The effect of haloxyfop-R-methyl ester and imazamox herbicides, tine or no tillage and nine different medic cultivars on the seed and dry matter production as well as the quality of medic pastures

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Declaration

I, the undersigned, hereby declare that the work contained in this thesis is my own original work and that I have not in its entire entity or in part submitted it at any other University for a degree.

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Abstract

The aim of this study was to determine the effect of a grass herbicide, a broadleaf herbicide with some grass control capabilities, method of tillage (tine and no-tillage) at planting of wheat as well as different medic cultivars on the regeneration, dry matter (DM) production and quality of a medic pasture.

The trial was conducted at Langgewens experimental farm in the Swartland wheat producing area. Nine medic cultivars of three different species were evaluated after being sprayed with either haloxyfop-R-methyl (HAL) ester or imazamox (IMI) and subjected to either a tine tillage or a no tillage treatment at planting of wheat. Soil samples were taken during January 2000 to determine the size of the medic and weed seedbank as well as the degree of dormancy in the medic seeds, while DM samples were taken throughout the growing season to determine the DM production of the different medic cultivars and weed species. DM samples taken during October 1998 on the same pasture, were used to determine the crude protein (CP) and neutral detergent fibre (NDF) content of the pasture. The samples were subjected to *in vitro* digestion and the digestibility of pasture CP (DCP), NDF (DNDF) and DM (DDM) were determined.

Results showed that seedling establishment differed between cultivars used, herbicide treatments applied as well as the crop stage in the rotation. The cultivars produced more seedlings where IMI was applied compared to HAL as well as where the area consisted of two year pasture compared to one year pasture (1998) and one year wheat (1999). After a year of pasture and a year of wheat, cultivars Sephi and Paraggio produced the most seedlings, while Caliph and Orion produced the least. Caliph however, showed a very high degree of seed dormancy while Orion's low seedling establishment was due to its sensitivity to the IMI herbicide used.

Little difference was found between the nine cultivars early in the season (July - August) with regard to cumulative DM production, except for Orion, whose growth was severely damaged by the IMI treatment. At the end of the growing season (October), the cultivar Caliph's cumulative DM production (2010.1 kg/ha)

was significantly higher than all the other cultivars, except for Parabinga (1053. 4 kg/ha).

Different pasture samples, of which the botanical composition was known, was analysed for CP, NDF, DDM, DCP and DNDF. There was no significant difference in pasture composition during 1998 but variation in the pasture composition did however cause the IMI treatment, compared to the HAL treatment, to have a lower DNDF and DDM content. A modelling procedure was used to predict the pasture quality parameters (CP, NDF, DDM, DCP and DNDF) from the pasture composition (medic hay, medic pods, grassy and broadleaf weeds). This prediction of CP, NDF, DDM, DNDF and DCP from the pasture components had a relative low accuracy (49 -74.1 %) and a further refinement of this model for possible use on farms in order to improve grazing management and animal production is advised.

In conclusion it could be said that broadleaf weed control caused a definite increase in medic seed and DM production, but Orion should not be used with an IMI herbicide. All the cultivars, except for Orion, produced enough seedlings up to the second year to ensure sustainability of the medic pasture. All the cultivars, except for Orion, produced a sufficient amount of DM early in the growing season. Caliph however, produced by far the most DM later in the growing season.

A reduction of broadleaf weeds and medic pods will increase the digestibility of NDF and DM and therefore increase the quality of the pasture. Pods however are an important part of summer forage and the aim should therefore rather be to reduce the number of broadleaf weeds in the pasture.

Uittreksel

Die doel van hierdie studie was om die effek van 'n gras en breëblaar onkruiddoder (wat sekere grasse beheer), metode van bewerking tydens die saai van koring asook nege verskillende medic kultivars op die regenerasie, droë materiaal produksie en kwaliteit van medic weidings te bepaal.

Die proef is gedoen op Langgewens proefplaas wat geleë is in die Swartland koring produserende gebied. Nege medic kultivars is geëvalueer nadat die weiding met of haloxyfop-R-metiel ester (HAL) of imazamox (IMI) onkruiddoders gespuit is en onderwerp is aan of 'n vlak tand of geen bewerking tydens die saai van koring. Grondmonsters is geneem in Januarie 2000 om die grootte van die medic en onkruid saadbank asook om die graad van dormansie in die verskillende medic kultivars se sade te bepaal. Droë materiaal monsters is gedurende die 2000 groeiseisoen geneem om die droë materiaal produksie van die verskillende medic kultivars asook onkruid spesies te bepaal. Droë materiaal monsters is gedurende Oktober 1998 geneem en gebruik om die ruproteïn (CP) en neutraal oplosbare vesel (NDF) inhoud van die weiding te bepaal. Die monsters is *in vitro* verteer en die verteerbaarheid van CP (DCP), NDF (DNDF) en droë materiaal (DDM) is bepaal.

Resultate wys dat saailing vestiging verskil tussen die verskillende kultivars wat gebruik is, verskillende onkruiddoder behandelings asook die stadium van die weidings/koring. Die kultivars het meer geproduseer waar die weiding met IMI behandel is in vergelyking met waar HAL toegedien is, asook waar koring nog nie gesaai is nie. Na 'n jaar van weiding en 'n jaar van koring, het die kultivars Sephi en Paraggio die meeste saailinge, en Caliph en Orion die minste saailinge gehad. Caliph het egter 'n hoë graad van dormansie in sy saad getoon, terwyl die swak vestiging van Orion die gevolg is van diè kultivar se hoë sensitiwiteit teenoor IMI.

Min verskil is gevind tussen die nege kultivars, vroeg in die groei seisoen (Julie - Augustus), wat kumulatiewe droë materiaal produksie betref, behalwe vir Orion wat erg beskadig is deur die IMI behandeling. Aan die einde van die groeiseisoen

(Oktober 2000) was die kumulatiewe droë materiaal produksie van die kultivar Caliph (2010.1 kg/ha) betekenisvol hoër as al die ander kultivars behalwe vir Parabinga (1053. 4 kg/ha).

Weidingsmonsters, waarvan die botaniese samestelling bekend was, is ontleed vir CP, NDF, DDM, DCP en DNDF. Daar is geen betekenisvolle verskille gevind in die botaniese samestelling van die weidingmonsters geneem in 1998 nie,maar die variasie in botaniese samestelling het veroorsaak dat IMI in vergelyking met HAL 'n laer DNDF and DDM inhoud het. 'n Model is opgestel wat die weidingskomponente (medic hooi, medic peule, gras en breëblaar onkruide) gebruik om die kwaliteits parameters (CP, NDF, DDM, DCP en DNDF) van die weiding te skat. Hierdie skatting van CP, NDF, DDM, DCP en DNDF deur van die weidingskomponente gebruik te maak het 'n relatiewe lae akuraatheid gehad (49 -74.1 %) en verdere verfyning van hierdie model vir moontlike gebruik op plase, ten einde weidings bestuur en diere produksie te verbeter, word voorgestel.

Die gevolgtrekking kan gemaak word dat breëblaar onkruidbeheer 'n definitiewe verbetering in die medic saailing en droë materiaal produksie van die medics te weeg gebring het, maar die kultivar Orion behoort nie saam met 'n IMI gebruik te word nie. Al die getoetste kultivars, behalwe Orion, het voldoende saad oorlewing vertoon tot en met die tweede jaar van die rotasie om lewensvatbaarheid van die sisteem te verseker en alle kultivars, behalwe Orion, het voldoende droë materiaal produseer vroeg in die groeiseisoen. Caliph het egter laat in die groeiseisoen by verre die meeste droë materiaal geproduseer.

'n Vermindering in die hoeveelheid breëblaar onkruide en peule in die weiding sal tot 'n verhoging in die verteerbaarheid van NDF en DM lei en dus 'n verhoging in die kwaliteit van die weiding tot gevolg hê. Peule is egter 'n belangrike bron van voedsel aan weidende diere gedurende droë somermaande en die verbetering van weidings moet eerder gedoen word deur te poog om breëblaar onkruide te beheer.

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List of Abbreviations

2P	Two years pasture
Al	Aluminium
a.i.	Active ingredient
B	Blocks
C	Cultivar/s
°C	Degrees Celsius
C_p	Mallows' C_p
CP	Crude protein
cm	Centimetre
CV	Coefficient of variance
DCP	Digestible crude protein
DDM	Digestible dry matter
DM	Dry matter
DNDF	Digestible neutral detergent fibre
g	Gram
H	Hydrogen or herbicide treatment
ha	Hectare
HAL	Haloxyfop-R-methyl ester
IMI	Imazamox
kg	Kilogram
l	litre
LSD	Least significant difference
N	No-tillage
NDF	Neutral detergent fibre
M	*Medicago*
m^2	square meter
m^{-2}	per square meter
me	Milli-equivalent
ME	Metabolisable energy

mg	Milligram
MJ	Mega joules
mm	Millimetre
%	Percentage
p	Probability
P	Phosphorus
PCP	Percentage crude protein
PNDF	Percentage neutral detergent fibre
PW	A year of pasture and a year of wheat
spp.	Species
t	Ton
T	Tine tillage
X	Indicates interaction between treatments
$\leq$	Smaller or equal to

Contents

Language and style used in this thesis are in accordance with the requirements of the *South African Journal of Plant and Soil.* This thesis represents a compilation of manuscripts where each chapter is an individual entity and some redundancy between chapters has, therefore been unavoidable.

CHAPTER 1

Introduction

In the Southern Cape and Swartland regions of South Africa (Figure 1) it is important to make use of species rotation in crop-animal production systems to improve sustainability by decreasing the incidence of diseases and by increasing the organic nitrogen content of the soil.

The crop-pasture rotations in these areas can be divided in two main groups. The first, mainly used in the Southern Cape, exists of a longer type of rotation and includes the use of perennial lucerne for an average of five but even up to 10-15 years (Van Heerden & Tainton, 1987) followed by crops (wheat, barley, canola or lupins) for a period of five or at most 10 years. The length of different crop or lucerne (*Medicago sativa*) phases in the rotation may vary according to soil, climatic or economical factors. In the Swartland area, and less frequent in the Southern Cape, because of climatic and soil conditions, a shorter rotation system is used. This system implies the use of annual legumes such as medics (*Medicago* spp), subterranean (*Trifolium subterraneum*) and other types of clovers (*Trifolium* spp). These annual legumes are recommended to be used in a rotation of alternating legume pastures and wheat crops in successive years.

The use of *Medicago* (e.g. medics and lucerne) and *Trifolium* species (e.g. subterranean and balansa clover) as pasture have several advantages in both long term (five years lucerne and five years cereal) and short term (one year medics and one year wheat) rotation systems. The break in cereal/crop production in successive years, by planting a pasture legume, helps to increase the organic nitrogen content of the soil because lucerne and medics have the capability to bind atmospheric nitrogen through *Rhizobium* bacteria (Du Toit, 1978; Ladd, Oades & Amato, 1981) and helps to control root diseases such as take-all (*Gaeumannomyces graminis* var. *tritici*). The latter is only true if grasses that act as hosts to diseases are controlled by means of herbicides, grazing or cultivation. For this reason weed control in the pasture will most likely result in an increase in wheat yield the year after weed was controlled, but the response will depend on the degree of weed infestation (Macleod & Macnish, 1989; Macleod, Macnish & Thorn, 1993).

Weed control in pastures may also help to improve pasture quality which will increase wool and meat production if sufficient dry matter and energy rich pastures are available after weeds have been controlled. Thus, weed control may improve the quality of a pasture by removing plants lower in protein and possibly lower in digestibility (Marten & Anderson, 1975).

The sustainability (both economical and biological) of medic pastures in a rotation of one year wheat followed by a year of medics, depends largely on the ability of the annual legume to regenerate/re-establish itself after a wheat year and to produce sufficient grazing of a high quality. Seed production and dry matter production, and thus sustainability in a given environment (soil and climate), depend largely on the cultivar used, but are also affected by the method of tillage used for wheat production (Kotze, Langenhoven & Agenbag, 1998) and the control of problem weeds. Weeds of the Southern Cape and Swartland region can be divided in two groups namely grassy- and broadleaf weeds. The most important grass weed species in legume pastures and crops are: rye grass (*Lolium multiflorum* and *L. rigidum*), brome grass (*Bromus diandrus*), mouse barley (*Hordeum murinum*), wild oats (*Avena fatua*), canary grass (*Phalaris canariensis*), annual blue grass (*Poa annua*) and volunteer wheat (*Triticum* spp) (Le Roux, 1986). Volunteer wheat may be a weed in wheat when the cultivars differ from the one sown in a previous year. There are also several broadleaf weeds, but the most important ones in wheat and legume pastures are cape marigold (*Arctotheca calendula*), wild radish (*Raphanus raphanistrum*) and spiny emex (*Emex australis*) (Le Roux, 1986).

At present, little is known about the effect of these weeds on pasture yield and quality and the response of different cultivars to chemical and physical control methods.

The objective of this study can be derived from the above as to help improve the choice of medic cultivar used as well as accessing the advantages or disadvantages of imazamox and haloxyfop-R-methyl ester herbicides and tillage methods (Tine or No-till) used in wheat/medic pasture rotation systems in the Swartland wheat producing area of South Africa.

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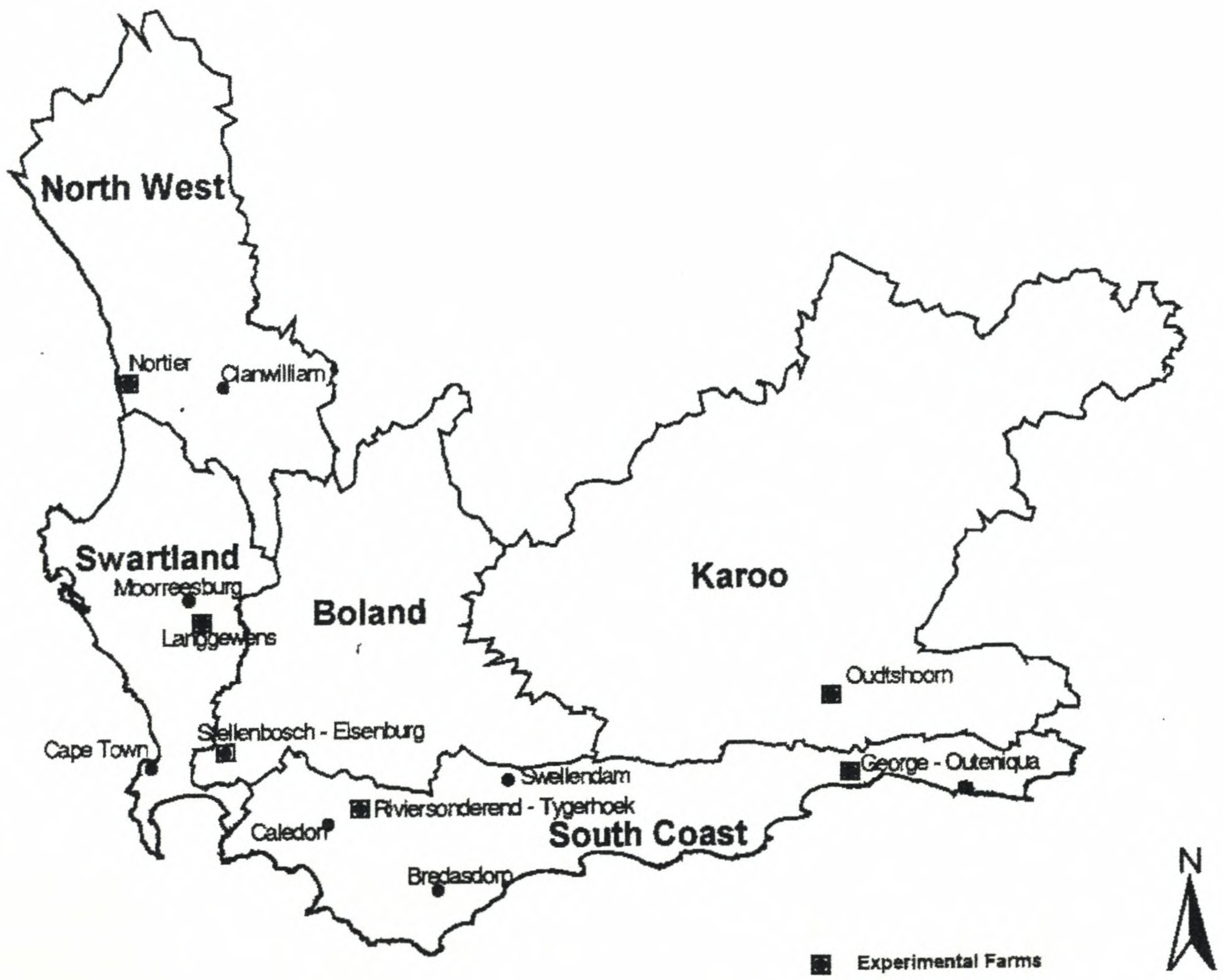

Figure 1 Homogenous sub regions constituting the winter rainfall area (Brand, 1995)

CHAPTER 2

Literature review: Factors influencing the success of medics in rotational systems with cereals

Cultivar choice

1.1 Soil and climatic requirements

The choice of the best cultivar where medics (*Medicago* spp) is used in rotation with crops will depend largely on the fertility and pH of the soil as well as climatic conditions. Metcalfe (1990) showed that different medic species and cultivars differ with regard to soil pH, texture and rainfall requirements, while Kotze (1990) found significant differences between *Medicago* species with regard to their response to daylength and temperature regimes. The average requirements for medics are a soil pH of moderately acidic to alkalic, a rainfall of 350 mm during the growing and a loamy soil texture (Metcalfe, 1990).

