made in a 5.6 mm sieve, followed by a visual inspection, and manual sorting as required. When the two species were split, the pods were threshed by hand and the seed was separated from remaining soil and vegetable matter with trichloroethylene by the method described by Carter *et al.* (1977). Naked seed in the soil could not be classified into specie: however, this component comprised less than 2% of total seed weight and were disregarded apart from at the initial sampling for volunteer medic seed in 1991.

4.3 Results

4.3.1 Impact of sheep grazing on seed yields in 1991

The effects of grazing and herbicide treatments on Harbinger AR and Paraggio seed yields are presented in Table 4.1.

Table 4.1. The effect of herbicide and grazing treatments applied during 1991 on Harbinger AR and Paraggio seed yields (kg/ha)

Stocking rate	Herbicide treatment	Harbinger AR seed yield (kg/ha)		Paraggio seed yield (kg/ha)	
		Ungrazed	Grazed	Ungrazed	Grazed
0 DSE/ha	Nil	73		78	
	Pasture topping	17		33	
	Winter cleaning	55		98	
	Sel. grass cont.	106		80	
1.4 DSE/ha	Nil	80	71	57	48
	Pasture topping	13	10	21	14
	Winter cleaning	55	57	104	92
	Sel. grass cont.	134	122	85	77
2.8 DSE/ha	Nil	89	70	38	41
	Pasture topping	9	22	16	14
	Winter cleaning	67	65	39	46
	Sel grass cont.	122	92	65	53
l.s.d.(P=0.05)Sr x Herb xTime		ns		55	

Grazing at 2 DSE/ha during the winter of 1991 interacting with the Winter cleaning treatment reduced the seed yield of Paraggio in comparison to 0 and 1 DSE/ha. However, grazing at 2.8 DSE/ha during the spring did not reduce seed yields. Paraggio had similar or higher seed yields than Harbinger AR following both glyphosate treatments. Harbinger AR had similar or higher seed yields than Paraggio when glyphosate was not used.

4.3.2 Pasture residues 1991

Table 4.2 presents the comparative amounts of dry pasture residue, retained in December 1991, to establish any relationship between the percentage of permeable seed, pasture residue levels and temperature insulation.

Table 4.2. Dry pasture residues (kg DM/ha) in December 1991 following herbicide treatments and three stocking rates

Herbicide treatment		Stocking rate	
	0 DSE/ha	1 DSE/ha	2 DSE/ha
Nil herbicide	3235	3672	2180
Pasture topping	2910	3354	1522
Winter cleaning	2612	3112	1543
Selective grass control	2580	3084	1899
l.s.d.(P=0.05) Sr x Herb		927	
l.s.d.(P=0.05) within each Sr		499	

The 2 DSE/ha stocking rate over the period June to December 1991 reduced pasture residue in comparison to the 0 and 1 DSE/ha treatments. The Nil herbicide treatment maintained higher residue levels compared to Selective grass control within the 0 and 1 DSE/ha stocking rate treatments.

4.3.3 Permeable seed 1991/92

The amount of permeable seed was measured four times during the summer-autumn period to establish the potential for any seed loss which might occur in response to a summer rainfall event. The percentage of permeable seed in response to three stocking rates at four collection times is presented for Paraggio in Figure 4.1 (a) and Harbinger AR in Figure 4.1 (b). The percentage of permeable Paraggio and Harbinger AR seed in response to herbicide treatments at four times of collection is presented in Figure 4.2 (a) and in Figure 4.2 (b) respectively.

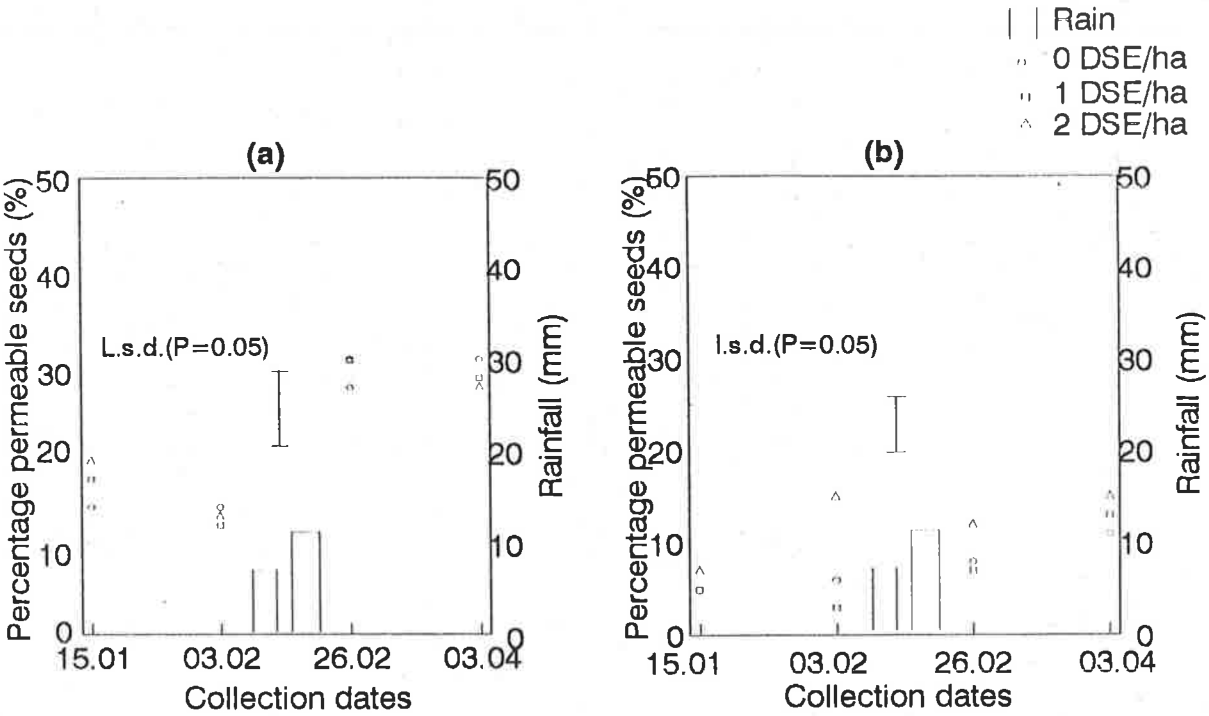


Figure 4.1 The percentage of permeable Paraggio (a) and Harbinger AR (b) seed at four collection times in 1992 interacting with three stocking rates. The dates and amount of rain during the 11 week period are shown.