1.2 Dry matter and seed production

Cultivars differ in their ability to produce dry matter and pods during the growing season. It is however their ability to adapt to the environment that will ensure high yields in risky environments. Drought may have a large effect on the amount of burrs produced in a year and thus influencing the size of the seed bank (Gillespie, 1983), while Collins (1981) found that seed yield of subterranean clover is reduced when the growing season is shortened. This response may be due to either reduction in the number of burrs produced and/or, to a lesser extent smaller seeds in the pods. Van Heerden and Wasserman (1977) also found a reduction in seed production where the growing season was shortened due to time of planting rather than weather conditions. Collins and Quinlivan (1980) found that both a sub- and supra-optimal moisture supply for subterranean clover resulted in a reduction in seed production.

1.3 Seed dormancy and breakdown of dormancy

A very important contributing factor to the success of annual legume species in a variable rainfall environment is the rate of breakdown of dormant seeds (Rossiter, 1977). The more dormant the seeds, the larger the seedbank will be and the longer the annual legume will persist in the rotation (Blumenthal & Ison, 1994). Medics produce a seedbank which consists of up to 90% dormant seeds (Cocks, 1988) and this seedbank allows the medics to survive during the wheat/crop phase and provide a buffer against drought and over-grazing. It is therefore important to have a sound knowledge of the seedbank to be able to manage sustainable cereal pasture rotations (Quinlivan, 1971). Cocks (1992) found that the seedbank composition of a mixture of medics species, stabilised one season after the medics were sown. This is probably due to the non-selective grazing of pods during the summer months and differences in the seed production ability and rate of breakdown of dormancy between cultivars. Smith, Cocks and Ewing (1998) investigated short-term seed softening (breaking down of dormancy) of *Trifolium subterraneum*, *T glomeratum* and *Medicago polymorpha*. They found that *M polymorha* (cv. Serena) tends to soften more rapidly during the autumn and subterranean clover more rapidly during the summer months. They also found that larger seeds were more likely to soften during the first year after production. Their results confirmed earlier findings by Taylor (1981). Autumn seed softening is a desirable characteristic of annual legumes in Mediterranean climates because it prevents summer germination due to false breaks in season and hence death of seedlings (Taylor, 1996b). This phenomenon makes the choice of cultivar even more important. More than half of the seeds softened between March and June (autumn) for the cultivars Serena and Santiago (*Medicago polymorpha* L.) when grown under a wide range of environmental conditions (Taylor, 1996a), while *M truncatula* was found to be more vulnerable to seedling losses due to seed softening and germination during January-February, and *M scutellata* to seedling losses during August-December (Lloyd, Taylor, Johnson & Teasdale, 1997). Taylor (1996b) found that autumn seed softening apparently did not relate to production region, but is of the opinion that this tendency needed further investigation in the country of cultivars' origin. He also suggested that this measurement might be a good characteristic to include in selection programs.

Dormancy in subterranean clovers and medics can be broken by artificial heat treatment. Taylor (1981) found that constant heat treatment of *Trifolium subterraneum* seeds (max. 80 °C) softened the seeds, but alternative high and low temperature treatments (60/15 °C) caused even more rapid changes in seed softening. Taylor (1981) suggested a possibility of two stages of thermal seed softening, one being the weakening of the strophiolar region and the second where the strophiole is rendered permeable to water through fluctuating temperatures.

McComb and Andrews (1974) found that seeds of *Medicago littoralis*, *M scutellata*, *M tornata* and *M truncatula* soften faster if out of the burr opposed to being inside the burr when fluctuating temperatures (15-16°C daily) are applied. Similar results were not found for *M polymorha* and *M rugosa*. *Medicago* seeds soften first at the calyx end of the burr and then soften in sequence up the burr spiral (McComb & Andrews, 1974; Porqueddu, Loi & Cocks, 1996). Seed softening may also be enhanced by damaging the seed coat (Evans & Smith, 1999). Seed softening may for this reason also be affected by method of soil tillage. It can be expected that seed softening will be slower when no tillage is practiced compared to intensive and aggressive mould-board and disc ploughing.

Production techniques

2.1 Weed control

Weed control in a pasture-crop rotation is defined as the removal of those plants that will cause a decline in either crop or sheep production. It is necessary to control some weed species in pastures because they will cause injury to sheep, e.g. brome grass or cause a decline in the quality and palatability, e.g. wild radish of the pasture (Aligianis, 1977; Marten & Anderson, 1975). Others need to be controlled to maximise wheat yield, especially weeds with high competitive and disease carrying capabilities, e.g. wild radish and mouse barley respectively (Aligianis 1977). There are several factors influencing the amount of weedy plants in a pasture and there are numerous ways to control them. These methods of weed control are divided into three groups (Rao, 2000):

1) Physical: This includes cultivation, burning of weed stubble, hay cutting, time of sowing, fertilisation, etc.

2) Chemical: This is the control of weeds by use of synthetic chemicals, which are applied to the weed plants or the soil. Different groups of herbicides include contact or systemic; pre- or post-emergence; soil or leaf applied; broad spectrum or specific (grass or broadleaf weeds or specific species of weeds) and are classified with regard to the mode of action by which they kill the plants.

3) Biological: This is control of weeds by means of other biological agents. Grazing is probably the best example of biological weed control in pastures. Other methods of biological weed control include the use of fungi and insects (natural enemies).

2.1.1 The effect of weed control in pasture-crop rotation systems

2.1.1.1 Wheat yield

Grassy weeds compete with wheat for nutrients and water and may cause a decrease in wheat yield. In a study by Le Roux, Agenbag and Mills (1995) in a 1:1 medic/wheat rotation system, grassy weeds (*Bromus diandrus* Roth.) and *Lolium* spp.) were controlled by fluazifop-buthyl and Quazalofop-P-ethyl. This treatment reduced the number of grasses and incidence of take-all disease and increased the wheat yield for two years succeeding the herbicide application. These results support earlier findings by Venn (1984). Aligianis (1977) named the following grass species as possible hosts for wheat diseases: *Hordeum* spp (barley grasses), *Bromus* spp (brome grasses), *Lolium* spp (ryegrasses) and *Avena* spp (wild oats) may act as hosts for *Rhizotonia* root disease. Different stem, leaf and head diseases can also be hosted by these vectors/grasses. Barley grass may carry stem rust (*Puccinia* spp), while brome grass may carry glume blotch (*Septoria nodorum*). Wong, Dowling, Tesoriero and Nicol (1993) showed that weed control by high concentrations of glyphosate (0.72 kg a.i/ha) or pre-planting cultivation decreased take-all and *Rhizotonia* root rot diseases in wheat.

2.1.1.2 Animal production

Aligianis (1977) showed a decline in the quality of wool, meat and skins of sheep grazing on pastures highly infested by grasses such as *Bromus diandrus* and *Hordeum murinum*. These grasses may also injure sheep if their seeds penetrate the eyes of the animal. Van Heerden (1990) showed that grass control with fluazifop-buthyl and propisamide caused an increase in wool production and annual daily gain in weight of sheep on lucerne pastures (*Medicago sativa*). These results however did not apply for annual medics (*Medicago* spp). Weed control may influence the quality of the pasture and therefore animal production. The pasture may be influenced as follows:

2.1.1.2.1 The amount of feed on offer

Dove (1994b) found that as the amount of feed available to the animal declines, so does the performance of the animal. He found that pasture intake per bite will be close to maximum when the pasture contains more than 70 % digestible dry matter, more than 10-11 MJ ME/kg DM and more than 15 % crude protein. In general, green pasture supply begins to limit intake when the amount of feed on offer decreases below 1.2 to 1.5 t/ha.

Allden and Whittaker (1970) concluded that herbage intake relates more strongly to herbage length/height (estimated from tiller length) than with herbage yield and that there is little relation between herbage yield and intake. Bite size increased almost linearly with increase in tiller length. They also found that at larger tiller lengths, bite size and rate of biting varied inversely to maintain a constant rate of intake. Therefore, to compensate for low herbage availability, sheep can extend their grazing period from 6-13 hrs/day, but as the sheep extended their grazing period the compensation became progressively more incomplete.

2.1.1.2.2 Pasture digestibility

Pasture intake declines steadily as digestibility of the pasture decreases from 80 to 70 %, whereas the latter are taken as the minimum digestibility for economical feasibility. Sheep grazing a pasture with digestibility of 50-55 % would therefore be unable to maintain their weight (Dove, 1994b).

2.1.1.2.3 Botanical composition

When a legume (e.g. medics or lucerne) is included in a pasture, sheep tend to eat more of the pasture regardless of the digestibility of the pasture. This is because the feed is broken down quicker by the rumen organisms and as a result, leaves the rumen in a shorter time space and the feed intake increases (Dove, 1994b). His results have shown that sheep would eat 15-20 % more on pure legume stands compared to pure grass pastures. Legumes have a positive effect on animal performance by making the digested mixture of protein and volatile fatty acids in the rumen more efficient for use in animal growth.

2.1.1.2.4 Pasture protein content

When a pasture is in vegetative growing phase, grazing sheep normally selectively consumes high quality feed with digestibility higher than 75 % and crude protein content of above 20 % (Dove, 1994a). The only problem in this situation is that the protein content of the pasture is too high and causes a relative inefficient use of available protein. It is only with dry pastures where the protein content may be as low as 6 % that protein would be inefficient for animal production (Dove, 1994b).

2.1.1.3 Medic yield

Cotterill (1990) found that a grass content (*Bromus, Hordeum, Lolium and Vulpia* spp) of up to 40 % in pastures did not influence the dry matter production of subterranean clover (*Trifolium subterraneum*), but did influence seed production of legumes. When spray-topping is practised to control grass seed set (especially *Hordeum* and *Bromus* spp.), the time of application, rate and herbicide choice is important to ensure the sustainability of the annual legume (Gillespie, 1983). Wallace, Lancaster and Hill (1998) found that of the three most commonly used herbicides for spraytopping (non-selective), namely glyphosate, MCPA and paraquat, glyphosate and MCPA had the largest effect on seed production in medics when applied at rates higher than 90 g a.i./ha in mid to late flowering stage. Medic seed yield was reduced by up to 90 % if rates of 112 g a.i./ha glyphosate were applied in early to mid flowering. Paraquat applied at 100 g a.i./ha reduced seed yield of subterranean clover (*Trifolium subterraneum*) by 25-50 %. Wallace, Lancaster and Hill (1998) also found that MCPA and glyphosate reduced the dormancy in medic seeds, which makes the seeds more susceptible to germination during summer and early autumn. Thus, using these herbicides in a Mediterranean climate to control grasses may result in poor regeneration in a 1:1 wheat-medic rotation system, due to low seed production and summer germination. Differences in susceptibility of cultivars to herbicide application have been found by Pepler (1996) and his results for some medic cultivars are given in table 1. He found that at the prescribed rate of 48 g of a.i./ha imazamox, cultivar Orion was severely damaged, while the other medic cultivars tested showed only minor effects. As the rate of application increased so did the negative effect on the different cultivars but with the exception of Orion, all effects at the normal rate of 48g/ha may be regarded as very slight. Imazamox's effect on Orion will however definitely cause a decrease in seed production (Table 1).

Table 1 The influence of imazamox applications (48 and 96 g/ha) on different medic cultivars

		Cultivar								
		Cyprus	Mogul	Orion	Parabinga	Paraggio	Sephi	Serena	Santiago	Caliph
Phyto-toxicity Score	48 g/ha	1	1	5	1	1	1	1	2	*
	96 g/ha	2	4	5	4	2	4	1	5	*

* Not tested but might react the same as Cyprus

1=No Symptoms

2=Very Slight

3=Mild Symptoms

4=More Severe (Just Acceptable)

5=Heavy Stunting (Not Acceptable)

(Pepler, 1996)

Sandral, Dear and Coombes (1995) found a significant locality X cultivar X herbicide interaction in an Australian study where Bromoxinil, MCPA, 2,4-D, MCPA + terbutryn and MCPA + diuron were applied to different *Trifolium subterraneum* cultivars. These herbicides are used to control broad leaf weeds like paterson's curse (*Echium plantagineum*), capeweed (*Arctotheca calendula)* and a range of thistles (*Carduus* spp. and *Onopordum* spp.) in annual legumes. At the higher rainfall site, seed production was either not influenced or depressed by as much as 60 % whereas at the lower rainfall area, seed yield increased with as much as 115 %. Increases in seed yield was most profound in cultivars that matured in mid season and least in those that matures later (differential tolerance). They also found an increase in seed yield at lower application rates of these herbicides.

Herbicides may also be used to reduce certain medic or subterranean cultivars in the pasture. Schroder and Stapleton (1992) found that if dicamba, 2,4-D amine or glyphosate were sprayed during early flowering on *Trifolium subterraneum* (cv. Mount Barker) to deliberately reduce seed production, a reduction of 80, 46 and 39 % was found respectively. 2,4-D amine and MCPA+dicamba caused a decline of 83 and 77 % in cv. Yarloop respectively when sprayed during flowering. Thus, very little or no Yarloop or Mount Barker seeds will be added to the seed bank if these cultivars are sprayed by dicamba at 1.0 liter/ha during flowering. This method can therefore be used to reduce the seed bank of old cultivars (e.g. Mount Barker and Yarloop) in a pasture so that new cultivars can be introduced (e.g. Trikkala).

2.1.2 Methods of weed control

2.1.2.1 Physical weed control

There are several physical methods for controlling weeds, especially grassy weeds, in pasture-crop rotation systems. Competitiveness of legume species in pastures may be increased by phosphorus fertilisation because of an improved growth rate (Bolland & Baker, 1989). Other practices include burning, heavy grazing, hay making (Reeves & Smith, 1975), time of seeding (Regnier & Bakelana, 1995) and soil tillage (Forcella & Gill, 1986). The use of soil tillage as a method of weed control is diminishing due to the lower costs of herbicides and the high running costs of implements used for soil tillage. Although soil tillage is very effective as a method of weed control, the problem thereof in a medic/wheat rotation system is that the pods and seeds of the medics may be buried and therefore prevented to germinate after the wheat year.

Forcella and Gill (1986) found that time of tillage alters the seedbank of different pasture and weed species. Brome grass (*Bromus rubens*), silver grass (*Vulpia* spp) and subterranean clover (*Trifolium subterraneum*) became dominant only if the pasture was tilled in summer and early autumn. Annual ryegrass (*Lolium* spp) on the other hand became more abundant with late autumn and early winter tillage, while sorrel (*Rumex acetosella*) and wireweed (*Polygonum aviculare*) became only significant in winter ploughed soils. Jensen (1995) showed that cultivation during the day resulted in both higher emergence of weeds and emergence from greater depths than cultivation during the night-time. This is due to the stimulation of germination by light.

Smith, Cocks and Ewing (1998) found that sowing early in the growing season of *Trifolium glomeratum*, resulted in a higher dry matter production, seeds per inflorescence, inflorescence per m^2 and total seeds produced compared to sowing late in the growing season.
Although reduced tillage and direct drilling reduces runoff, lowers the pH and leads to an increase in total nitrogen in the soil in pasture crop rotation systems (Packer & Hamilton, 1993), chemical weed control was found to be very important to ensure successful crop production in the rotation systems (Le Roux, Agenbag & Mills, 1995).

2.1.2.2 Biological weed control

Grazing are regarded as the most important method of biological weed control in pastures, although others which include the use of fungi (Panetta, 1990) and natural competition between species (Panetta & Randall, 1993) do exist.

2.1.2.3 Chemical weed control

Herbicides are generally divided into different categories according to time or place of application, mode of action and selectivity. There are several herbicides that can be used for weed control in pastures. These herbicides vary from non-selective herbicides such as glyphosate and paraquat and broad spectrum herbicides such as 2,4 D and MCPA, to herbicides used for the selective control of either grasses (Aryloxyphenoxy propionic acid and cyclohexanedione oximes) or broadleaf species (imidazolinones). Because all non-selective and broad spectrum herbicides have an effect on annual legumes, these herbicides are used at reduced application rates (Rao, 2000).
Damage done to different *Medicago* spp with broadleaf weed control differs between different species. Chemical control of broadleaf weeds in medics and subterranean clover is also difficult because most chemicals have a detrimental effect on growth and thus seed production of medics and clovers, depending on

the growth conditions (Gillespie, 1988). Care should therefore always be taken when broadleaf herbicides are used on medic or subterranean clover pastures.

2.2 Soil tillage

Soil tillage in rotation systems is mostly done only at planting of the wheat or other cash crop and/or during the initial establishment of the pasture. It is generally excepted that the higher the cropping frequency the less burrs are produced in the long term, which will lead to a steady deterioration of the legume pasture (Gillespie, 1983).
Depth of sowing and the quality (especially seed size) of medic seeds used at planting are also important factors when establishing a medic-wheat rotation system. Black (1956) showed an increase in medic seedlings when seeds are larger and planted shallower. Soil tillage is often used to improve seedbed conditions and root development of wheat crops but it is important to know what the effect of different methods of soil tillage may be on the sustainability of the rotation system.

2.2.1 Methods of tillage

Kotze, Langenhoven and Agenbag (1998) and Cocks (1994) found that method of tillage (tine, disk or mould board) used for seedbed preparation of wheat in a 1:1 wheat/medic rotation system did not influence wheat yield significantly, but mouldboard and disk tillage decreased the amount of medic seedlings the following year due to burial of seeds. The deeper the tillage the more seeds will be buried and the poorer the regeneration (Reeves & Smith, 1975; Crawford & Nankivell, 1989). Carter and Fulwood (1993) showed that tillage method in an annual legume-crop rotation may also have a detrimental effect on legume dry matter and seed production. They found that deep burial of seed by disc or mouldboard tillage may bury seed too deep and hamper emergence, while normal scarifying at 6-8 cm causes little loss of potential legume seed germination and seedling emergence. Crawford and Nankivell (1989) found that

Medicago rugosa, *M scutellata* and *M truncatula* seed reserves lasted for a maximum of seven years in different rotation systems if tillage was done to a depth of 6 cm with a tine implement prior to wheat planting and all crops were harrowed directly after sowing. They also found that the more dormant the cultivar's seed the longer it will persist in the rotation system under these conditions. Shallow tine tillage therefore proved to be the best tillage method for medic re-establishment after wheat, but deeper (150 mm) tine cultivation is important to ensure maximum yield as a result of better root development. Taylor (1985) found that in a rotation system of one year pasture followed by a cash crop, no-tillage buried 44 % of clover seeds (*Trifolium subterraneum*) compared to 65 % by conventional tillage (disc plough once and scarifier twice at appropriate time intervals at 10 cm). Because of this, no-tillage resulted in a higher seedling density in the first year of regeneration of the pasture while the seedling density were higher where conventional tillage was practised in the second and third year. This is probably due to the larger number of residual seeds in the soil. Conventional tillage might therefore be advantageous in areas where seed production by annual pastures are unreliable, helping with the persistence of the pasture by bringing the buried seeds closer to the soil surface and burying hard seeds in good seed production years (Taylor, 1985).

2.2.2 The effect of burial on the regeneration of different medic cultivars in the pasture

Cocks (1994) found seedling re-establishment due to method of tillage to be better in *M. polymorpha* than in *M. rigidula*. Depth of sowing and the quality (especially seed size) of medic seed to be sown are also important when establishing medics into a wheat/medic rotation system. Black (1956) showed an increase in medic seedlings when seeds are larger and planted shallower.

2.2.3 Effect of burial on the breakdown of dormancy

Germination of annual legumes over a period of more than one growing season are regulated by dormancy (seed coat impermeability) (Quinlivan, 1971). Taylor and Ewing (1996) investigated the influence of burial over a period of 4-12 years on seed softening of seeds of cultivars Serena (*M polymorpha*) and Cyprus (*M truncatula*). Deeper buried seeds tend to soften slower but stay viable for a longer period. Burial of seeds during the crop year has the advantage in terms of legume persistence but could be disadvantageous when it comes to pasture replacement. In an earlier study Taylor and Ewing (1988) also found a reduction in rate of seed softening with increase in depth of burial, but no significant decline in seed numbers of Nungarin (*Trifolium subteraneum*) after 4 years of burial at a depth of 10 cm. They also found that barrel (*Medicago truncatula*) and burr medic (*M polymorpha*) were much more resilient against seed softening at the soil surface especially during the first summer following seed set, however burial had a smaller effect on rate of seed softening in these species than in the case of subterranean clover. This indicates that tillage practices to preserve seeds can be done to a lesser extent in medics than with subterranean clover.

2.3 Fertilisers

Cook, Blair and Lazenby (1978) showed that fertilising and grazing management are important factors influencing the persistence of a perennial ryegrass-white clover pasture. Superphoshate at 500 kg/ha annually minimised the invasion of weeds and other native plants with the result that persistence of the pasture was only affected by grazing management. Cook, Lazenby and Blair (1978) found that where 1300 kg superphosphate/ha was applied annually, it resulted in the reduction of the ryegrass content (15 % after two and a half years) of the mixed ryegrass-white clover pasture. An application of 250-500 kg P/ha annually, however enhances the persistence of the grass component (53 % after two and a half years). From these results it seems that the correct soil nutrient balance may be used to control or enhance certain plant species in the pasture.

Thomson and Bolger (1993) found that subterranean clover (*Trifolium subterraneum*) seeds with a high P concentration (0.75 %) emerged quicker, had a higher germination count, and a higher dry matter weight than seeds low in phosphorus (0.48 %). The application of phosphorus on medic pastures may increase seed and herbage yield in the year of application. Phosphorus concentration in seeds may also increase as a result of this, eventually leading to an increase in seed and herbage yield in subsequent years. Medic plants may also be able to cope better with pests and diseases as a result of the increased vigour with sufficient fertilisation (Bolland & Baker, 1988; 1989).
Gillespie (1983) showed that micro element deficiencies may also reduce both seed set and growth.

2.4 Disease and insect control

The increase in soil organic matter caused by the legume pasture may increase soil fungi and insects, which might be harmful to the legumes (Gillespie, 1983). Damage done by such insects to the cotyledons of *Trifolium subterraneum* can lead to a growth reduction of between 15 % and 70 %. Rossiter (1992) showed that damage of the cotyledons by red legged earth mites (*Halotydeus destructer)* were more destructive to legume pastures than grazing animals.

Management of pastures

Conlan, Dear and Coombes (1994) accessed the influence of grazing intensity and number of grazings on the herbage production and seed yields of *Trifolium subterraneum*, *Medicago murex* and *Ornithopus compressus*. They found that seed yield responses to grazing were highly variable between species and cultivars. Of all the species tested, it was only the Murex medic's seed yield that was not influenced significantly by grazing till very late in the growing season.
Regular defoliation by grazing/cutting may result in a 30 % increase in seed yield of subterranean clover (Collins 1978), however Collins, Rhodes, Rossiter and

Palmer (1983) found that seed production was, except for severe cases, not influenced by defoliation in two strains of subterranean clover. These differences between the two subterranean clover strains were due to differences in sensitivity to defoliation.

Because sheep are very successful utilisers of medic pods during dry months (Gillespie, 1983; Cocks, 1988), they will eat almost all pods during extended periods of grazing. It is therefore important to remove the sheep in time to ensure optimum regeneration the following pasture year.

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CHAPTER 3

The effect of weed control by imazamox and haloxyfop-R-methyl ester, and tillage on the production properties of nine medic (*Medicago* spp.) cultivars. 1. Germination and regeneration studies

Abstract

The trial was conducted at Langgewens experimental farm to determine herbicide and tillage treatment effects on nine different medic cultivars. Two post emergence herbicides namely imazamox and haloxyfop-R-methyl ester was used to control weeds in the pasture. In the wheat years two tillage methods namely, a tine cultivation followed by a conventional drill and a no-till planter were used to establish the wheat. The area was divided into 8 blocks and each sown with 9 medic cultivars in 1998. In 1999 four of the blocks were sown with wheat and the other remained under medics. Soil samples, taken in January 2000, were used for germination tests. Medic-, grass- and broadleaf weed seedlings were counted after which dormant seeds were determined. Wheat production in 1999 reduced the number of medic seedlings in the following year in comparison with the blocks under pasture for two years. Medic cultivars, Sephi (410.7) and Cyprus (691.7) produced the most seedlings/m^2 in the first and latter cases while Parabinga (145.7) and Orion (105.0) the least. It appeared as if dormancy was to a great extent broken during the period (4 months) between the pre-growing season germination trial and the on-site count of seedlings because the ranking of medic cultivars changed somewhat except for Orion which remained in the last position. The percentage of dormant seed after the wheat year was the highest for Caliph (90.6 %) and the lowest for Orion (54.9 %). As expected, the haloxyfop-R-methyl ester and imazamox herbicides controlled grasses and broadleaf weeds respectively. The tine tillage treatment only had a significant effect on grass seedling number, while no-tillage decreased the number of grass seedlings in both the pre-growing season and on-site trials.

Keywords

Dormancy, Haloxyfop-R-methyl ester, Imazamox, Medicago, Seedling regeneration

Introduction

Annual legumes [e.g. medics (*Medicago* spp.) and subterranean clover (*Trifolium subterraneum*)] are used worldwide as pasture to increase sheep production and crop yield. In South Africa the use of these species as pastures are largely confined to the Swartland and Southern Cape regions which receives rain primarily during the months April-October. These Mediterranean type pastures are adapted to winter production and survival during dry summers by producing a high number of dormant seeds. Seed dormancy of these pasture species is important to minimise germination during summer months, which could lead to seedling losses. Annual legumes need time to germinate, flower and produce seeds before dry summer conditions set in (Quinlivan, 1971; Rossiter, 1977; Lodge, 1993).

The largest problem with medic-crop (ex. Wheat) rotation systems are the regeneration of the annual medic (Rossiter, 1977; Lodge, 1993) after the wheat year or dry summer. Poor seedling regeneration may be the result of a multitude of factors of which poor cultivar choice, poor grazing management, poor weed control in either wheat or medics, and intensive tillage practices before or at the planting of wheat, which causes deep burial of seed, are the most common factors influencing seedling regeneration.

The effect of herbicide treatment on seed production of medics and subterranean clover

Weed control in medics are important to ensure optimal growing and seed production conditions when these legume pastures are in a rotation system with wheat or other crops on a 1:1 basis (Le Roux, Agenbag & Mills 1995).

The most important grass weeds, in the Swartland region, in legume pastures and crops are: rye grass (*Lolium multiflorum* and *L. rigidum*), brome grass (*Bromus diandrus*), mouse barley (*Hordeum murinum*), wild oats (*Avena fatua*), canary grass (*Phalaris canariensis*), annual blue grass (*Poa annua*) and volunteer wheat (*Triticum* spp.) (Le Roux, 1986). The most important broadleaf weeds in medic pastures are Cape marigold (*Arctotheca calendula*), wild radish (*Raphanus raphanistrum*) and spiny emex (*Emex australis*) (Le Roux, 1986).

There is a wide range of herbicides that can be used to control the above mentioned weeds. Propizamide (pre-emergence), fluazifop-buthyl (post-emergence) and glyphosate control most of the above mentioned grasses. Low application rates of glyphosate may also be used in so-called "pasture-topping-systems". These low rates of application do not kill the grass weeds but prevent seed production. In the spray topping system of weed control, low dosages of 2,4-DB are applied on the pasture and cause an increase in the palatability of broadleaf weeds due to the conversion of starch into sugars. Medics are susceptible to most of the broadleaf weed herbicides (including 2,4-DB at normal application rates), however this method of weed control has its advantages compared to the total control of weeds due to the utilisation of broadleaf weeds by grazing animals. Imazamox is a new herbicide registered to control mainly broadleaf, but also a few grass species such as *Avena fatua, Hordeum murinum, Lolium multiflorum* and *Bromus diandrus* in legume pastures. Pepler (1996) however, found that at the prescribed rate of 48 g of a.i./ha imazamox causes damage to some medic cultivars.

Non-selective herbicides are seldom used in medic pastures, except possibly where there is a very big weed problem.

It is generally excepted that herbicides, which control grassy weeds, seldom have any direct effect on medic pasture legumes, unlike some broad spectrum and broadleaf herbicides. The aim of grass control in pastures is to increase wheat yield and pasture production by reducing competition by grasses and volunteer wheat and to prevent infection by diseases of wheat, carried by some grassy weeds.

The effect of tillage on the seed production and regeneration of medics

Tillage has little influence on medic seed production, but does influence the number of seeds available for germination, the size of the seedbank and the rate of breakdown in dormancy of seeds. Kotze, Langenhoven and Agenbag (1998) and Cocks (1994) found that pre-growing season mouldboard and disk cultivation decreased the number of medic seedlings due to deep burial of seeds, while shallow tine cultivation had a smaller negative effect on medic re-establishment. Cocks (1994) also found that seedling re-establishment was better in *M. polymorpha* compared to *M. rigidula* when different cultivation treatments were applied. Taylor and Ewing (1996) investigated the influence of burial over a period of 4-12 years on seed softening of seeds of cultivars Serena (*M polymorpha*) and Cyprus (*M truncatula*). Deeper buried seeds tend to soften slower but stays viable for a longer period. Burial of seeds during the crop year has the advantage in terms of legume persistence but could be disadvantageous when it comes to pasture legume species replacement. Taylor (1985) found that in a rotation system of one year pasture/one year crop, no-tillage treatment buried 44 % of clover seeds (*Trifolium subterraneum*) while conventional tillage (1 X disc plough and 2 X scarifier at appropriate time intervals at 10 cm) buried 65 %. In the first year of regeneration of the pasture the no-tillage treatment had a higher seedling density, while in the second and third year the seedling density were higher where conventional tillage were practised. This is due to the larger seedbank in the soil. Conventional tillage might therefore be advantageous in areas where seed production by annual pasture species are unreliable and thus might help with the persistence of the pasture by bringing the buried seeds closer to the soil surface and burying hard seeds in good seed production years.

Taylor and Ewing (1988) found a reduction in rate of seed softening with increase in depth of burial with no significant decline in seed numbers after 4 years of burial of Nungarin (*Trifolium subteraneum*) at 10 cm. Barrel medic (*Medicago truncatula*) and burr medic (*M polymorpha*) were much more resilient at the soil surface, especially during the first summer following seed set. Burial however, had a smaller effect on rate of seed softening than in the case of subterranean clover, which will cause a larger number of seed to be lost by deep germination. This indicates that tillage practices, as a method to preserve legume pasture seeds, can be used to a lesser extent in medic than in subterranean clover pastures.

The effect of cultivar on regeneration of medics and subterranean clover

Variation exists in the seed and dry matter production for different cultivars and different species (*Medicago truncatula*, *M. aculeata*, *M. scutullata*, *M. laciniata* and *Trifolium subterraneum)* of annual pasture legumes. Some species can withstand grazing better than others can and some species' seeds soften more rapid than others do (Young, Morthorpe, Nicol and Croft, 1994). They also found that earlier sowing dates and less grazing (compared to heavy grazing) resulted in a higher seed and dry matter production for all annual pasture legumes.
Lloyd, Taylor, Johnson and Teasdale (1997) investigated the patterns of seed softening for six different *Medicago* species. They found that burial (7 cm) had little effect on the rate of softening of *M orbicularis* but almost halved the rate of breakdown of *M truncatula*, *M polymorha*, *M littoralis*, *M scutellata* and *M rugosa*.
From the introduction it is clear that medic cultivars differ in their ability to re-establish, produce dry matter and withstand burial. Differences in susceptibility to different herbicides are also mentioned. The aim of this study was therefore to determine the influence of herbicides (a broadleaf and a grass herbicide) and method of tillage (no-till and tine) at planting of wheat on the regeneration of nine different medic cultivars of three different species.

Materials and methods

Locality

The trial was conducted at Langgewens experimental farm (33° 17' S; 18° 42' E) in the Swartland wheat producing area of South Africa during the period 1998 to 2000. Typically of all areas with Mediterranean climates, this area experiences hot and dry summers and moderate, rainy winters (Table 1). At Langgewens experimental farm almost 80 % of its mean annual rainfall of 350 mm occurs during the months April to September, reaching a peak during the months June to August, followed by a sharp decline in rainfall during September and October. For this reason dryland farming is limited to the production of winter crops with a growth period between April and October.

From Table 1 it is clear that climatic conditions during the experimental period did not differ much from the 40-year average, although September 1999 received above average rainfall and was followed by a very dry October.