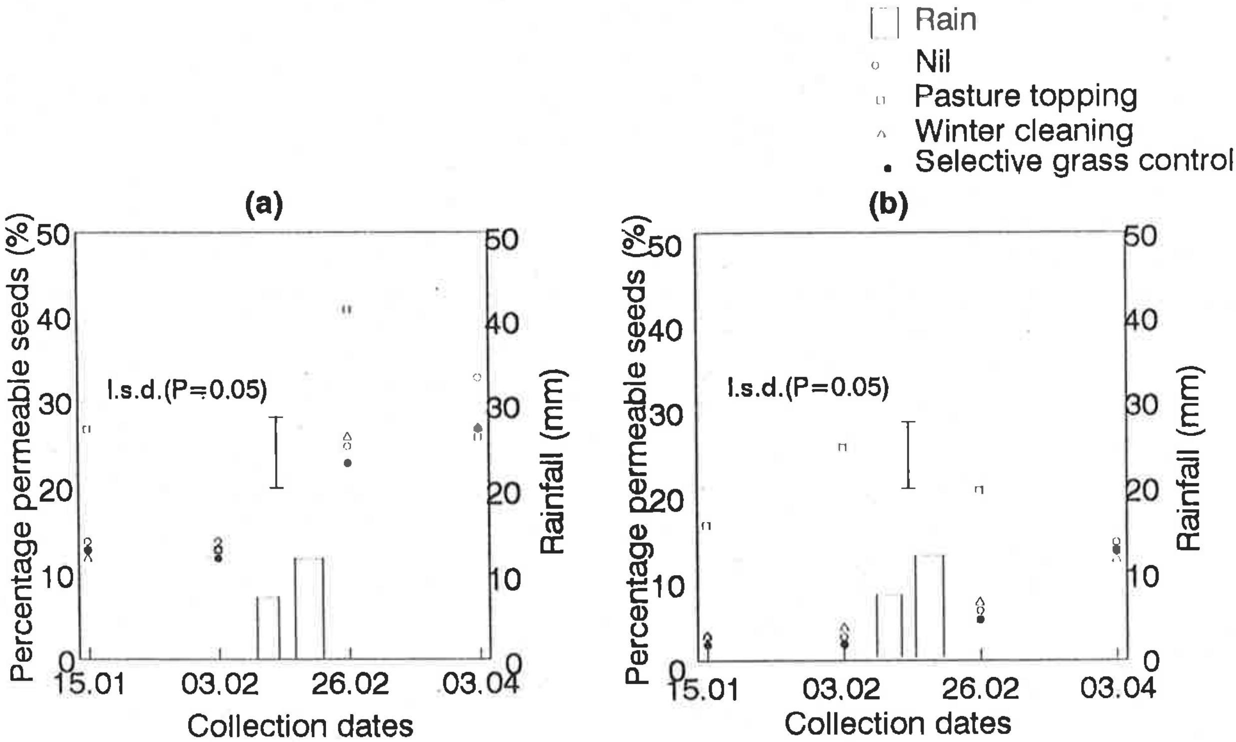


Figure 4.2 The percentage of permeable Paraggio (a) and Harbinger AR (b) seed at four collection times in 1992 interacting with four herbicide treatments. The dates and amount of rain during the 11 week period are shown.

Seven mm on 4 February and 11 mm on 12 February were the only significant amounts of rain during the study period. The percentage of permeable Paraggio seed increased between 3 and 26 February at all stocking rates. At 2 DSE/ha the permeable seed levels of Harbinger AR increased between 15 January and 3 February. In response to Pasture topping, Paraggio had a higher percentage of permeable seed on 15 January and 26 February and Harbinger AR at each sampling time until 3 April than the other herbicide treatments. The data suggests a loss of Harbinger AR seed between the 3 February and 3 April possibly due to imbibition and subsequent dessication. Irrespective of previously-applied stocking rates or herbicide treatments the percentages of Paraggio and Harbinger AR permeable seed had equalised at about 30% and 13% respectively by 3 April, 1992.

The seed numbers in each pod and the single seed weight of Paraggio and Harbinger AR as a result of the pasture herbicide treatments are presented in Table 4.3.

Table 4.3. Seed (numbers/pod) and seed weight (mg) of Paraggio and Harbinger AR in response to pasture herbicide treatments applied during 1991

	Paraggio		Harbinger AR	
Herbicide treatment	Seeds (numbers/pod)	Seed weight (mg)	Seeds (numbers/pod)	Seed weight (mg)
Nil herbicide	5.6	2.87	3.4	1.92
Pasture topping	3.1	2.95	0.9	2.05
Winter cleaning	5.7	3.27	3.3	2.10
Sel. grass cont.	5.7	3.16	3.5	2.00
l.s.d.(P=0.05)	0.5	0.19	0.3	0.15

Seed numbers/pod were reduced by the Pasture topping treatment in both Paraggio and Harbinger AR. The average single seed weight of Paraggio was increased by Selective grass control and Winter cleaning, Harbinger AR single seed weight was increased only by the Winter cleaning, in comparison to the Nil herbicide treatment.

4.3.4 Seed reserves 1992

Table 4.4 presents the Paraggio and Harbinger AR medic seed yield (current seasons seed yield on surface) at the time of stock removal on 16 December, and the seed reserve (current and previous seasons seed yields including reserve in soil profile) retained in April 1992.