Table 1 Climate data for Langgewens experimental farm

Mean daily temperature (°C)

Month	April	May	June	July	August	September	October	April-Oct.
40 year average	19.3	15.9	13.7	12.5	13	14.6	17.3	15.2
1999	21.1	17.1	15.1	13.4	13.9	13.8	19.9	16.3

Total monthly rainfall (mm)

Month	April	May	June	July	August	September	October	April-Oct.
40 year average	30.5	58.3	64.4	58.2	61.7	36.8	24.3	334.2
1999	26.0	50.7	50.9	62.9	70.8	84.0	0.4	345.7

Aridity index (Evaporation/Rainfall)

Month	April	May	June	July	August	September	October	April-Oct.
40 year average	5.6	1.9	1.2	0.8	1.4	3.3	8.2	5.6
1999	6.9	1.7	1.4	1.0	1.1	1.1	563.5	144.2

(Agromet, 2000)

Like most soils of the Swartland area, the soil at the experimental site was a shallow loamy soil with a very high (44.6 %) gravel and stone content. The A-horizon with a depth of 250-300 mm gradually grades into a B-horizon of fragmental shale and ph,yllite. Although the soil is characterised by a low organic carbon content, soil pH as well as macro- and micro-nutrient content met the requirements of winter crops such as wheat and annual legumes such as medics (*Medicago* species) (Table 2).

Table 2 Soil characteristics of experimental site

	Depth	
Characteristic	0-150 mm	150-300 mm
Soil texture	loam	loam
pH (KCl)	5.5	5
Sodium (mg/kg)	15	19
Phosphorus (mg/kg)	47	42
Potassium (mg/kg)	110	55
Calcium (me %)	1.33	1.02
Magnesium (me %)	0.55	0.40
Clay (%)	11.0	11.0
Silk (%)	8.0	8.0
Sand (%)	81.0	81.0
Carbon (%)	0.52	0.37
Acid (H + Al)		0.51

(Elsenburg production technology, 2001)

Experimental design/layout

In this experiment where medic pastures were rotated annually with spring wheat cultivars, the effect of method of tillage used for seedbed preparation of the wheat and herbicides used for weed control in the medic pastures was evaluated on seed production and regeneration of nine medic cultivars (three different medic species). After the trial was established in 1998, half of the area was planted with wheat in 1999 (PW) while the remaining half remained tmedic pasture (2P). Data was collected before the growing season of 2000 on the two year pasture (2P:1998-1999) and the one year pasture, one year wheat (PW:1998, 1999) halves of the trial area. A factorial design, laid out as split-plots with two replications (blocks), was used. To ensure both a wheat and pasture crop, every year the number of blocks were doubled.

a) Cultivars

Nine medic cultivars of three different species (*Medicago truncatula*, *M polymorha*, *M sphaerocarpus*) were used namely Caliph, Cyprus, Mogul, Parabinga, Paraggio, Sephi (*M truncatula*); Serena, Santiago (*M polymorpha*) and Orion (*M sphaerocarpus*). Some growth requirements and characteristics for the different medic cultivars are shown in Table 3 by different sources and should therefore be handled circumspectly.

b) Herbicide treatments

Two post emergence herbicide treatments, namely an imidazolinone, at a rate of 48 g a.i./ha imazamox (IMI) and a haloxyfop, at rate 108 g a.i./ha haloxyfop-R-methyl ester (HAL) were applied during 1998 and 2000 to control weeds in the above mentioned medic cultivars. The HAL herbicide is a true grass-weed herbicide and controls a wide spectrum of annual grasses. The IMI herbicide on the other hand is a broadleaf-weed herbicide that controls only a few grassy weeds such as *Avena fatua, Bromus diandrus, Hordeum murinum and Lolium multiflorum* when applied at early growth stages. Herbicides were applied 2-3 weeks after germination of the weeds (end of May) with a tractor sprayer and a spray volume of 200 l/ha. During the wheat years no chemical wheat control, except for a non-selective herbicide (glyphosate at 360 g a.i./ha), which was sprayed before planting, was done.

Table 3 Requirements and some characteristics of the different medic (*Medicago* spp.) cultivars used in this trial

Specie/ Cultivar	**Rain Required (mm)**	**Days to flower**	**Soil pH-require-ments**	**Soil-texture**	**Dormancy**	**Aphid resistance (Blue-green)**
M. truncatula						
Cyprus	230-325**	80-85**	Neutral-alkalic**	Sa Lm-Sa Cl Lm**	moderate/high *d*	Susceptible *d*
Parabinga	225-350**	75-80**	Neutral-calcareous**	Lm Sa-Sa Lm**	moderate/high *d*	Moderate *d*
Sephi	350-450**	95-100**	Neutral-alkalic**	Sa Lm-Sa Cl Lm**	high *d*	Moderate *d*
Paraggio	350-500**	95-100**	Neutral-alkalic**	Lm Sa-Sa Lm**	moderate/high *d*	Moderate d
Caliph	275-400 *b*	80-85 *d*	Neutral-alkalic *b*	Lm-Cl Lm *b*	moderate/high *d*	Good *d*
Mogul	>350 *a*	95-100 *d*	Neutral-alkalic *d*	Lm-Cl Lm *a*	moderate/high *d*	Good *d*
M. polymorha						
Serena	225-350**	65-70**	Moderately acidic - neutral**	Sa Lm-Sa Cl Lm**	very high *d*	Susceptible *d*
Santiago	325-450**	80-85**	Moderately acidic**	Sa Lm-Sa Cl Lm**	very high *d*	Susceptible *d*
M. sphaerocarpus						
Orion	350-550 *a*	99 *c*	Moderately acidic - neutral *c*	Lm-Cl Lm *d*	high *d*	Susceptible *a*

** = (Metcalfe, 1990)

a = http://www.agric.nsw.gov.au/reader/1440 (Gillespie, D., 1994. Orion -The first variety of sphere medic, *Farm note* 49/94)

b = http://www.agric.wa.gov.au/agency/Pabns/farmnote/1993/f01593.htm

c = http://www.agric.wa.gov.au/WHATS_NEW/News97/d_Apr97p/medicrot.html-ssi

d = Agricol

Sa = Sand, Lm = Loam, Cl = Clay

c) Tillage treatments

Two tillage methods were used to do the seedbed preparation and planting of the wheat during 1999 namely:

i) Tine tillage (T) using a chisel plough to cultivate the soil to a depth of 150 mm directly before planting with a conventional seed drill in May.

ii) No-tillage (N) using a no-till drill (starwheelplanter) to plant the seed in an undisturbed seedbed.

Production techniques and pasture utilisation

Medic cultivars were initially sown in May 1998 at a rate of 20 kg/ha to insure a good stand. During the pasture years, pastures were grazed during the months May to the end of November at a stocking rate of eight sheep/ha. During the months December to May, sheep utilised the wheat stubble as well as dry material and pods from the pastures at a stocking rate of four sheep/ha.

Tests done to determine medic regeneration

a) Pre-growing season germination and dormancy study

To determine the size of the medic and weed seedbank and dormancy status there-of, soil samples were taken during the dry months of January and February 2000 on all the plots. Soil samples were taken by inserting a steel cylinder, with area 0.066052 m^2, to a depth of 50 mm into the ground after the soil was loosened with a pickaxe. Due to the experimental lay out, half the plots at that stage have experienced two years of medics (2P) and the other half one year of medics and one year of wheat (PW). The soil samples were wetted in two litre containers (210 mm * 140 mm * 80 mm) and seeds were allowed to germinate under 50% shaded netting. After three weeks the different grass, broadleaf and medic seedlings were counted.

After the medic and weed seedlings were identified and removed, the clay and silt (≤0.05) fraction of the soil samples were washed away through a sieve and dormant seeds were counted. The seeds that did not germinate were taken to be dormant.

b) On-site seedling study

Medic, grass and broadleaf seedlings were counted on the plots that have been sown with wheat after one year of medics. A ring with size 0.066052 m^2 was used. Seedlings were counted two weeks after the first medic seedlings emerged (middle May 2000).

Statistical analyses

All data was subjected to an analysis of variance, using SAS (1990). Differences were measured between blocks, herbicide treatments, cultivars used, cultivation methods at planting of wheat and herbicide X block, cultivar X herbicide, herbicide X cultivation, cultivar X cultivation and cultivar X herbicide X cultivation interactions. The different contribution of the sources to the variance was calculated by dividing the sum of squares into the sum of squares of the model. By multiplying this by 100 the percentage of contribution of each source of variation was calculated (Table 4).

Results and Discussion

Table 4 is included to show the contribution of different sources of variation to the total variation and to help simplify the discussion of the results. Small contributions, although significant, to the total variance are not discussed due to the high coefficient of variance (CV) and therefore low accuracy. Interactions between treatments are included largely in above-mentioned category and are therefore not discussed. Significant differences between blocks will not be discussed because it might be the result of probable differences in soil conditions, selective grazing by sheep and the uneven distribution of weed over the total trial area.

Table 4 The contribution (%) of different sources of variation to the variance in The different parameters measured in the pre-growing season (seedling germination and dormant seeds) and on-site experiments.

Parameter:	**Source of variation:**										
Pre-growing season/soil sample exp.	**B**	**H**	**HxB**	**C**	**CxH**	**B (CxH)**	**T**	**HxT**	**CxT**	**CxHxT**	**CV (%)**
Medic Seedlings/m^2 (2P)	3.7	3.1		73.9*	19.2						55.9
Medic Seedlings/m^2 (PW)	5.6*	26.5*	1.7	22.5*	9.6	17.9	6.5*	2.6*	4.8	2.3	45.2
Grass Seedlings/m^2 (2P)	15.1	0.3		41.7	42.9						83.1
Grass Seedlings/m^2 (PW)	14.0*	23.4*	2.1	2.8	7.1	13.8	14.4*	1.3	10.1	6.1	116.4
Broadleaf Seedlings/m^2 (2P)	42.4*	12.2		12.7	15.1						69.8
Broadleaf Seedlings/m^2 (PW)	2.7*	45.7*	2.7*	5.5*	7.5*	14.3*	6.9*	3.3*	6.1*	5.2*	34.1
% Dormant Medic seed(2P)	2.1	2.9	7.8	59.0	28.1						19.9
% Dormant Medic seed(PW)	4.1*	0.0	0.0	53.9*	7.3	25.3	1.1	1.0	2.6	4.6	17.7
On-site exp.											
Medic Seedlings/m^2 (PW)	17.0*	23.6*	0.6	26.2*	10.7	9.9	2.3	0.2	4.2	5.4	40.8
Grass Seedlings/m^2 (PW)	7.2*	45.9*	3.8*	6.0	5.1	9.8	10.8*	1.8	3.9	5.7	60.1
Broadleaf Seedlings/m^2 (PW)	5.2	37.0*	1.1	9.6	13.1	16.2	0.7	0.1	9.9	6.9	162.4

2P=pasture in 1998 and 1999; PW = pasture in 1998 and wheat in 1999

B = Block; H = Herbicide; C = Cultivar; T = Tillage; H x B, C x H, B(C x H), H x T, C x T and C x H x T= interaction between main treatments; CV (%) = coefficient of variance

* = $p \leq 0.05$

The effect of cultivar used, herbicide and tillage treatments applied on the number of medic seedlings, dormancy and weed seedlings in both the pre-growing season germination trial (PW and 2P) and the on-site seedling trial will be discussed.

Medic seedlings:

Pre-growing season germination trial

After one year pasture (1998) and one year wheat (1999) (PW) the number of medic seedlings in the pre-growing season germination and dormancy study were significantly ($p \leq 0.05$) affected by blocks, herbicide treatment, cultivars, tillage treatment and herbicide X tillage interaction. The main factors, herbicide treatment and cultivar, however, contributed most (26.5 and 22.5% respectively) to variation in the number of medic seedlings (Table 4) and only these influences will be discussed in detail. The small effect of the tillage treatment on medic seedling number is probably due the relative small difference between the type of cultivation used, with regard to their soil mixing and thus seed burial effects (Cocks, 1994). Although significant, differences between blocks, which was probably due to difference in grazing intensity will not be discussed in this chapter.

Sephi (410. 7) and Paraggio (400.3) produced, with the exception of Santiago (315.1) significantly more medic seedlings/m^2 than the other cultivars tested (Table 5). These differences in the number of seedlings between cultivars may be due to the ability of some cultivars to produce more seeds/pods than others, their seeds be less dormant, some cultivars more sensitive to the herbicides applied (Pepler, 1996) or some cultivars might be better suited for different soil types. Pepler (1996) found that at the prescribed rate of 48 g of a.i./ha of imazamox (IMI), Orion was damaged severely, while all the other cultivars showed minor or no effects. Medic seedling numbers also differed between the type of herbicide used (Table 6). The IMI treatment, which was applied one and a half years earlier, resulted in a significantly higher medic seedling number compared to the haloxyfop-R-methyl ester (HAL) treatment. It is generally accepted that both crops and pasture species produce more dry matter and seeds/grain when competition by other plants are minimised. From the results, medic seed production and thus number of seedlings were increased where broadleaf weeds and some grass species were controlled in comparison with grassy weeds only.

This could be due to the higher competitive ability of the broadleaf weeds compared to grassy weeds or the fact that grasses are more palatable than broadleaf weeds and were therefore grazed more readily.

Table 5 The effect of different cultivars on the number of medic seedlings/m^2 and % dormant seeds in the pre-growing season soil sampling and on-site trials. Differences were recorded after two years of medic pasture (2P) and one year of medic pasture and one year wheat (PW).

Pre-growing season germination trial				On-site seedling count		Pre-growing season germination trial			
Medic seedlings /m^2 (PW)		Medic seedlings /m^2 (2P)		Medic seedlings /m^2 (PW)		% Dormant seed (PW)		% Dormant seed (2P)	
Cultivar	Mean	Cultivar	Mean	Cultivar	Mean	Cultivar	Mean	Cultivar	Mean
Sephi	410.7^{a}	Cyprus	691.7^{a}	Santiago	682.2^{a}	Caliph	90.6^{a}	Caliph	96.4^{a}
Paraggio	400.3^{a}	Paraggio	494.0^{ab}	Serena	661.4^{ab}	Parabinga	88.1^{a}	Serena	89.4^{ab}
Santiago	315.1^{ab}	Sephi	432.5^{ab}	Mogul	654.8^{ab}	Santiago	84.6^{ab}	Mogul	88.4^{ab}
Cyprus	253.6^{bc}	Serena	372.8^{bc}	Cyprus	492.0^{abc}	Serena	83.9^{abc}	Santiago	87.7^{ab}
Mogul	233.7^{bc}	Parabinga	365.2^{bc}	Parabinga	475.9^{abc}	Paraggio	72.7^{bcd}	Parabinga	87.4^{ab}
Serena	217.6^{bc}	Santiago	248.9^{bc}	Paraggio	467.4^{bc}	Cyprus	70.2^{cd}	Orion	75.2^{ab}
Orion	208.2^{bc}	Mogul	232.8^{bc}	Caliph	440.9^{c}	Sephi	63.4^{de}	Paraggio	72.9^{ab}
Caliph	189.2^{c}	Caliph	121.1^{c}	Sephi	421.1^{c}	Mogul	60.6^{de}	Sephi	72.5^{ab}
Parabinga	145.7^{c}	Orion	105.0^{c}	Orion	168.4^{d}	Orion	54.9^{e}	Cyprus	70.1^{b}
LSD = 125.26		LSD = 283.76		LSD = 210.8		LSD = 13.78		LSD = 24.58	

Means with different superscripts (a, b, c...) in the same column indicate significant differences

LSD = Least significant difference ($p \leq 0.05$)

2P = Two years of pasture; PW = One year pasture then one year wheat before sampling

After two years of medic pasture (2P) the only significant difference ($p \leq 0.05$) in the number of medic seedlings, in the pre-growing season germination and dormancy study, was found between cultivars (Table 5). Cyprus (691.7) produced significantly ($p \leq 0.05$) more seedlings/m^2 than the other cultivars except for Paraggio and Sephi. On average a higher number of seedlings/m^2 was produced where wheat has not intervened in the rotation (Table 5). Crawford and

Nankivell (1989) also found that where no wheat or other crop has been planted, more seedlings emerged in the third year than where a crop has been planted.

Table 6 The effect of herbicide and tillage treatment on the number of medic seedlings (/m^2) in the pre-season germination trial and the on-site seedling count after two years pasture (2P) and one year pasture and one year wheat (PW)

	Pre-growing season germination trial		On-site seedling count
Treatment	PW	2P	PW
Herbicide	Mean	Mean	Mean
IMI	358.5^{a}	376.4^{a}	639.0^{a}
HAL	169.1^{b}	304.5^{a}	353.1^{b}
	LSD = 59.1	LSD = 133.7	LSD = 99.4
Tillage	Mean	No tillage has been applied yet.	No significant effect by tillage on medic seedling number.
N	217.0^{b}		
T	310.6^{a}		
	LSD = 59.1		

Means with different superscripts (a, b, c...) in the same column indicate significant differences
LSD = Least significant difference ($p \leq 0.05$)
2P = Two years of pasture; PW = One year pasture then one year wheat before sampling
IMI = Imazamox; HAL = Haloxyfop-R-methyl ester; N = no-tillage and T = shallow tine treatment

The IMI treatment may be the reason for poor seedling establishment of Orion (Pepler, 1996), but differences between other cultivars was probably due to genetic, climatic or soil condition preferences. The herbicide treatment applied during 1998 had a significant influence on the medic seedling number (Table 6) where wheat was grown in 1999 (PW) but not after two pasture years (2P). We might speculate that the herbicide effect in the second pasture year (1999) could have been nullified because of large numbers medic seeds produced in the second pasture year, while their numbers were limited if wheat, in which all weeds and medic seedlings were controlled before planting by glyphosate (a.i. 360 g/l) was produced. It is possible that the wheat year had a stabilising effect on the number of medic seeds in the soil and thus the differences between herbicides after wheat intervened.

On-site seedling study

The on-site assessment of medic seedling number (PW) after a year of pasture crop (1998) and a year of wheat crop (1999) resulted in significant difference ($p \leq 0.05$) between blocks, herbicide treatment and cultivars tested. Herbicide treatment and cultivars contributed 23.6 and 26.2% respectively to the variation in medic seedling number (Table 4). Only the differences in medic seedling number caused by the different cultivars and herbicides applied will be discussed. In the on-site counting of medic seedlings, the cultivar Santiago had the most seedlings and Orion the least (Table 5). The poor performance of Orion may, as already explained, be due to its sensitivity to IMI (Pepler 1996). On average seedling number/m^2 were at this stage (end of May 2000) higher than in the pre-growing season germination trial. The higher average seedling number on-site compared to the pre-growing season germination trial were probably due to the period in between (4 months), in which dormancy could be broken. The breakdown of dormancy during the changing temperatures in autumn is a characteristic of all annual legumes to prevent untimely germination (Taylor, 1996).

Herbicide treatment affected the number of medic seedlings similar to the pre-growing season germination trial. IMI also proved to be less harmful towards medic seedling establishment (Table 7) probably due to the reduced competition because both broadleaf weeds and some grass were controlled as well as the better utilisation of grass by sheep in these plots.

Dormancy studies

The percentage of dormant seeds in the pre-growing season germination and dormancy study, after one year of pasture and a year of wheat (PW), differed (p

≤ 0.05) only between different cultivars and blocks. Cultivars contributed 53.9 % to the variance in percentage of dormant seeds compared to the 4.1 % of blocks. For this reason only the effect of cultivar on the percentage of dormant seeds in the soil will be discussed (Table 4). The cultivars Caliph and Parabinga produced, with the exception of Santiago and Serena a significantly higher percentage of dormant seeds compared to the other cultivars tested (Table 5). The percentage dormant seeds indicate the degree of dormancy that exist, at a specific time after seed production, within the seeds of the different cultivars. This could however also be an indication of seed production. When a cultivar did produce few seeds during the first two years, it is obvious that the amount of dormant seeds available will be less with the result that the ratio of dormant to germinable seeds could remain the same. In order to determine the reason for the differences in percentage dormant seeds between cultivars we should keep in mind that there was no cultivar effect where wheat has not been planted. From Table 5 it is clear that Caliph (189.24) and Parabinga (145.73) produced the lowest number of seedlings/m^2 but had the highest percentage of dormant seeds (90.6 and 88.1 % respectively). This does indicate that a high degree of dormancy exists in their seeds and seed production was not influenced to a great extent by the different treatments. Orion however produced 208.2 seedlings/m^2 and only had 54.9 % dormant seeds left in the soil (Table 5). Orion produced very little seeds under the trial conditions, which might be due to its sensitivity to IMI herbicides (Pepler 1996).

No significant differences were found in terms of the percentage of dormant medic seed in the soil after two years of pasture (Table 4) however cultivar made the largest contribution to the total variation.

Weed seedlings:

Pre-growing season germination trial

In the pre-growing season germination study, after one year of pasture (1998) and a year of wheat (1999) the number of grass seedlings (PW) differed significantly between blocks, herbicide- and tillage treatments. The contributions (%) of herbicide- and tillage treatments to the variance in grass seedling number were the highest (45.7 % and 14.4 % respectively) and are therefore regarded as the most important effects (Table 4). Only the effect of the herbicide- and tillage treatments on grass seedling number will be discussed. Significantly more grass seedlings were found where the soil was cultivated with a tine implement prior to planting in comparison with the treatment where wheat was planted in a undisturbed seedbed with a starwheelplanter (No-till) (Table 7). This supported

Table 7 The effect of herbicides and tillage treatments on grass- and broadleaf weed seedling number in the pre-growing season and on-site trials

After one year pasture and a year of wheat (Pre-growing season germination study)					
Herbicide	Grass seedlings/m^2	Broadleaf seedlings/m^2	**Tillage**	Grass seedlings/m^2	Broadleaf seedlings/m^2
	Mean	Mean		Mean	Mean
IMI	343.0^a	66.2^b	**N**	150.8^b	223.5^a
HAL	135.6^b	292.5^a	**T**	327.8^a	135.2^b
	LSD = 137.9	LSD = 30.3		LSD = 137.9	LSD = 30.3
After two years of pasture (Pre-growing season germination study)					
IMI	277.4^a	303.6^a	No tillage has been applied on this part of the trial. It has not been planted to wheat yet.		
HAL	294.4^a	215.7^a			
	LSD = 166.95	LSD = 127.45			
After one year pasture and a year of wheat (On-site weed count)					
IMI	426.9^a	4.4^b	**N**	190.3^b	17.4^a
HAL	108.3^b	27.3^a	**T**	344.9^a	14.3^a
	LSD = 79.6	LSD = 12.8		LSD = 79.6	LSD = 12.8

Means with different superscripts in the same column indicate significant differences

IMI = Imazamox; HAL = Haloxyfop-r-methyl ester

T = 150 mm deep tillage treatment before wheat planting; N = No tillage treatment before wheat was planted

LSD = Least significant difference with $p \leq 0.05$

the findings of Pollard and Cussans (1976), who found that dicotyledonous weed species' regeneration (e.g. *Raphanus raphanistrum*) were less influenced by mouldboard cultivation, which causes seed burial, compared to annual grass species. This fact makes broadleaf weed re-establishment less sensitive to any kind of cultivation than grassy weeds. Grass weed species e.g. *Avena fatua* however, were for that reason, favoured by reduced cultivation (deep tine-160 mm and shallow tine-80 mm). Another and probably more relevant reason for the influence of tillage on the number of grass seedlings may be due to the stimulation of grass seed germination by the tine cultivation in 1999 during the wheat phase of the rotation. Because weeds were only sprayed before planting and no additional weed control was done after the wheat was planted, the plots where tine tillage was used produced more grass seeds due to a denser stand of grass in the wheat. Imazamox caused a higher number of grass seedlings because it controls only certain grass species while HAL is a true grass herbicide, and therefore controls most of the problem grass species (Table 7). The difference in grass seedling number between herbicide treatments was therefore expected.

The number of broadleaf seedlings differed significantly between blocks, herbicide treatment, cultivar, cultivation method used at planting of wheat; herbicide X block, cultivar X herbicide, herbicide X cultivation, cultivar X cultivation, cultivar X herbicide X cultivation interactions and cultivar X herbicide interaction within blocks. The different herbicides used, had by far the largest effect on the total variation (45.7 %) in broadleaf weed seedling number (Table 4). The effect of herbicide treatment on broadleaf weed seedling number are therefore regarded as the most important and will be the only source of variance that will be discussed. As expected, imazamox (66.2 m^2) controlled broadleaf weeds to a greater extent than HAL (292.5 m^2)(Table 7).

After two years of pasture (1998 and 1999) no significant differences ($p \leq 0.05$) in the number of grass seedlings (2P) were found in the pre-growing season germination and dormancy study. Broadleaf weed seedling number only differed significantly ($p \leq 0.05$) between blocks (Table 4) and are regarded as less important because block differences occurred between all parameters tested. The fact that no significant differences between herbicide or tillage treatments were found for either grass or broadleaf weeds may indicate that the herbicide treatment in 1998 was nullified during the 1999 pasture season.

On-site seedling study

In the on-site seedling study, statistical analyses showed that grass seedling number (PW) after one year of pasture (1998) and a year of wheat (1999) were significantly ($p \leq 0.05$) affected by block, herbicide- and tillage treatment as well as herbicide X block interaction. Herbicide treatment (45.9 %) and to much lesser extent tillage methods (10.8 %) were by far the largest contributors to the total variation in weed seedling number (Table 4). Only these sources of variation will for this reason be discussed. The tine tillage treatment (344.9) caused a significant ($p \leq 0.05$) higher number of grass seedlings/m^2 compared to the no-tillage treatment (190.3) (Table 7). The haloxyfop-R-methyl ester treatment (108.3) caused a significantly lower number of grass seedlings/m^2 in the pasture compared to the imazamox treatment (426.9) (Table 7). Broadleaf seedling numbers only differed significantly ($p \leq 0.05$) between herbicide treatments. Haloxyfop-R-methyl ester (27.3) being a grass herbicide caused a significant higher number of broadleaf weed seedlings/m^2 compared to the imazamox treatment (4.4) which control a large spectrum of broadleaf weeds (Table 7). The differences between grass and broadleaf weed seedling numbers in this study, supported the results of the pre-growing season germination study. Effects of different herbicide- and tillage treatments may therefore be explained as for the pre-growing season germination study.

Conclusions

Seed production capacity and seed dormancy are important characteristics of different medic cultivars in order to ensure sustainability in rotational systems. In this study seed production capacity, as measured by number of seedlings emerging in soil samples and on-site, differed between cultivars but were also affected by herbicide treatment and cropping sequence in the rotation. In this study, seed production benefited more from the use of a broad spectrum herbicide (IMI) which controls both broadleaf and some grassy weeds, than from the use of a grass herbicide (HAL). Some cultivars like Orion were however seriously damaged by the use of a broadleaf herbicide such as imazamox. As expected the number of dormant seeds were mostly affected by the cultivar grown, while production techniques had little effect.

Although the type of herbicide used during the pasture phase was the main attributer to the size of the weed seedbank, as measured by weed seedlings emerging during the germination test, cultivation practices used to sow the wheat also had a significant effect. Numbers of grass weed seedlings were increased by the use of tine tillage compared to no-tillage. This tendency was however not true for broadleaf weeds, which may indicate that broadleaf weeds were, in contrast to grassy weeds, not stimulated by the tine cultivation.

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CHAPTER 4

The effect of weed control by imazamox and haloxyfop-R-methyl ester, and tillage on the production properties of nine medic (*Medicago* spp.) cultivars. 2. Dry matter and pod production

Abstract

The experiment was conducted at Langgewens experimental farm during 1998 to 2000. This trial aimed to determine the effect of imazamox (IMI) and haloxyfop-R-methyl ester (HAL) herbicides, shallow tine (150 mm)(T) and no-tillage (N) cultivation and the use of nine different medic (*Medicago*) cultivars on pasture (medic and weed) dry matter (DM) and pod production. Three *Medicago* species, *M. polymorpha, M truncatula* and *M sphaerocarpus* were used in a 1:1 medic wheat rotation system. The medics were planted in 1998; half of the area was planted with wheat in 1999 while the other half remained as medic pasture. The pasture half of the trial area in 1999 was planted with wheat in 2000 while the wheat half was left to re-establish as medic pasture. DM samples were taken on the latter during the 2000 growing season. Samples were taken at 6-8 week intervals during the growing season. Cages were used to determine the DM production of the pasture while the pasture was grazed. Initially the cultivar Parabinga produced the most DM, but after 15 August 2000 the cumulative DM production of Caliph, Sephi and Cyprus were the highest. Orion produced very little DM throughout the trial due to its sensitivity to the applied imazamox herbicide. Tillage methods used in the wheat phase had very little effect on the DM production of medics. Imazamox increased the percentage of medics in the pasture but this treatment, which controls only some grassy weeds, resulted in a higher percentage of grassy weeds in the pasture compared to the haloxyfop-R-methyl ester treatment, which controls most of the grassy weeds. In conclusion it could be said that broadleaf weed control by imazamox increased medic production to a greater extent than where only grassy weeds were controlled by haloxyfop-R-methyl ester.

Keywords

Haloxyfop-R-methyl ester, Imazamox, Medics, Weed control

Introduction

Annual legumes such as medics (*Medicago* spp.) and subterranean clover (*Trifolium subterraneum*) are used worldwide, especially in Mediterranean climate regions, as pasture to increase sheep production and improve soil fertility for crop production (Du Toit, 1978; Ladd, Oades & Amato, 1981). In South Africa the use of these species as pasture are largely confined to the Swartland and Southern Cape regions.

These Mediterranean type pastures are adapted to winter production and survival during dry summers by producing a large number of dormant seeds. Due to the dry summer conditions of these areas it is therefore important for these pasture species to germinate as early in the growing season as possible and keep on growing as long as possible in order to maximise seed and animal production by producing more dry matter (Quinlivan, 1971; Rossiter, 1977; Lodge, 1993).

Yield and seed production as well as the quality of medic pastures are affected by several factors of which some will be discussed.

Cultivar choice

In order to choose the correct medic cultivar for specific climatic and soil conditions, it is important to know what the regeneration and production potential of the specific species is (Lodge, Cullis & Welsby, 1993). This information may help to increase both wool and meat production from sheep. In New South Wales Australia, Lodge, Cullis and Welsby (1993) found that subterranean clover var. Seaton Park and Woogenellup had the highest dry matter (DM) production and

Medicago polymorpha cultivars of the lowest DM production of 15 annual legumes they tested. This was most probably due to differences in the length of their growing season. For instance, at day 300 (October) Clare (*Trifolium subterraneum*) and *Medicago truncatula* had respectively 85 and 52% DM as green material left.

Lodge (1996) found that rainfall at emergence affected the size of the seedling pool positively, while post emergence rainfall interacted with legume species (*Medicago* and *Trifolium* spp.) and emergence time to affect the rate and extent of seedling survival. The larger the seedling pool the higher the survival of the seedlings of different annual legume species, but cultivars do differ with regard to their rainfall requirements and this might play an important role in the sustainability of the legume specie in the pasture.

Weed control

Similar to other crops, pasture specie DM yield, quality and seed production are reduced by weeds by competition for water, light and nutrients. Some weeds may be unpalatable, poisonous, or have barbs and thorns (e.g. *Bromus diandrus*) which may irritate grazing animals, damage the skin and carcass or get caught in the wool of sheep (Aligianis, 1977). Others are hosts for diseases of small grain crops that are grown in rotation with medics (Le Roux, 1986). In order to maximise legume pasture yield it is necessary to control weeds especially those that are strong competitors and have a negative effect on crop, pasture and animal production (Cotterill, 1990). The most important grass weeds in the Swartland region in legume pastures and crops are rye grass (*Lolium multiflorum* and *L. rigidum*), brome grass (*Bromus diandrus*), mouse barley (*Hordeum murinum*), wild oats (*Avena fatua*), canary grass (*Phalaris canariensis*), annual blue grass (*Poa annua*) and volunteer wheat (*Triticum* spp.) (Le Roux, 1986). Most of these grasses can be utilised by sheep and are an important part of the pasture during the winter months. Volunteer wheat may also be a weed in wheat when the cultivar differs from the one that is sown in a particular year. There are also numerous broadleaf weeds, but the most important ones in wheat and legume pastures in this region are Cape marigold (*Arctotheca calendula*), wild radish (*Raphanus raphanistrum*) and spiny emex (*Emex australis*) (Le Roux, 1986). There are a wide range of herbicides that can be used to control the above mentioned weeds. Propizamide, for example are a pre-emergence herbicide which controls all of the above mentioned grasses, while 2,4-DB, MCPA and Bromoxinil are some of the herbicides used on broadleaf weeds in the spraytopping system of weed control. Medics however are harmed by most of the broadleaf and non-selective herbicides (including MCPA, paraquat and glyphosate) and spraytopping (low dosages of broadleaf herbicide) where grazing animals can utilise these weeds has therefore its advantages compared to the total control of broadleaf weeds where higher applications are needed (Young, Morthorpe, Croft & Nicol, 1992; Dear, Sandral & Coombes, 1995).