Table 4.4. Seed yield and seed reserve (kg/ha) of Paraggio and Harbinger AR present on 16 December 1991 (seed yield) and 21 April 1992 (seed reserve)

Stocking rate	Herbicide treatment	Harbinger AR (kg/ha)		Paraggio (kg/ha)	
		Seed yield 16.12.91	Seed reserve 21.4.92	Seed yield 16.12.91	Seed reserve 21.4.92
0 DSE/ha	Nil	73	70	78	57
	Pasture topping	17	10	33	16
	Winter cleaning	55	47	98	54
	Sel. grass cont.	106	95	80	63
1 DSE/ha	Nil	70	82	48	52
	Pasture topping	10	11	14	9
	Winter cleaning	57	55	92	47
	Sel. grass cont.	122	104	73	53
2 DSE/ha	Nil	70	81	40	22
	Pasture topping	22	11	14	16
	Winter cleaning	65	51	46	27
	Sel. grass cont.	88	96	53	31
l.s.d.(P=0.05) Sr x Herb x Time		ns		46	
l.s.d.(P=0.05) within each Sr x Time		ns		27	

Harbinger AR recorded no significant seed reduction between December and April although the Pasture topping treatment indicated some loss (Table 4.4) as was shown in Fig. 4.2(b). Paraggio with Winter cleaning applied had a seed loss when compared at the 0 and 1 DSE/ha stocking rates, although this was not evident in Fig. 4.2(a). Data which suggests some increase in seed reserves over initial yields may be as a result of previous seed burial.

4.3.5 Impact of sheep grazing on seed yields in 1992/93

Table 4.5(a). The seed yield (kg/ha) of Harbinger AR measured at four times with two stocking densities between October 1992 and February 1993 following previous herbicide and stocking rate treatments in 1991 and 1992

		Harbinger AR seed yield (kg/ha)			
Stocking density	Herbicide treatment	5 Oct	16 Dec	30 Dec	30 Jan
17 DSE	Nil	165	115	115	106
	Pasture topping	181	125	118	114
	Winter cleaning	142	151	137	130
	Selective grass control	175	178	158	150
8.5 DSE	Nil	151	130	152	135
	Pasture topping	155	126	138	119
	Winter cleaning	207	167	169	138
	Selective grass control	258	244	220	222
17 DSE	Nil	185	171	167	146
	Pasture topping	199	142	126	109
	Winter cleaning	240	223	205	176
	Selective grass control	337	257	247	264
l.s.d.(P=0.05)Sr x Herb x time			113		

The Harbinger AR seed yields were not reduced (P=0.05) s a result of the stocking rates or herbicide treatments, although trends indicated a decrease (Table 4.5(a)). The Paraggio seed yield was reduced at the high stocking rate (17 DSE/ha) and at all herbicide treatments as a result of the 120 day grazing period (Table 4.5(b)). There were no clear trends in grazing preference as a result of the different pasture components, due to the herbicide treatments applied in 1991, and the initial seed yields were generally maintained in the same relative order throughout the grazing period. A sample of sheep dung was collected on 30 January 1993 and dissected to measure levels of medic seed passed through the sheep. Less than 10 kg/ha of medic seed was measured from each of the 3 stocking rates. This constituted less than 5% of the more than 200 kg/ha of ingested seed was passed through the grazing animal and agrees with Carter *et al* (1988).

Table 4.5(b). The seed yield (kg/ha) of Paraggio measured at 4 times with two stocking densities between October 1992 and February 1993 following previous herbicide and stocking treatments in 1991 and 1992

Stocking density	Herbicide treatment	Paraggio seed yield (kg/ha) 5 Oct	16 Dec	30 Dec	30 Jan
17 DSE	Nil	375	307	326	189
	Pasture topping	370	332	319	215
	Winter cleaning	392	362	278	223
	Selective grass control	484	350	311	285
8.5 DSE	Nil	410	293	262	182
	Pasture topping	345	331	297	214
	Winter cleaning	374	329	320	255
	Selective grass control	499	418	317	333
17 DSE	Nil	285	218	193	120
	Pasture topping	350	351	248	181
	Winter cleaning	356	308	220	219
	Selective grass control	433	357	281	217
l.s.d.(P=0.05) Sr x Herb x Time			138		

4.3.6 Pasture residues 1992/93

Table 4.6. Reduction of pasture residue (kg DM/ha) as a result of grazing sheep at two stocking rates between October 1992 and February 1993 and previous herbicide treatments and stocking rates imposed in 1991 and 1992

Stocking rate	17 DSE/ha 1992/93		8.5 DSE/ha 1992/93		17 DSE/ha 1992/93	
	0 DSE/ha 1991		1 DSE/ha 1991		2 DSE/ha 1991	
Herb. treatment	5 Oct.	30 Jan.	5 Oct.	30 Jan.	5 Oct.	30 Jan.
Nil	3881	3528	3810	3395	4254	2640
Pasture topping	4781	3202	3356	4174	5321	2651
Winter cleaning	4895	3062	4237	3615	4763	3027
Sel. grass cont.	5098	3249	4995	3655	5357	2753
l.s.d.(P=0.05) Sr x Herb x Time				789		
l.s.d.(P=0.05) within each Sr x Time				676		

The Selective grass control herbicide treatment had similar or greater amounts of pasture residue compared to all other herbicide treatments at the commencement of the study on 5 October 1992. The pasture residue was reduced (up to 2.5 t/ha) from the Selective grass control, at a similar or greater level, than all other herbicide treatments, as a result of the 120 day grazing period (Table 4.6). The results show that the greater the grass component the lower was the reduction in pasture residue over the period. Either or both sheep grazing preference and/or more rapid breakdown of vegetable matter due to plant morphological factors would be the cause.

4.3.7 Permeable seed 1992/93

There was no difference in the percentage of seed permeability in response to imposed stocking rates, pasture residue or pasture components from previously applied herbicide treatments, and results are presented as means of all treatments (Fig.4.3). The percentage of permeable Paraggio seed increased at each sampling time after the 30 December. The percentage of permeable Harbinger AR seed did not increase over the course of the study. The percentage of permeable seed was much lower in 1993 when compared to the 1991/92 results; Paraggio 12% compared to 30%, Harbinger AR less than 1% compared to 13% (refer Figs. 4.1, 4.2).