It is generally accepted that herbicides, which control grassy weeds, seldom have any direct effect on medic pasture species (Van Heerden, 1990). The control of grassy weeds in the pasture is aimed at improving pasture production by reducing competition by grasses and volunteer wheat and to improve pasture quality (Cotterill, 1990). Wheat crops that succeed the pasture may also benefit from grass control in the pasture due to fewer weeds, less disease and more nitrogen (Le Roux, Agenbag & Mills, 1995, Du Toit, 1978).

Removal of annual grasses by herbicides such as propyzamide from an annual grass-legume pasture was however found to reduce DM production of the pasture in the year of spraying, but not in the second year (Thorn & Perry, 1987). Van Heerden (1990) found that grass control in two successive years caused an increase in wool production and a slight increase in annual daily gain in wethers on lucerne, but this was not the case with medics. Weed control however, caused an increase in pod production of medics in his study. Fluazifop-butyl in snail medics (*Medicago scutellata*) gave excellent grass control (especially *Lolium rigidum* and *Hordeum glaucum*) especially where planting are by means of direct drilling which enhances the grass weed problem. This is because the regeneration of grasses is more sensitive to cultivation due to burial of seeds compared to broadleaf weeds (Venn, 1984).

Grasses may however provide useful early feed and their control should be limited to the years preceding crops as a preventative measure against root diseases and volunteer grass competition. In other pasture years grazing should be used to control grasses. This will however require optimum stocking rates and timing of grazing (Wallace, Evans & Bowran, 1995).

Tillage method used for wheat production

Tillage methods used for seedbed preparation of wheat crops produced in rotation with annual legume pastures may have a large influence on the number of medic seedlings established in pasture years that follows the wheat crop. These differences in seedling numbers and thus plant populations may also have an effect on DM production. A deep mouldboard type cultivation will for example cause burial of medic seeds and thus a lower seedling number, resulting in a reduction in pasture production. Tillage methods which on the other hand keep all seeds on the soil surface or the top 100 mm of the soil profile may enhance emergence and therefore also DM production (Kotze, Langenhoven & Agenbag, 1998; Cocks, 1994).

Weed control to minimise competition from weeds as well as tillage treatments to improve wheat root development are necessary to optimise wheat production while the pasture is not influenced too severely. The aim of this study was therefore to determine the effect of herbicide- and tillage treatments on the DM production of different *Medicago* cultivars and weedy plants.

Materials and Methods

The trial was conducted at Langgewens experimental farm which experiences hot and dry summers and moderate, rainy winters. From Table 1 it is clear that the rainy season in 2000 started later compared to the 40-year average. The total rainfall for the months April to October was also far below average and only the months July and September received more rain than the 40-year average. The soil characteristics fit the requirements for medics and were described in detail in Chapter 3. The experimental design for this trial was the same as was described in Chapter 3 and included the same treatments, namely the imazamox (IMI) and haloxyfop-R-methyl ester (HAL) herbicide, the tine tillage (T) and no-tillage treatments (N) as well as the nine different medic (*Medicago* spp) cultivars. Herbicides and tillage were applied in mid July 2000 and in 1999 before wheat was planted respectively. The medics were planted in 1998 and some of these cultivars' requirements and characteristics are shown in Chapter 3. Statistical analysis for the data was also as described in Chapter 3.

Table 1 Climatic data for Langgewens experiment farm

Mean daily temperature (^oC)

Month:	April	May	June	July	August	September	October	April-Oct.
40 year average	19.3	15.9	13.7	12.5	13	14.6	17.3	15.2
2000	23.9	20.2	17.2	15.6	21.8	14.7	14	18.2

Total monthly rainfall (mm)

Month:	April	May	June	July	August	September	October	April-Oct.
40 year average	30.5	58.3	64.4	58.2	61.7	36.8	24.3	334.2
2000	4.0	28.5	25.6	70.1	47.6	69.2	12.1	257.1

Aridity index (Evaporation/Rainfall)

Month:	April	May	June	July	August	September	October	April-Oct.
40 year average	5.6	1.9	1.2	0.8	1.4	3.3	8.2	22.4
2000	43	4.4	3.2	0.2	1.6	1.4	19.6	73.5

(Agromet, 2000)

Data collection

Dry matter production of medics, grass and broadleaf weeds were measured every six to eight weeks during 2000 (7 July, 15 August and 2 October 2000) starting at six weeks after the first winter rain and continuing till the plants started ripening. Round cages (1 m in diameter and 1 m high) were used to keep the sheep (8 sheep/ha) out and cages were moved to a new position in the plot after a sample of the green material was taken, both inside and outside the cages. Sampling sizes were 1655.35 cm^2 and were done by putting a ring on the soil surface and removing all material within. These samples were sorted in three groups: medics, grass weeds and broadleaf weeds. After sorting, the green material was dried and weighed thus working on DM basis. The weight of DM for medics, grass and broadleaf weeds were multiplied by 60.41 to calculate the amount of DM/ha.

Unfortunately grass and broadleaf weed DM were not measured during sampling on 2 October 2000 due to technical problems. The cumulative DM production was calculated by subtracting the amount of material outside the cage at the previous sampling date, e.g. 7July, from the amount inside at the "present" sampling date, e.g. 15 August and the result is the amount of DM produced between sampling dates and then these values for each sampling period were added as the growing season progressed.

Pods were gathered on 4 December 2000 by means of sweeping the area inside the rings (same size rings used for DM sampling) with a broom and hand. Pods were dried and weighed as with the green material.

Results and discussion

General tendencies with regard to pasture composition, cumulative DM production and utilisation are summarised in Table 2. From this it is clear that the percentage medics in the pasture remained at a constant level of about 60 % during the early part of the growing season (7 July-15 August). The percentage grassy weeds and volunteer wheat on the other hand declined, while the percentage broadleaf weeds in the pasture increased dramatically during this period. Total percentage of weeds however remained at about 40 %. Cumulative DM production of medics and grass improved little from 7 July to 15 August which yielded 51.6 and 52 kg/ha DM between these sampling dates respectively while broadleaf weeds produced 210 kg/ha during this time. The average DM production at 2 October 2000 for the different medic cultivars were 660.0 kg/ha and thus producing 261 kg/ha since the sampling on 15 August. The amount of pods produced were the only characteristic measured on the 4th of December while the utilisation of pods were measured between the 2nd of October and the 4th of December. These data will not be discussed further and are only shown to give a general idea of the pasture composition, DM production and utilisation by grazing sheep.

Table 3 is included to show the contribution of different sources of variation to the total variance and to help simplify the discussion of the results. Small contributions, although significant, to the total variance are not discussed due to the high coefficient of variance (CV) and therefore low accuracy. Interactions between treatments are included largely in above-mentioned category and are therefore not discussed. Significant differences between blocks will not be discussed because it might be the result of probable differences in soil conditions, selective grazing by sheep and the uneven distribution of weed over the total trial area.

The differences in DM production for the different medic cultivars will be discussed for the different sampling dates followed by the DM production of grassy and broadleaf weeds.

Dry matter; pod production and percentage of medic in the pasture:

At the first sampling date (7 July 2000) the percentage of medic DM in the pasture differed significantly ($p \leq 0.05$) between blocks and different cultivars used in this trial. Although a significant block X herbicide treatment interaction was found, this interaction contributed only 4.9 % to the total variation in medic DM (Table 3). Different medic cultivars contributed 24.6 % to the total variance and were for this reason regarded as the most important source of variation. Only differences between cultivars will therefore be discussed. At this stage Santiago plots (72.0 %) showed the highest percentage of medic DM but with the

Table 2 Production and utilisation results regarding the average for all the blocks and treatments during sampling dates in 2000 for medics, grass, wheat and broadleaf weed production

	Date of sampling		
	7 July	15 August	2 October
Pasture composition			
% Medic	58.1	61.0	unavailable
% Grass	10.9	5.8	unavailable
% Grass/Wheat	29.2	13.8	unavailable
% Broadleaf weeds	12.7	24.9	unavailable
% Weed	41.9	39.0	unavailable
Cumulative production			
Cumulative medic production (kg/ha)	347.4 (160-189)	399.0 (160-228)	660.0 (160-276)
Cumulative grass/wheat production (kg/ha)	171.5 (160-189)	223.5 (160-228)	Unavailable
Cumulative broadleaf production (kg/ha)	64.9 (160-189)	274.9 (160-228)	Unavailable
Production rate and utilisation			
Medic Production rate/day (kg/ha)	12.0 (160-189)	1.3 (189-228)	5.4 (228-276)
Medics utilised (kg/ha)		51.5 (189-228)	261.0 (228-276)
Total Medics utilised (kg/ha)			312.5 (189-276)
Medic utilisation rate (kg/sheep/day)			0.4 (189-276)
4 December			
Average pod production (kg/ha)	no pods	no pods	808.7 (276-339)
Pods utilised (kg/ha)	no pods	no pods	98.4 (276-339)

*The pasture were grazed at a rate of 8 sheep per ha during the active growing stage of the year (day 189- 276) and at a rate of 4 sheep/ha during the dry summer up to day 339.

exception of Orion, which showed by far the lowest percentage of medic DM in the pasture (31.2 %), did not differ significantly ($p \leq 0.05$) from the other cultivars (Table 4). The percentage of medics in the pasture illustrates the ability of specific cultivars to compete against weeds. This also indicates medics' resistance against aphids and diseases, their ability to produce enough seedlings in order to ensure a dense enough stand after a wheat year, their ability to adapt to the environmental conditions and in this case, sensitivity to the type of herbicide used to control weeds in the pasture. From these results and the

Table 3 The contribution (%) to total variance by different sources of variance on different sampling dates

Source of Variation:	B	H	HxB	C	CxH	B (CxH)	T	HxT	CxT	CxHxT	CV(%)
7 July 2000											
Medics (kg/ha)	12.7*	0.4	1.9	29.2*	12.3	33.9	0.1	0.8	5.0	3.6	47.6
Grass/Wheat (kg/ha)	4.7	28.7*	1.5	6.2	7.3	25.2	4.2	0.6	8.0	13.6	81.8
Broadleaf (kg/ha)	12.7*	33.8*	11.6*	8.8	11.2	9.8	2.2	1.0	3.7	5.1	118.7
% Medic	26*	0.0	4.9*	24.6*	9.4	21.3	0.7	0.0	9.2	3.8	29.6
% Grass	0.1	18.5*	0.2	7.7	11.4	27.3	0.0	0.6	16.9	17.3	152.8
% Grass/Wheat	6.7*	33.9*	0.5	12.1	4.7	19.7	6.4	1.4	6.0	8.6	152.8
% Broadleaf	10.7*	33.5*	10.1*	15.4*	13.7*	6.3	2.1*	1.2	2.9	4.1	74.3
% Weed	32.9*	0.0	4.9*	24.6*	9.4	21.3	0.7	0.0	9.2	3.8	41.1
15 August 2000											
% Medic	31.8*	22.6*	8.6	22.3*	2.1	6.0	1.0	0.4	2.4	2.7	24.2
% Grass	1.4	30.4*	2.2	8.6	9.6	27.4	3.2	6.2*	5.1	5.9	109.5
% Grass/Wheat	2.5	48.7*	3.4*	15.7*	13.5*	8.6	0.1	1.1	2.4	4.0	67.8
% Broadleaf	17.1*	56.9*	11.2*	4.7	1.7	5.1	0.6	0.0	1.5	1.1	48.5
% Weed	31.8*	22.6*	8.6*	22.3*	2.1	6.0	1.0	0.4	2.4	2.7	37.8
Cumulative medic (kg/ha)	21.6*	0.4	6.2	13.8	12.9	27.8	0.5	1.3	4.7	10.8	156.3
Cumulative Grass/wheat (kg/ha)	10.7	27.8*	2.6	9.5	10.5	24.9	1.1	1.1	3.8	7.9	142.6
Cumulative broadleaf (kg/ha)	2.6	21.2*	1.2	10.3	12.5	23.6	0.6	0.0	12.3	15.6	213.4
2 October 2000											
Cumulative medic (kg/ha)	16.5*	1.6	1.0	27.6*	3.2	26.0	0.1	0.1	11.2	12.7	163.4
4 December 2000											
Pods produced (kg/ha)	4.0	1.1	0.2	42.8*	14.2	10.3	13.4*	1.1	3.2	9.8	60.8

*=Means that differ significantly ($p \leq 0.05$)

B = Block, C = Cultivar, H = Herbicide, T = Tillage; HxB, CxH, HxT, CxT, CxHxT = Interactions between treatments/sources of variance; B(CxH) = Interaction between herbicide and cultivar within blocks; CV (%)= coefficient of variance

Table 4 Factors influencing the percentage and cumulative production of different medic cultivars in the pasture at different sampling dates in 2000

Day 189 (7 July 2000)				Day 228 (15 August 2000)				Day 276 (2 October 2000)		Day 339 (4 December 2000)	
% Medic		Medic (kg/ha)		% Medic		Cum. Medic (kg/ha)		Cum. Medic (kg/ha)		Medic pods (kg/ha)	
Mean	Cultivar	Mean	Cultivar	Mean	Cultivar	Mean	Cultivar	Mean	Cultivar	Mean	Cultivar
72.0^{a}	Santiago	428.9^{a}	Parabinga	74.8^{a}	Santiago	651.7^{a}	Parabinga	2010.1^{a}	Caliph	1510.2^{a}	Caliph
65.7^{a}	Sephi	415.3^{a}	Sephi	70.1^{ab}	Parabinga	589.8^{a}	Santiago	1053.4^{ab}	Parabinga	968.8^{b}	Sephi
64.8^{a}	Caliph	414.6^{a}	Cyprus	68.8^{ab}	Mogul	540.7^{a}	Cyprus	720.4^{bc}	Serena	922.0^{b}	Cyprus
62.1^{a}	Parabinga	404.8^{a}	Mogul	67.5^{ab}	Serena	500.6^{a}	Sephi	681.9^{bc}	Mogul	914.5^{b}	Parabinga
61.2^{a}	Serena	387.4^{a}	Santiago	61.5^{ab}	Paraggio	453.8^{a}	Caliph	672.8^{bc}	Santiago	788.4^{b}	Paraggio
56.4^{a}	Mogul	376.8^{a}	Caliph	59.8^{ab}	Caliph	345.9^{a}	Serena	586.7^{bc}	Sephi	741.5^{b}	Santiago
55.1^{a}	Cyprus	320.9^{a}	Serena	59.4^{ab}	Sephi	299.8^{a}	Mogul	430.4^{bc}	Paraggio	682.6^{b}	Mogul
54.9^{a}	Paraggio	283.2^{a}	Paraggio	54.8^{b}	Cyprus	139.7^{a}	Orion	-7.6^{bc}	Orion	601.1^{bc}	Serena
31.2^{b}	Orion	95.2^{b}	Orion	32.2^{c}	Orion	68.7^{a}	Paraggio	-208.4^{c}	Cyprus	149.5^{c}	Orion
$LSD_{0.05}=18.1$		$LSD_{0.05}=173.7$		$LSD_{0.05}=15.5$		$LSD_{0.05}=654.9$		$LSD_{0.05}=1132.6$		$LSD_{0.05}=516.7$	
				Mean	Herbicide					Mean	Tillage
				72.8^{a}	IMI					618.7^{b}	T
				49.1^{b}	HAL					998.8^{a}	N
				$LSD_{0.05}=7.3$						$LSD_{0.05}=243.6$	

Means with different superscripts (a, b, c...) in the same column indicate significant differences ($p < 0.05$)

$LSD_{0.05}$=Least significant difference where $p \leq 0.05$

Cum. Medic (kg/ha)= Cumulative medic production in kg/ha; IM I= Imazamox; HAL = Haloxyfop-r-methyl ester

NOTE: % Medic refers to the green fraction of medics although some cultivars, like what seemed the case with Cyprus and Orion, has a shorter growing season characteristics and requirements of the nine medic cultivars used in this trial (Chapter 3) it is clear that with the exception of Orion, cultivars did not differ much. The poor performance of Orion was most probably due to the high sensitivity of this cultivar to the herbicide imazamox (Pepler, 1996) applied in 1998. Although no herbicides had been applied at the time of the first sampling (7 July 2000), these results can be attributed to the negative effect of the imazamox herbicide applied during 1998 on seed production and therefore seedling production as has been shown for Orion in Chapter 3.

Total medic DM production (kg/ha) at this stage (7 July) only differed between blocks and the different cultivars used in the trial as this measurement was taken prior to herbicide application. The different cultivars contributed 29.2 % (Table 3) to the total variance which was with the exception of the block X cultivar X herbicide interaction, by far the largest and are therefore regarded as the most important contributing factor influencing total medic DM at this stage. Although the mentioned interaction contributed 33.9 % to the total variation, this effect was not significant. From Table 4 it is however clear that cultivars did not differ significantly except for Orion (95.2 kg/ha), which produced by far the lowest amount of medic DM. Parabinga, Sephi, Cyprus and Mogul on the other hand showed the highest production. These cultivars produced between 400 and 430 kg DM/ha (Table 4). The low production of Orion may again be attributed to the negative effect of imazamox sprayed in 1998.

During the sampling on 15 August 2000 the percentage medics in the pasture differed significantly between blocks, herbicides treatment and different cultivars used in this trial. The effect of herbicide and cultivar are regarded as most important because of their contribution to the total variance and only these effects will be discussed.

At this stage the percentage of medic DM in the pasture of Santiago (74.8 %) was significantly higher than that of Cyprus (54.8 %) and Orion (32.2 %), whereas Cyprus showed a significantly higher percentage compared to Orion (Table 4). The other cultivars tested did not differ significantly from Santiago and Cyprus, but were significantly higher than Orion. As herbicides have been applied at this stage, it was expected that the percentage of medics in the pasture should increase, but as already shown (Table 2) remained more or less the same (61.0 %) compared to the earlier sampling. The imazamox treatment however resulted in a significantly higher percentage of medics in the pasture at this stage (Table 4). This is probably due to the absence of competition by different broadleaf weeds (especially wild radish and cape marigold were observed) and some grass species that were controlled by imazamox.

The cumulative medic production (kg/ha) on 15 August 2000 showed no significant difference ($p \leq 0.05$) between cultivars, herbicide- or tillage treatments (Table 3). This lack of significant differences between treatments were probably due to the relative dry conditions for the first part of the growing season (Table 1), which had a pronounced effect on plant growth.

During sampling on 2 October 2000, only medic DM was determined due to technical difficulties. Significant differences were again found between blocks and the different cultivars used in this trial. Different cultivars as a source of variance contributed 27.6 % to the total variation in DM at this stage (Table 3) and Caliph (2010.1 kg/ha) produced significantly more DM than all the other cultivars tested except for Parabinga (1053.4 kg/ha) (Table 4). Due to an unexpected decrease in DM production of cultivar Cyprus, this cultivar showed by far the least cumulative DM at this stage. The reason for Orion and Cyprus's low DM production might be their susceptibility to blue-green aphids (Chapter 3) and Orion's sensitivity to Imazamox. Because other susceptible cultivars like Serena and Santiago did not show the same tendency, aphid damage may be ruled out. The low value found for Cyprus must thus be attributed to a sampling error.

Pod production was measured on 4 December 2000 and was influenced by different cultivars and the tillage method used to plant the wheat during 1999. These sources of variation contributed 42.8 and 13.4 % respectively to the total variance (Table 3). Because method of tillage did not affect DM production of medics at any stage, the influence of tillage on pod production were most likely due to sampling error because the tine tilled plots were more rugged than the no-till plots, which made it difficult to collect all the pods. It is therefore clear that differences in cultivar were the most important regarding pod production. The pod mass of Caliph (1510.2 kg/ha) exceeded that of all the other cultivars while that of Orion (149.5 kg/ha) were by far the lowest. Only Serena (601.1 kg/ha) was not significantly higher than Orion (Table 4).

The high pod production by the cultivar Caliph may be due to genetic superiority as reflected in very large dry material production (Table 4). Orion's low production of pods, on the other hand, may be attributed to the small number of plants per unit area as a result of the imazamox treatment during 1998 (see Chapter 3) and 2000.

Weed dry matter production (kg/ha) and the percentage of weed in the pasture

Weed mass (grass- and broadleaf weeds as well as volunteer wheat) on 7 July 2000, showed only significant differences ($p \leq 0.05$) between herbicide treatments (Table 3). Significantly more grass DM were produced on the plots sprayed with imazamox compared to the haloxyfop-R-methyl ester plots (Table 5), because IMI only controls some grass species while HAL controls a broad spectrum of grassy weeds. As this sampling was done before the herbicides were applied to the pasture, results clearly showed that the plots sprayed with haloxyfop-R-methyl ester in 1998 were much less infested by grasses than the imazamox plots. Although imazamox controlled some grass species the difference between the two herbicides (haloxyfop-R-methyl ester (99.5 kg/ha) compared to the imazamox (243.5 kg/ha)) may have been further enhanced by the fact that sheep would graze imazamox treated areas more readily due to the absence of high and rugged growing wild radish.

The percentage of grass DM in the pasture, on 7 July 2000, again differed significantly between herbicides used only (Table 3) with a significantly higher percentage in the imazamox treated areas (Table 5). This effect of the herbicides were expected due to the above mentioned reasons.

Table 5 The effect of herbicide treatments on the DM production of grass and broadleaf weeds at different sampling dates during the 2000 growing season

	Date of sampling					
DM production	**7 July**			**15 August**		
	Herbicide			Herbicide		
	IMI	HAL	$LSD_{0.05}$	IMI	HAL	$LSD_{0.05}$
% Grass	17.7^{a}	4.1^{b}	8.3	10.5^{a}	1.1^{b}	3.2
% Grass/Wheat	40.0^{a}	18.3^{b}	9.5	23.6^{a}	4.0^{b}	4.6
Grass/Wheat production (kg/ha)	243.5^{a}	99.5^{b}	69.5	340.5^{a}	106.6^{b}	157.9
% Broadleaf	1.4^{b}	24.0^{a}	4.7	3.1^{b}	46.7^{a}	6.0
Broadleaf production (kg/ha)	6.9^{b}	123.0^{a}	38.3	40.8^{b}	508.8^{a}	290.4
% Weed of total	41.4^{a}	42.3^{a}	8.5	27.2^{b}	50.9^{a}	7.3
	Mean	Cultivar	$LSD_{0.05}$	Mean	Cultivar	$LSD_{0.05}$
% Weed (% Grass +% Broadleaf + % Wheat) as influenced by Cultivars	68.8^{a}	Orion	18.1	67.8^{a}	Orion	15.5
	45.1^{b}	Paraggio		45.2^{b}	Cyprus	
	44.9^{b}	Cyprus		40.6^{bc}	Sephi	
	43.6^{b}	Mogul		40.2^{bc}	Caliph	
	38.8^{b}	Serena		38.5^{bc}	Paraggio	
	37.9^{b}	Parabinga		32.5^{bc}	Serena	
	35.2^{b}	Caliph		31.2^{bc}	Mogul	
	34.3^{b}	Sephi		29.9^{bc}	Parabinga	
	28.0^{b}	Santiago		25.3^{c}	Santiago	

Means with different superscripts (a, b, c...) in the same column indicate significant differences

$LSD_{0.05}$= Least significant difference ($p \leq 0.05$)

Herbicides: IMI = Imazamox; HAL = Haloxyfop-R-methyl ester

NOTE: Only green material was sampled and identified. E.g., % Grass refers to the green grass in the pasture.

Percentage of combined grass weeds and volunteer wheat in the pasture showed significant difference ($p \leq 0.05$) between blocks and herbicide treatments. The contribution of the herbicide treatment (33.9 %) to the total variance (Table 3) was however convincingly higher compared to the contribution of blocks (6.7 %) and showed the same tendency (for the same reasons) as shown for percentage grass weeds alone.

Broadleaf weed DM production (kg/ha) on the 7th of July 2000 differed significantly ($p \leq 0.05$) between blocks, herbicide treatment and showed a significant blocks X herbicide interaction. Herbicide treatment contributed 33.8 % compared to the 12.7 and 11.6 % of blocks and the blocks X herbicide treatment interaction to the total variation (Table 3) and only the effect of herbicide treatment on broadleaf weed will for this reason be discussed. The haloxyfop-R-methyl ester treatment resulted in a significant higher DM production of broadleaf weeds (123.0 kg/ha) compared to the imazamox treated (6.9 kg/ha) plots (Table 5). This effect of the herbicides was, as has been explained, expected due to their different modes of action (weed spectra controlled). It was also clear that before the application in 2000 that the blocks sprayed with haloxyfop-R-methyl ester in 1998 were more infested by broadleaf weeds compared to the imazamox plots.

The percentage broadleaf weeds in the pasture differed significantly ($p \leq 0.05$) between blocks, herbicide, cultivar and the herbicide X blocks and cultivar X herbicide interactions. The herbicides, as a source of variance, contributed 33.5 % compared to the 10.7, 10.1, 15.4 and 13.7 % of blocks, blocks X herbicide treatment, cultivar and cultivar X herbicide interaction to the total variance (Table 3). Only the herbicide treatment's effect will be discussed due to its large contribution to the variation in the percentage of broadleaf weeds in the pasture. It is however important to remember that at this stage the effect of the herbicide treatment was due to applications in 1998, because the herbicide treatment for 2000 was applied shortly after sampling on 7 July 2000. The haloxyfop-R-methyl ester treatment (24.0 %) caused a significantly higher percentage of broadleaf weeds in the pasture compared to the imazamox treatment (1.4 %)(Table 5). This effect of the herbicides was as expected and it was quite clear before the application that the plots sprayed with haloxyfop-R-methyl ester in 1998 were more infested by broadleaf weeds than the imazamox plots.

The total percentage of weeds at 7 July 2000 in the pasture differed significantly between blocks, cultivar and blocks X herbicide interaction (Table 3). The effect of the blocks and the herbicide X block interaction are regarded as less important due to block differences measured between all parameters used in this trial. The effect of cultivar will be the only effect on the percentage of weeds that will for this reason be discussed. The percentage weed in the pasture is an indication of all the green volunteer wheat, grass and broadleaf weeds in the pasture. Table 4 shows that significantly more weed DM was produced on the plots where the cultivar Orion was grown. This high percentage of weed in the Orion plots was due to the effect of the imazamox treatment, which reduced the growth of this cultivar severely (95.2 kg/ha) in comparison to the other cultivars grown. This poor medic growth resulted in more vigorous weed growth (in the absence of competition from the medics) and explains the high percentage of weeds found in these plots.

On 15 August 2000 cumulative combined grass and volunteer wheat production (kg/ha) differed significantly ($p \leq 0.05$) between herbicide treatments only (Table 3). The difference in cumulative combined grass and volunteer wheat between herbicide treatments followed a similar trend as for sampling on 7 July 2000, where the imazamox treatment resulted in a higher (340.5 kg/ha) production of grassy weeds in the pasture compared to the haloxyfop-R-methyl ester treatment (106.6 kg/ha) (Table 5). This effect of the herbicides was as expected as it was before the application in 2000 already quite clear that the plots sprayed with haloxyfop-R-methyl ester in 1998 were less infested by grass weeds compared to the imazamox treated plots. This difference between the herbicides, as has been explained, may have been further enhanced due to the fact that sheep would graze imazamox treated areas more readily due to the absence of high and rugged growing wild radish.

The percentage of grassy weeds in the pasture during the sampling on 15 August 2000 differed significantly ($p \leq 0.05$) between the herbicide treatments only (Table 3). Imazamox application caused a higher (10.5 %) fraction of grass compared to the haloxyfop-R-methyl ester treatment (1.1 %)(Table 5). This effect of the herbicides was for the reasons already explained, expected.

The percentage of combined grass weeds and volunteer wheat at 15 August 2000 differed significantly ($p \leq 0.05$) between herbicide treatment, cultivars used, and blocks X herbicide and herbicide X cultivar interactions. Because the herbicide treatment contributed 48.7 % to the variation compared to the 3.4, 15.7 and 13.5 % of block X herbicide, cultivars used and cultivars used X herbicide respectively (Table 3), only this effect will be discussed. The imazamox application, as for percentage grassy weeds, resulted in a higher percentage (23.6 %), compared to the haloxyfop-R-methyl ester treatment (4.0 %), of grass and wheat in the pasture (Table 5).

The only significant difference found in cumulative broadleaf weed production (kg/ha) on 15 August 2000 was due to herbicide treatments (Table 3). The haloxyfop-R-methyl ester treatment caused a higher production (508.8 kg/ha) of broadleaf weeds in the pasture compared to the 290.4 kg/ha of the imazamox treatment (Table 5). The effect of the herbicides was as expected due to their respective registered weed control spectra and because it was before the 2000 application of herbicides already clear that the plots sprayed with haloxyfop-R-methyl ester in 1998 were more heavily infested by broadleaf weeds in comparison to the imazamox plots. The effect of imazamox on the broadleaf weed DM on 15 August showed a similar tendency to that found on 7 July 2000, confirming the carry-over effect of the herbicide treatment in 1998.

The percentage broadleaf weed in the pasture on 15 August 2000 differed significantly ($p \leq 0.05$) between blocks, herbicide treatment and the interaction between blocks and herbicide treatment but the contribution of herbicide treatment, as a source of variation were 56.9 % and much higher compared to blocks (17.1 %) and blocks X herbicide treatment (11.2 %) (Table 3). Results and tendencies were similar to that found at the earlier sampling dates. The haloxyfop-R-methyl ester treatment caused a convincingly higher percentage (46.7 %) of broadleaf weeds in the pasture compared to the imazamox treatment (3.1 %) (Table 5).

The total percentage of weed in the pasture on 15 August 2000 was influenced significantly ($p \leq 0.05$) by blocks (31.8 %), herbicide treatment (22.6 %), cultivars used (22.3 %) and the interaction between blocks and herbicides (8.6 %) (Table 3). The relatively high contribution of blocks to the total variation will not be discussed due to the differences between blocks for almost every parameter measured in this trial. Only the differences between herbicide treatment and cultivars used will be discussed due to their relative high contribution to the total variance. Haloxyfop-R-methyl ester which controls only grassy weeds caused the higher percentage (50.9 %) of weed in the pasture compared to the imazamox treatment (27.2 %) which controls both broadleaf as well as some grassy weeds (Table 5). Broadleaf weeds like *Raphanus raphanistrum* are known as very vigorous growers which produce more DM per surface area as opposed to the different grass species in the pasture. Another reason might be that sheep graze grasses (found in IMI plots) more readily compared to broadleaf weeds (found in HAL plots) because grasses are more palatable than most broadleaf weeds (Marten & Anderson, 1975).

The significant differences between cultivars with regard to the percentage of broadleaf weeds were due to the poor performance of Orion for reasons already explained.

Conclusions

The use of annual legumes in a rotation system of one-year medic pasture followed by a wheat crop may have several advantages with regard to both crop and animal production, but the choice of the best adapted medic and wheat cultivars as well as sustainable production techniques are needed to ensure optimal economical advantages.

In this study medic cultivar Caliph showed the highest DM and pod production, but with the exception of Orion, cultivars tested did not differ much and Orion produced the least DM and pods due to its high sensitivity to imazamox and should therefore not be used in combination with an imazamox herbicide application. None of the other cultivars tested showed any sign of sensitivity to this herbicide.

Imazamox which controls both broadleaf weeds and some grass species, in spite of its detrimental effect on Orion, resulted in a significant higher percentage of which controls only grassy weeds) towards the end of the growing season. This may have an effect on the palatability, nutritional value and quality of the pasture. Although tillage methods used to establish wheat crops in a pasture/wheat rotation in this study did have an effect on weed seedlings in the germination study, pasture composition was not affected significantly. Tillage methods should therefore not be considered as an effective method to improve pasture quality.

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CHAPTER 5

The effect of weed control by imazamox and haloxyfop-R-methyl ester on the quality of medic (*Medicago* spp.) pastures with reference to NDF-, CP content and *in vitro* digestibility

Abstract

Pasture sampling was done at Langgewens experimental farm in the Swartland wheat producing area of South Africa. Samples were analysed for crude protein (CP) and neutral detergent fibre (NDF) content, and subjected to *in vitro* digestion. The pasture consisted of nine medic cultivars sown separately and was treated with either an imazamox (IMI) or a haloxyfop-R-methyl (HAL) ester herbicide. Significant differences were found between the dry matter (DM) production of the different medic cultivars but the herbicides did not significantly influence the amount of weeds or medics in the pasture. HAL however yielded a significantly higher digestible NDF (DNDF) (38.8 %) and digestible DM (DDM) (55.3 %) content in the pasture compared to IMI (34.1 and 52.2 % respectively). The pasture components (medic hay, medic pods, grass and broadleaf weeds) were used to predict the pasture quality parameters: digestible CP (DCP), DNDF, DDM, as well as the percentage of CP (PCP) and NDF (PNDF). The amount of variation explained by the regression equations differed, but the correlation between the quality parameters and pasture components increased, as the number of pasture components used to determine the different quality parameters, increased. Further study might refine these equations for use on the farm to predict/improve animal production.

Keywords

Crude protein, Digestible dry matter, Medic pasture quality, Neutral detergent fibre

Introduction

Medicago (e.g. medics and lucerne) and *Trifolium* species (e.g. subterranean and balansa clover) are used in the Swartland and Southern Cape regions of South Africa in rotation with crops (e.g. wheat and barley). The amount of weed over either the long term (five years lucerne and five years cereal) or the short term (one year medics and one year wheat) rotation systems may have an effect on the quality of the pasture and thus animal production and may influence the yield of crops in the years after the pasture.