The seed numbers/pod in Harbinger AR and Paraggio at five sampling times from 16 December 1992 to 17 April 1993 are presented in Figure 4.4. Paraggio had a seed loss of 0.6 seeds/pod between 30 January and 1 March. Harbinger AR had no seed loss. There was no difference in the seed numbers/pod in either cultivar due to stocking rates or pasture specie compositions during 1992 at any of the five sampling times.

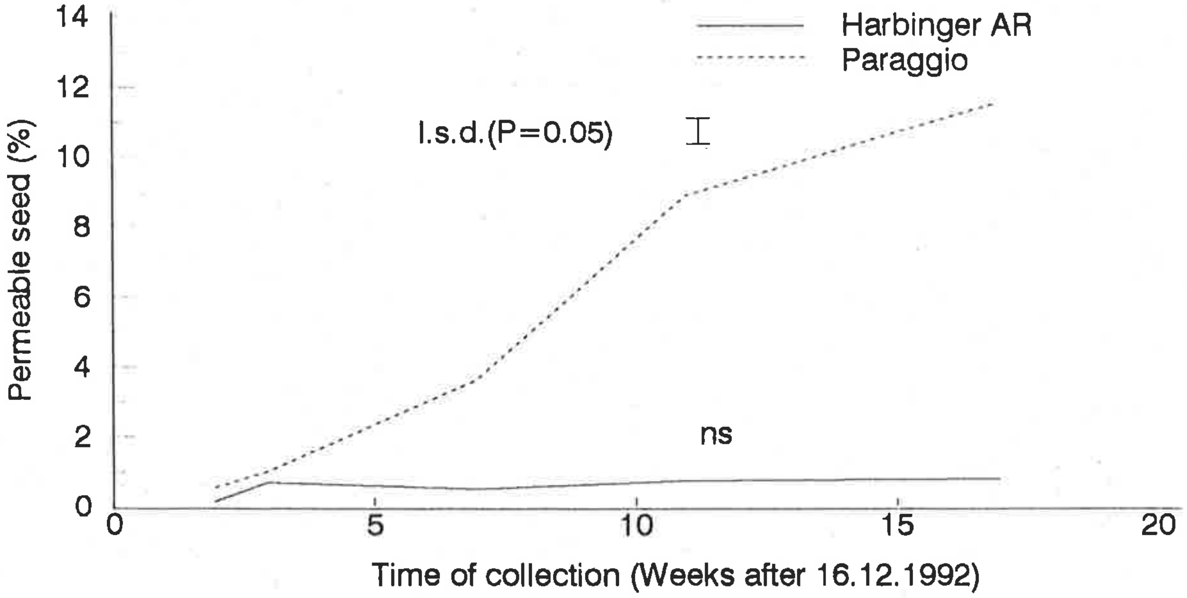


Figure 4.3. The percentage of permeable seed of Harbinger AR and Paraggio measured at 5 times from December to April 1992/93.

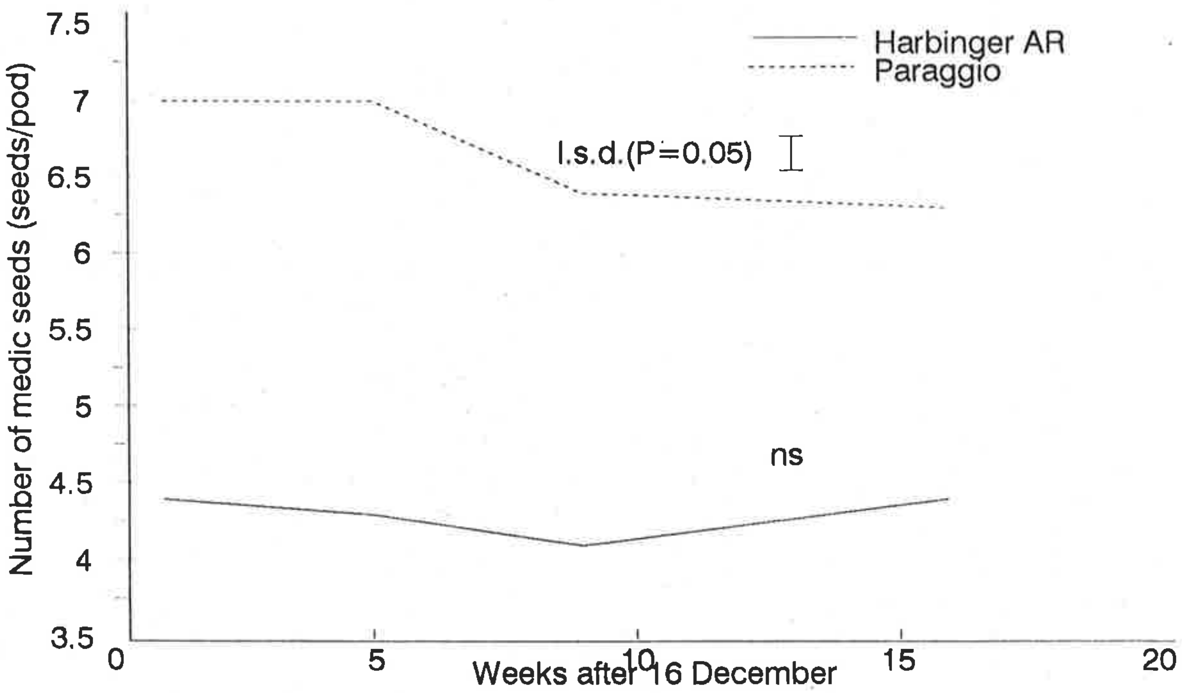


Figure 4.4. Seed numbers/pod of Harbinger AR and Paraggio measured at five times from December to April 1992/3.

4.3.8 Seed reserves 1993

Table 4.7 Medic seed yield and subsequent seed reserve (kg/ha) of Paraggio and Harbinger AR present on 30 January (seed yield) and 5 July 1993 (seed reserve)

Stocking rate	Herbicide treatment	Harbinger AR (kg/ha)		Paraggio (kg/ha)	
		Seed yield 30 Jan.	Seed reserve 5 July	Seed yield 30 Jan.	Seed reserve 5 July
0 DSE/ha	Nil	106	142	189	184
	Pasture topping	114	128	215	173
	Winter cleaning	130	152	223	168
	Sel. grass cont.	150	196	283	194
1 DSE/ha	Nil	135	144	182	229
	Pasture topping	119	164	214	204
	Winter cleaning	138	190	255	238
	Sel. grass cont.	222	264	334	298
2 DSE/ha	Nil	146	192	120	146
	Pasture topping	109	108	181	178
	Winter cleaning	176	206	219	169
	Sel. grass cont.	264	303	217	217
l.s.d.(P=0.05) Sr x Herb x Time		119		119	
l.s.d.(P=0.05) within each Sr x Time		58		61	

The trends showed Harbinger AR seed reserves were higher than the seed yields. This suggests that some of the 1991 Harbinger AR and Paraggio seed yield had been buried with the prickle chain in March 1992, and/or by the sheep prior to January 1993 and not measured in the surface seed yield on 30 January. However, the Paraggio seed reserves were lower than the yields or at a similar level between January and July (Table 4.7). Permeable Paraggio seed throughout the study period (refer Fig. 4.3) was approximately 10%, compared to Harbinger AR less than 1%, and Figure 4.4 indicated a seed loss of about 10% in response to rain in late January and February and possibly due to improved seed-soil contact following the initial cultivation in preparation for the wheat crop in 1993.

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4.3.9 Permeable seed 1992 - 1994

Table 4.8. Permeable seed (%) of Paraggio and Harbinger AR in April of 1992, 1993 and 1994 prior to the seasonal break

	1992	1993	1994
Paraggio	30	12	18
Harbinger AR	12	1	4

The percentage of permeable Paraggio and Harbinger AR seed was less in 1993 than 1992 (Table 4.8). The majority of seed in each year was set in the immediate preceding season; rain was below average in 1991 and well above average in 1992 (Fig.3.1). The percentage of permeable seed from both cultivars were greater in 1994 following the cereal crop in 1993 than the 1993 levels but remained below the 1992 levels of permeable seed.

4.3.10 Seed reserves 1991 to 1994

Harbinger AR had higher seed reserves than Paraggio after the first 12 months of the pasture-pasture-cereal-pasture rotation (Fig.4.5). However, the position was reversed after the second year, which indicated the low and high rain environment of the 2 pasture years, and the adaptation of Harbinger AR to drier seasonal conditions (1991) and Paraggio to a wetter, longer growing season (1992). The reduction in the Harbinger AR seed reserve during the 1993/94 crop year in comparison to Paraggio may have been due to high mouse numbers, and their ability to extract seeds from the less spinier Harbinger AR seedpod relative to the Paraggio seedpod (Latta personal observations).

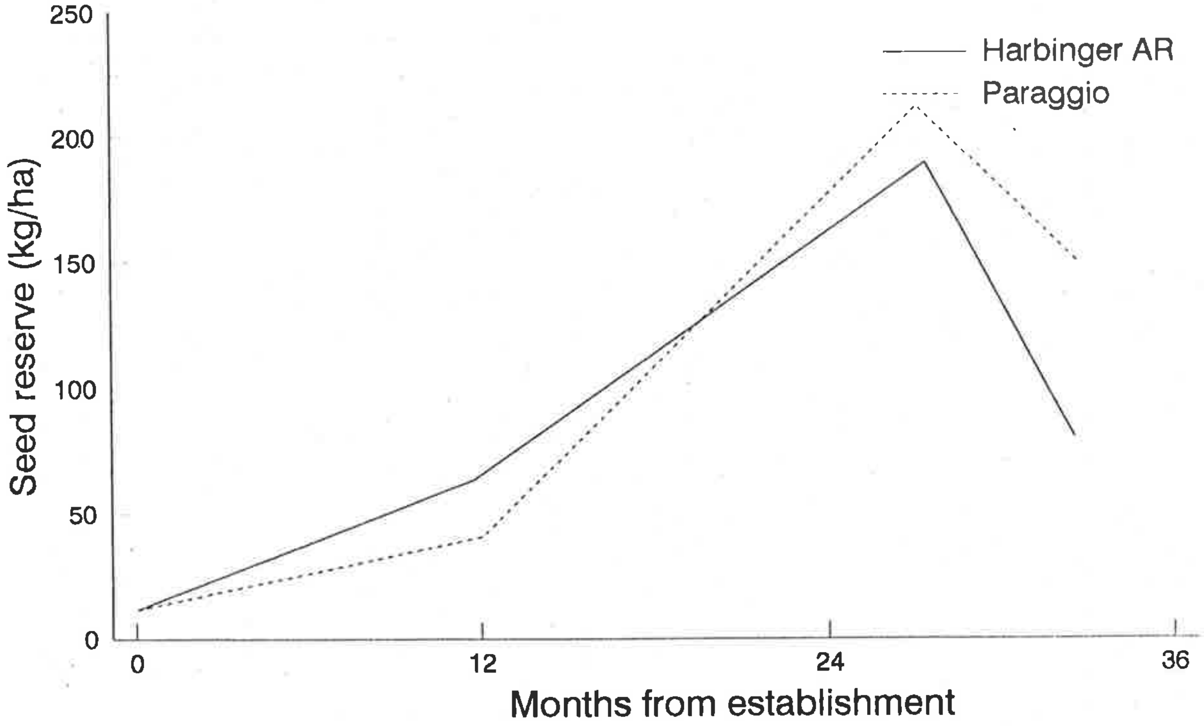

Figure 4.5. Seed reserves of Paraggio and Harbinger AR from April 1991 to February 1994.

4.4. Discussion.

This study evaluated the performance of two agronomically different medic cultivars, *Medicago littoralis* cv. Harbinger AR and *Medicago truncatula* cv. Paraggio, within a pasture-cereal rotation in which several pasture management treatments and grazing regimes were imposed. Clements (1989) described the qualities of a medic cultivar necessary to sustain productivity in cereal-pasture rotations and stressed the importance of, flowering and seed maturation time suitable for the target environment, and adequate seed production, to be important. Jones and Carter (1989), emphasised seed production was the foundation of a sustainable regenerating medic pasture, and this was largely controlled by the environment (rain particularly).

This thesis study at Walpeup found that the environment had a major bearing on the medic seed yield and therefore the success of the ley-farming system in the semi-arid environment. When meaned over stocking rates and herbicide treatments, both Harbinger AR and Paraggio produced more seed in 1992 (200 and 389 kg/ha respectively) than 1991 (68 and 59 kg/ha respectively). This supported the study of Hochman (1987) who related seed yields to seasonal rainfall amounts and distribution. Muyekho (1993) showed that higher seed yields were achieved by earlier flowering in environments prone to moisture stress during flowering. However, without moisture stress a cultivars inherent ability to set a large number of pods was the criteria for increased seed production. Harbinger AR (early-flowering) produced more seed than Paraggio (mid-season-flowering) in the short (June to September) growing season in 1991. However, Paraggio had higher seed yields after the longer (May to October) growing season of 1992. The seasonal rainfall interacting with the genetic potential of each medic cultivar determined the relative optimum seasonal seed production. However, the pasture herbicide applied and the sheep stocking rate controlled the ability of the cultivar to reach that seasonal seed yield.

The seed yield of Paraggio was reduced by grazing the medic pastures, up to and during seed maturation, however, Harbinger AR did not suffer a similar reduction even though the meaned seed yield was higher than Paraggio in 1991. Thorn and Revell (1987) reported similar decreases in seed yields of Paraggio and Harbinger in response to grazing but they were grazed as single species stands, not as mixtures as was the case in this study.

Glyphosate applied in September 1991 (Pasture topping) reduced the total seed yield of both Paraggio and Harbinger AR below a sustainable level, 36 kg/ha, compared to an experiment mean of 130 kg/ha. This was reflected by the fact that the seeds in each pod of Paraggio were reduced by almost 50% and Harbinger AR by almost 75%. This difference was most likely due to the glyphosate being applied during the peak flowering period of Harbinger AR and prior to the peak flowering period of the later-maturing Paraggio. If this result is true, the extensive use of the pasture topping strategy in the semi-arid regions of Australia, to control grass seed set in medic pastures, may have caused significant losses in seed yield and have reduced the success of the ley-farming system.

Glyphosate applied in July 1991 (Winter cleaning) reduced the seed yield of Harbinger AR due to the non-selective nature of the herbicide: however, it did not cause a comparable reduction in the seed yield of Paraggio which indicated a measurable degree of tolerance to sub-lethal doses of the herbicide. This tolerance has been confirmed (A Lake pers. comm.). The use of glyphosate as a winter grass control strategy is widely practised on farms in the semi-arid zone of south-east Australia, (as is Pasture topping) and the success of this practice appears to depend in part on the medic cultivar.

Fluazifop applied in July 1991 (Selective grass control) increased the seed yield of Harbinger AR and Paraggio above all other treatments, except Paraggio with the winter cleaning treatment. The removal of grass competition resulted in a total medic seed yield of about 200 kg/ha, considered by Carter (1981), as a minimum amount to maintain the stability of a pasture-cereal rotation.

The seed yields achieved by each cultivar in 1992 in response to the herbicides applied in 1991 reflected the later maturing pattern of Paraggio, and the success of the grass control (1991) and the subsequent grass densities (1992). The reduction in grass competition resulted in increased seed yields: Paraggio with Selective grass control had a seed yield of 499 kg/ha, with Nil herbicide 357 kg/ha, Harbinger AR 257 and 167 kg/ha with the same treatments applied. The above average rain during seed set in 1992, would have reduced the effect of grass competition on the seed yield. Scott (1985b) found that in a season of average rainfall, at Condobolin, grass removal competition increased medic seed yields by more than 100%.

Grazing the mature medic seed pods over the summer of 1992/93 confirmed the results of the studies by Carter (1981). He showed that greater survival and persistence occurred in species with small seeds and seed pods, compared to larger seeds and seed pods, which is a better reflection of Harbinger AR compared to Paraggio. The mean seed reserves of Paraggio were reduced from 309 to 184 kg/ha and Harbinger AR 198 to 174 kg/ha, during the period December 1992 to 30 January 1993 when stocked at 17 DSE/ha. This constituted an annual stocking rate of 3 DSE/ha which is close to the district average. These reductions represented a 40% decrease in the Paraggio seed reserve and 10% in the Harbinger AR. Carter (1981) reported comparable results when he applied an annual stocking rate of 10 DSE/ha and measured a 90% decrease from a *Medicago truncatula* seed reserve on a hard-setting red-brown earth. The results of this thesis study clearly indicate that sheep will remove significant levels of medic seed and grazing should be closely monitored over the summer-autumn period in the Mallee environment. Sheep grazing over the summer-autumn period will bury large amounts of pod; however, the potential for wind erosion on the sandy mallee soils as a result of prolonged grazing and denuding the soil is a second important consideration.

The retained seed reserve, of about 350 kg/ha, concurs with Cocks (1988) as to the value and potential of the medic seed pod as a grazing resource. However, consideration must be given to stocking level and timing of stock removal, as grazing may reduce seed reserve below a sustainable level. The above-average rain in 1992 resulted in seed yields much higher than that reported for the semi-arid regions (Latta and Quigley 1993) and this made grazing acceptable. However, if extended grazing had been practised in 1991 and caused a 40 to 50% reduction in seed reserves (from 130 kg/ha down to 60 to 70 kg/ha) the seed reserves would have been too low to allow a desirable plant emergence of 400 plants/m^2.

Pasture residue below 3 t/ha as a result of grazing at less than 3 DSE/ha during the late-spring period of 1991, increased the permeable seed percentage in Harbinger AR. This was most probably caused by decreased insulation as suggested by Quigley (1988), and the resultant greater temperature variation (Quinlivan 1971a). However, there was not a similar reaction from Paraggio, presumably because it has an inherently higher percentage of permeable seed, which may have reduced the impact of diurnal temperature fluctuations.

Pasture topping induced a higher level of permeable seed in Harbinger AR and Paraggio. The seeds/pod of Paraggio were reduced by almost 50% and Harbinger AR by almost 75%. However, the lower number of seeds/pod did not increase the seed unit weight, which could have explained the higher permeable seed percentage (Taylor 1971). The position of the seed in the pod may have had a significant effect. Less than 1 seed per pod in Harbinger AR, in response to the Pasture topping treatment, meant that each seed may have been at the calyx end of seed-pod, and therefore is more probable to become permeable and imbibe (McComb and Andrews 1974). Pasture topping may have shortened the length of time available for seed filling which in turn would have increased the percentage of permeable seed as discussed in Taylor and Ewing (1992).

The most desirable medic seed permeability pattern, as described by Crawford *et al.*(1989), have no permeable seed until mid-April when 30% of seed becomes immediately permeable, was not even approximated in this study. In 1991/92 Paraggio had 10 - 20% permeable seed during January which increased to near 30% by the end of February. Harbinger AR generally maintained less than 10% seed permeability until at least March, then it increased to 13%. Rain in early February 1992 (18 mm) may have caused a loss in seed reserves by imbibition and germination without emergence. This is reflected in the seed loss of Paraggio between 16 December 1991 and 21 April 1992 presented in Table 4.4.

The percentage of permeable seed of Harbinger AR and Paraggio was less throughout the 1992/93 summer-autumn period, than Latta and Quigley (1993) reported for Harbinger and Paraggio. Oram (1990) described Harbinger and Harbinger AR as similar agronomically and that comparability between the two cultivars is made in this thesis study. In this study Paraggio had increasing levels of permeable seed from 30 December at each of the subsequent three collection times. However, a maximum 11.5% permeable seed on 17 April was much less than the 20 to 40 % measured in 1991/92. The level of Harbinger AR permeable seed remained constant at less than 1% throughout the course of the study. High rainfall over the spring and early summer coupled with 3 to 3.5 t/ha of pasture residue may not have allowed the seed to initially dry adequately before undergoing the required temperature fluctuations as described by Quinlivan (1971a). Temperature data (Fig.3.1) indicates lower than average maximum temperatures over the 1992/93 summer period. Taylor and Ewing (1992) studied the effect that the growing environment has on the seed softening patterns of *Medicago* spp. and provided a feasible explanation for the lower seed permeability percentage in response to wetter, longer growing seasons. To sustain plant densities the higher seed yield as a result of the more favourable growing season would increase the available seed reserve to partially compensate for the lower soft seed percentage. The lower percentage of permeable seed than described by Crawford *et al.* (1989) and Latta and Quigley (1993) was maintained in April 1994 because most seed had been produced in 1992 and retained its high level of hardseededness as suggested by Taylor and Ewing (1992).

Paraggio had higher levels of permeable seed than Harbinger AR during February 1993. The number of Paraggio seeds/pod were reduced by 0.6 between 30 January and 1 March, while the number Harbinger AR seeds/pod recorded no loss. Several factors may have caused the 9% Paraggio seed loss: 1) 13.8 and 13.4 mm of rainfall on 25 and 27 January provided adequate moisture for germination; 2) cultivation on 2 February buried seed pods, which may have been the catalyst for increased permeability by reducing the plant residue, or by the extended seed moisture contact period.

The study showed the benefits of establishing a cultivar mixture of different maturity times, and seed permeability percentages, to best optimise productivity and persistence in variable seasonal conditions encountered in the semi-arid Mallee regions of south-east Australia. The potential medic seed losses, which may result from excessive summer-autumn grazing and premature germination due to summer rain, require continual monitoring to ensure the retention of a viable seed reserve. However, the evidence suggests that the medic seed and seedpod can provide a useful feed resource, and permeable seed levels of 30% have the potential to increase pasture productivity through increasing medic plant densities from a fixed seed reserve.

CHAPTER 5

GENERAL DISCUSSION AND CONCLUSIONS

5.1. The effects of pasture management strategies on the productivity of an annual medic pasture and the following wheat crop

Benefits derived from the use of grass-control herbicide strategies with the aim of reducing grass and maximising the medic component have been widely promoted through commercial interests over a number of years. In the semi-arid zone the benefits derived from using a grass-selective herbicide in comparison to non-selective options or alternatively accepting the grass component has not been well documented. The effects of sheep grazing on pasture yield and botanical composition in conjunction with concurrent herbicide applications is also not well documented.

Fluazifop (Fusilade^{R}) applied in Year 1 of a two year pasture phase increased the total herbage production in Year 2 and the medic seed yield in both years. It restricted the grass component below 10% and produced a 20% increase in wheat yields and a minimum 1% increase in grain protein levels in comparison to both non-selective and no herbicide applications.

Sheep grazed at approximately double the district stocking rate reduced the grass component and improved pasture quality through increasing the legume component, which improved wool production. Doubling the stocking rate over two years maintained similar wool production/head and live-weight on less available herbage. It also increased the wheat yield and grain protein levels.

The use of glyphosate at grass anthesis in Year 1 caused a significant reduction in medic seed yield. This subsequently reduced medic plant emergence and winter herbage production in Year 2. Glyphosate applied in Year 1 as a winter cleaning treatment reduced total herbage production: however, it did not reduce medic seed yields in Year 1 or herbage production in Year 2.

Both glyphosate treatments (applied in Year 1) reduced the grass densities which emerged in Year 2: however, the grass component constituted about 40% of the pasture component by 7 September (Year 2). This produced some improvement in wheat yields and grain proteins in comparison to the Nil herbicide treatment (about 60% grass component) in response to reduced levels of Take-all root disease.

The grass component in July of the second pasture year (1992) was reflected in the cereal root disease level in September (1993). Approximately 50 plants/m^2 of annual grass resulted in acceptable Take-all disease levels. However, annual grass competition in 1993 reduced the wheat yield potential of the glyphosate treatments.

The selective eradication of annual grasses from the annual medic pasture improved the productivity of both the pasture and wheat phase. These results differ from a number of studies which have found a reduction in total pasture production in the absence of annual grass (Venn 1984; Thorn and Perry 1987; Stephenson and Mitchell 1993). The interrelationship between early pasture production and plant density has been documented previously (Adem 1977; Abd El-Moneim and Cox 1986). Four hundred plants/m^2 has been considered an acceptable density to guarantee early feed production, overcome competition from neighbouring plants and produce adequate seed to maintain the seed reserve (Carter 1981). The unreliable rain which is a feature of agriculture in the semi-arid zone is the variable most likely to affect the optimum plant density. Below-average rain results in excessive plant competition which reduces seed yield in response to high plant densities. Above-average rain improves early herbage production in response to high plant densities.

In the establishment year of this study, 1991, a mixed pasture of 131 plants/m^2 of medic and 100 plants/m^2 of annual grass did not increase the winter herbage production compared to a grass-free 131 plants/m^2 of medic. However, the medic seed yield was reduced by the mixed pasture in a season of lower-than-average rainfall, 150 kg/ha compared to 200 kg/ha respectively.

In the second year (pasture regeneration in 1992) medic herbage production was correlated with plant densities. Production was increased at 600 plants/m^2 in comparison to 400 plants/m^2. In a year of higher-than-average rainfall there was no indication that 600 plants/m^2 of medic maximised the early herbage production as 400 plants/m^2 of medic in the Winter cleaning treatment had reduced early production in comparison. However, a mixture of 400 plants/m^2 of medic and 200 plants/m^2 of grass measured in the Nil treatment reduced both the herbage production throughout the season and the medic seed yield. The Walpeup study failed to confirm that increasing medic plant densities reduced the grass component due to competition. Approximately 400 plants/m^2 of annual medic can be considered an appropriate figure to provide a basis to maximise pasture and subsequent cereal productivity within the range of seasons encountered in this region. Rain is a major determinant of medic seed yields that are capable of providing regenerating medic plant densities of 400/m^2. However, volunteer plant competition can reduce medic seed yields by up to 50% irrespective of rain, hence weed control strategies are important options to maximise seed yields.

5.2. The effects of genetic diversity, plant density and rainfall on annual medic production and persistence

The persistence of medic cultivars provides the basis for the success of the genus in the semi-arid region and it is considered that an increased level of hard-seededness increases the persistence of a specific medic cultivar. This study has shown that there is a role for a later-maturing, soft-seeded cultivar (Paraggio) to be grown in conjunction with a hard-seeded, early-flowering, small-seeded cultivar (Harbinger AR).

The cultivars Harbinger AR and Paraggio improved the productivity of the pasture in response to contrasting seasonal conditions. In a growing season restricted to 4 months in Year 1, with less-than-average rain, Harbinger AR seed yields were generally higher than Paraggio. The increased seed yield of Harbinger AR compared to Paraggio was not reduced by the higher stocking rate. In Year 2, Paraggio produced double the seed yield of Harbinger AR under both low and high stocking rates. It better utilised the longer, seven month growing season of 1992 and higher-than-average rain. It also provided more high quality fodder over the summer months in the form of medic pods and retained 200 kg/ha of seed after being grazed at 17 DSE/ha for a period of 120 days (October to February).

In 1991/92 the percentage of permeable Harbinger AR seed was maintained at or below 10% until April when it increased to 13%. Paraggio had a permeable seed level varying between 10 and 30% over the course of the summer period. Paraggio could potentially have suffered a loss in seed reserves, in the event of significant summer rain, which would have limited viability in 1992. Harbinger AR had about 95% of seed protected from a 'false' seasonal break to ensure survival. However, in April 1993 when Harbinger AR had less than 1% permeable seed it could not be a significant pasture component. Following the cereal phase in the rotation in 1993 the percentage of permeable Harbinger AR seed had increased to 4% for the next pasture phase (1994), Paraggio had a permeable seed percentage of 18%. Paraggio retained seed reserves of about 150 kg/ha in the autumn of 1994, Harbinger AR about 100 kg/ha. Therefore about 25 kg/ha of Paraggio and Harbinger AR seed (approximately 10% permeable seed from the 250 kg/ha seed reserve) was available to regenerate in the 1994 pasture phase, assumming a 50% establishment rate a density of about 350 medic plants/m^2 should ensure.

From these studies at Walpeup the value of mixing cultivars with differing maturity and agronomic characteristics to maximise herbage and seed production over the range of seasons encountered in the Mallee region of Victoria has been established. If farmers within the region establish and maintain medic pastures with a low grass component and with plant densities of or more than 400 plants/m^2 there is likely to be a substantial increase in farm productivity through increased feed supply leading to higher stocking rates and decreased root diseases, notably "Take-all" and cereal cyst nematode with consequent higher returns from wool and wheat.

5.3. Recommendations

Medic-based pastures in semi-arid farming systems are often perceived to be having a declining impact in sustaining and improving cereal and livestock production. This study has produced results which give confidence in recommending pasture management strategies for a pasture-pasture-wheat rotation to improve farm returns. The key points of this recommendation include:

Year 1

1. Assessing medic seed reserves prior to the commencement of a pasture phase to

determine the need to sow more seed.

2. Sowing a 50/50 mixture of Harbinger AR and Paraggio medic at a rate which will establish more than 100 plants per m^2 (8 kg/ha if no significant numbers of volunteer medic are present).

3. Reducing the grass component in Year 1 (early in growing season) of the pasture phase with an above average stocking rate and herbicides (fluazifop preferably or glyphosate).

4. Restricting grazing pressure during flowering and seed maturation to maximise medic seed production.

5. Avoiding pasture topping in the medic establishment year.

6. Restricting grazing over summer to protect medic seed.

Year 2

7. Burying medic pods with light tillage during March prior to the second pasture phase to improve medic plant density and protect seed from grazing.

8. Assessing grass numbers after emergence in the second year to check that densities are less than 50 plants/m^2. Higher grass densities should be removed with glyphosate.

9. Maximise grazing at least until flowering and consider lambing in winter, instead of autumn, to the benefit of both the cropping and livestock enterprises.

10. Pasture topping at grass anthesis, if required, to reduce grass competition in the subsequent cereal phase.

Year 3

11. Continuing to graze to reduce pasture residue (medic pods are not overgrazed until plant residue falls below about 3 t/ha).

12. Cultivating in preparation for the cereal crop following summer/autumn rain.

13. Sowing wheat at optimum time, which has been made possible because of low grass populations.

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