The major limitations in the utilisation of pasture (Reid & Jung, 1982) as feedstuff for ruminants, are low intake and digestibility. The primary limitation on feed intake seems to be nutrient imbalances (Preston & Leng, 1987), since dietary deficiencies of nutrients essential to rumen microbes will reduce voluntary feed intake (Ellis, Wylie & Matis, 1988). DDM and CP content of a pasture are therefore some of the parameters used to measure/predict the nutritive value and grazing capacity of a pasture while NDF are used to predict the intake of a pasture, by grazing animals, as Hutjens (1992) has shown for dairy cows. Weeds in the pasture may have an effect on these parameters and thus the quality of the pasture.

Although weeds (broadleaf and some grasses) consist of a wide variety of species, weeds are considered to be lower in yield and quality than the legume pasture species (*Medicago* and *Trifolium* spp.), however many weeds are eaten along with desired forage grasses and legumes. This is because most weeds are high in digestibility during their early stages of vegetative growth and have an adequate CP content but their digestibility and CP-content decline as they mature and therefore decrease the quality of the pasture later in the growing season. It is thus important to utilise and control these weeds by grazing early in the growing season to benefit from their higher CP and DDM content (http://www.ca.edu/agc/pubs/agr/agr172/agr172. htm, 2001). Weeds differ in their contribution to total pasture quality. The average quality of broadleaf (with woody stems such as wild radish) and grassy weeds, compared to lucerne are, 50 % and 75 % respectively as far as CP are concerned. Weeds also differ in their DDM content, but are mostly lower compared to lucerne (http://agguide.agronomy.psu.edu/sect8/sec810a.htm, 2001). Where a pasture is highly infested by *Bromus diandrus* and *Hordeum murinum* in the ripening stage, quality of wool, meat and skins of sheep will decline due to the barbed seeds of these grasses (Aligianis, 1977). This was also shown by Van Heerden (1990) where grass control by grass herbicides caused a definite improvement in sheep wool production and annual daily gain on lucerne (*Medicago sativa*). However, no improvement on annual medics (*Medicago* spp.) were found due to less DM produced by medics during the growing season. It is however important not to control all grasses because they form an important part of winter forage (Abadi Ghadim & Panell, 1991).

Denney, Hogan and Lindsay (1979) found that in a medic pasture, in rotation with cereals, will consist of green medic and weeds early in the rainy season, but after the rainy season it will consist of little green material but more medic hay, pods and weed dry material. During the dry season medic pods and hay will have a CP (g/100 g OM) content of 16.9 and 23.8 % respectively with an apparent digestibility of 65.9 and 63.3 % respectively. They also found that the indigestible fibre content of pods are however high in barrel medic pods and has a low nutritive value (Denney, Hogan & Lindsay, 1979).

There do however exist differences between cultivars' seed: pod ratio in their pods and therefore also their CP and DCP content (Thomson, Rihawi, Cocks, Osman & Russi, 1990; Kotze, Brand & Agenbag, 1995). As mentioned earlier, the digestibility of the different weed species will also decrease. Literature has shown no report of the effect of either a grass- or broadleaf weed herbicide on medic pastures' quality (CP, NDF and DDM content).

Therefore the aim of this study was to determine the influence of (a) different broadleaf and grass herbicides on pasture composition and (b) the influence of pasture composition on the quality of medic pastures.

Materials and Methods

The pasture was grown at Langgewens experimental farm (33° 17' S; 18° 42' E) in the Swartland wheat producing area of South Africa during 1998. Typically of all areas with Mediterranean climates, this area experiences hot and dry summers and moderate, rainy winters. Almost 80 % of its mean annual rainfall (350 mm) occur during April to September, reaching a peak during June to August, followed by a sharp decline during September and October. Therefore dryland farming is constricted to the production of winter crops with a growth period between April and October. In 1998 the rainy season started later than usual, when compared to the 40-year average (Agromet, 2000). The total rainfall for April to October was far below average and only during May did it exceed the average. The soil characteristics for the experimental site are described in Chapter 3.

In this experiment, medic-pastures (nine medic cultivars) were rotated annually with spring wheat cultivars. The nine medic cultivars were of three different species (*Medicago truncatula*, *M polymorpha*, *M sphaerocarpus*) namely Caliph, Cyprus, Mogul, Parabinga, Paraggio, Sephi (*M truncatula*); Serena, Santiago (*M polymorpha*) and Orion (*M sphaerocarpus*). These medic cultivars were initially sown in May 1998 at a rate of 20 kg/ha.

Two post emergence herbicide treatments, namely an imidazolinone, at a rate of 48 g a.i. ha^{-1} imazamox (IMI) and a haloxyfop, at a rate of 108 g a.i. ha^{-1} haloxyfop-R-methyl ester (HAL) were applied during 1998 to control weeds in the above mentioned medic cultivars. Herbicides were applied 2-3 weeks after germination of the weeds (end of May) with a tractor sprayer and a spray volume of 200 l ha^{-1}. The HAL herbicide is a true grass-weed herbicide and controls a wide spectrum of annual grasses. The IMI herbicide on the other hand is a broadleaf-weed herbicide, which controls only a few grassy weeds, mostly in the first leaf to first node stage, such as *Avena fatua, Bromus diandrus, Hordeum murinum and Lolium multiflorum.*

Pasture samples with a known quantity of broadleaf, grass, medic pods and medic green material were taken during October 1998. The sampling size was 1655.35071 cm^2 and sampling was done by placing a ring on the ground and removing all material within. The weight of DM for medics, grass and broadleaf weeds were multiplied by 60.41 to calculate the amount of DM per hectare during October 1998. Weeds and medics were added together and the samples were milled to a particle size of 0.5 mm and digested by the *in vitro* technique described by Tilley and Terry (1963). Samples were then analysed for DM and CP content according to the AOAC (1984) while the NDF content was determined by the method described by Van Soest and Wine (1967).

All pasture production data was subjected to an analyses of variance, using SAS (1990). Differences were measured between blocks, herbicide treatments, cultivars used and herbicide X block and cultivar X herbicide interactions. Results from the laboratory analyses were subjected to a modelling procedure using SAS (1990). The best regression equations were chosen by using the correlation between the dependent and independent variables and C_p (Mallows' C_p). The best fit will be where R^2 is the highest and where C_p = the number of variables used to calculate the dependent variable + 1 (the y-axes intercept).

Results and Discussion

The effects of different medic cultivars on the pasture composition are presented in Table 1. The different cultivars used in this trial caused significant differences ($p \leq 0.05$) between the medic, pod and total DM produced on the pasture as well as the percentage of medics and pods. In October 1998, the cultivar Paraggio (4047 kg/ha) produced significantly more dry medic material compared to Orion, Santiago, Mogul, Parabinga and Serena while Parabinga (1380 kg/ha) produced the largest amount ($p \leq 0.05$) of pods and Orion (207 kg/ha) the least, which is due to Orion's sensitivity to the IMI herbicide as has been found by Pepler (1996). The reason for the differences between cultivars has already been discussed in Chapters 3 and 4 and these results are shown to indicate the differences in

Table 1 The variation caused by the use of different medic cultivars in the total amount (kg/ha) and percentages of medics, medic pods, grass and broadleaf weeds available to grazing animals in the pasture during October 1998.

Cultivar	Medics		Medic pods		Medic+pods		Grass		Broadleaf		Tot. DM
	kg/ha	%	kg/ha	%	kg/ha	%	kg/ha	%	Kg/ha	%	kg/ha
Paraggio	4047^{a}	75^{ab}	699^{abc}	16^{c}	4747^{a}	91^{a}	169^{a}	5^{b}	211^{a}	5^{b}	5127^{a}
Sephi	3378^{ab}	78^{a}	530^{bc}	12^{c}	3909^{ab}	91^{a}	388^{a}	9^{ab}	20^{a}	0^{b}	4316^{abc}
Cyprus	2643^{abc}	57^{abc}	814^{abc}	21^{bc}	3457^{ab}	78^{a}	654^{a}	19^{ab}	113^{a}	3^{b}	4224^{abc}
Caliph	2255^{abc}	48^{cd}	1136^{ab}	24^{bc}	3391^{ab}	72^{ab}	485^{a}	10^{ab}	813^{a}	18^{ab}	4688^{ab}
Orion	1711^{bc}	42^{cde}	207^{c}	4^{c}	1918^{b}	47^{b}	591^{a}	22^{a}	640^{a}	31^{a}	3149^{bcd}
Santiago	1546^{bc}	53^{bcd}	521^{bc}	20^{bc}	2068^{b}	73^{ab}	325^{a}	13^{ab}	379^{a}	14^{ab}	2771^{cd}
Mogul	1444^{bc}	58^{abc}	447^{bc}	18^{bc}	1891^{b}	77^{ab}	231^{a}	9^{ab}	220^{a}	15^{ab}	2342^{d}
Parabinga	1395^{bc}	29de	1380^{a}	37^{ab}	2776^{ab}	66^{ab}	396^{a}	10^{ab}	835^{a}	24^{ab}	4007^{abcd}
Serena	787^{c}	23^{e}	1279^{ab}	49^{a}	2066^{b}	71^{ab}	594^{a}	24^{a}	121^{a}	5^{b}	2780^{cd}
LSD	2226	24	835	21	2567	31	569	18	886	25	1697
Average	2134	57	779	21	2913	78	426	11	373	10	3712

LSD = Least significant difference ($p \leq 0.05$)

Values with different letters (a, b, c...) in the same column differ significantly ($p \leq 0.05$)

composition between samples used in the *in vitro* digestion study. This results will not be discussed any further and are used to give the reader direction in the composition in the samples used for *in vitro* digestion.

The effects of the herbicide treatments on the pasture composition and pasture quality parameters are presented in Table 2. The herbicide treatments had no significant effect ($p \leq 0.05$) on the pasture composition and only the quality parameters, % DDM and DNDF were influenced significantly by these treatments. IMI, which controls broadleaf weeds and some grass species, e.g. *Bromus diandrus* and *Lolium multiflorum* (Pepler, 1996), yielded a lower DDM (52.2 %) and DNDF (34.1 %) content in the pasture compared to the HAL treatment (55.7 and 38.8 %). The lower DDM and DNDF, although not significant, in the IMI plots may be due to the higher percentage of pods and the higher percentage of broadleaf weeds (Table 2).

Table 2 The effect of IMI and HAL on medic pasture composition (%), production (kg/ha) and *in vitro* digestibility (n=18).

	Medics		Grass		Broadleafs		Pods		TotDM	CP	NDF	DDM	DCP	TotDCP	DNDF	TotDNDF	TotDDM
Herbicide	%	Kg/ha	%	kg/ha	%	kg/ha	%	kg/ha	kg/ha	%	%	%	%	kg/ha	%	kg/ha	kg/ha
IMI	51.6^{a}	2431.8^{a}	10.7^{a}	356.1^{a}	14.4^{a}	416.8^{a}	23.4^{a}	873.6^{a}	4078.3^{a}	16.2^{a}	54.5^{a}	52.2^{b}	70.2^{a}	503.5^{a}	34.1^{b}	745.0^{a}	2124.3^{a}
HAL	54.9^{a}	1836.5^{a}	16.1^{a}	495.4^{a}	10.9^{a}	328.2^{a}	21.4^{a}	685.0^{a}	3345.0^{a}	15.8^{a}	55.7^{a}	55.3^{a}	72.4^{a}	384.7^{a}	38.8^{a}	706.9^{a}	1831.3^{a}
Average	53.2	2134.2	13.4	425.7	12.7	372.5	22.4	779.3	3711.7	16.0	55.1	53.7	71.3	444.1	36.5	726.0	1977.8
LSD	11.5	1049.2	8.3	296.0	11.8	430.0	9.8	393.8	799.6	1.5	2.6	2.1	3.5	127.7	3.2	150.8	436.0

IMI = Imazamox

HAL = Haloxyfop-R-methyl ester

TotDM = total DM, DCP = Digestible CP, DNDF = Digestible neutral detergent fibre, DDM = Digestible DM,

NDF = Neutral detergent fibre in pasture, CP = CP, TotDCP = Total digestible CP,

TotDNDF = Total digestible neutral detergent fibre, TotDDM = Total digestible DM

LSD = Least significant difference ($p \leq 0.05$); Values in the same column with different letters (a, b, c…) differ significantly ($p \leq 0.05$)

Pods (Denney, Hogan &Lindsay, 1979) and woody broadleaf weeds (Marten & Anderson, 1975) such as wild radish (this was observed to be the primary weed specie infecting the pasture) are both low in digestibility. Herbicide treatment did not influence the amount of weed (grass and broadleaf) as a pasture component probably due to the time lapse between sampling (October) and herbicide application (May) the reasonably large weed seedbank that was observed prior to the planting of the pasture.

Pasture quality in terms of CP, NDF, DCP, total DCP (kg/ha), total DNDF (kg/ha) and total DDM (kg/ha) content was not influenced significantly by the different herbicides. This was probably due to the small effect the herbicide treatments had on pasture composition which, as been described by Marten and Anderson (1975), include weeds with lower digestibility, CP and fibre content. The small effect of the herbicide treatment will however cause variation in the contribution of the different pasture components(Table 2), which will cause variation in the quality of the pasture (CP, NDF, etc.) due to differences in nutritive value between the pasture and weed species (Marten & Anderson, 1975).

Table 3 shows the general regression of the attribution by the different pasture components to pasture CP, NDF, DDM, DCP and DNDF. The value of these dependent variables can partly be explained by the pasture composition as the R^2 values indicate (Table 3). The amount of variation explained by the composition differs widely depending on the number of independent variables that are used to calculate the regression equation. Pasture composition explains (R^2=) 57.2 - 70.2 % of the variation in the PCP, 49 - 64.3 % of the variation in the PNDF, 59.3 - 69.3 % of the variation in DDM, 63.6 - 74.1 % of the variation in DCP and 68.1 % of the variation in DNDF in the pasture, depending on the number of variables that are used to determine these dependent variables (Table 3). The best estimation for these variables will be where all the pasture components are used (medics, pods, grass and broadleaf weeds) as well as the interactions between the independent variables (pasture components) in determining their values.

Table 3 The effect of the different pasture components on the digestibility of CP, neutral detergent fibre and DM, and the percentage CP and neutral detergent fibre in the pasture as a whole.

N	R^2	C_p	MSE	Estimate intercept	Possible predictions for the different dependent variables
Percentage CP (PCP)					
2	0.5719	2.819	3.141	18.4116	PCP = -0.1027B - 0.00215MG + 18.4116
12	0.7022	12.83	3.135	-401.1	PCP = 26.3055M - 34.1096G - 0.2208MM + 0.3814GG + 0.0399BB + 0.0423PP + 0.1609MG - 0.1811MB - 0.1805MP + 0.4261GB + 0.4245GP + 0.0857BP - 401.1
Percentage neutral detergent fibre (PNDF)					
2	0.4904	2.807	6.72	60.1504	PNDF = -0.1447B - 0.00094MM + 60.1504
3	0.5051	3.86	6.73	58.7218	PNDF = 0.0733M - 0.1374B - 0.00166MM + 58.7218
10	0.6119	10.99	6.76	2236.5	PNDF = -21.8549M - 21.6047G - 104.8P - 0.2185BB + 0.8306PP - 0.2188MB + 0.8316MP - 0.222GB + 0.8279GP + 0.6113BP + 2236.5
12	0.6427	13	6.76	50.1321	PNDF = 179.7G + 13.9687B - 94.3714P - 1.7942GG - 0.1387BB + 0.9442PP - 1.7956MG - 0.1391MB + 0.9462MP - 1.9387GB - 0.8515GP + 0.8015BP + 50.1321
Digestible DM (DDM)					
3	0.5932	3.579	14.78	63.1457	DDM = -0.641P - 0.00165BB + 0.00725PP + 63.1457
11	0.6926	11.87	14.9	1024.9	DDM = -21.881M - 21.4588G + 2.5978B + 0.1226MM + 0.1187GG - 0.1237BB - 0.0964PP + 0.2391MG + 0.0207MP + 0.0196GP - 0.2257BP + 1024.9
11	0.6926	11.87	14.9	977.1	DDM = -21.2818M - 20.8658G + 2.9574B + 2.323P + 0.1214MM + 0.1175GG - 0.1225BB - 0.1149PP + 0.2367MG + 0.00101MP - 0.243BP + 977.1
11	0.6926	11.87	14.9	1171.6	DDM = -25.1747M - 11.3303G - 11.107P + 0.1409MM + 0.00276GG - 0.1123BB + 0.1414MG + 0.0295MB + 0.1353MP - 0.1045GB - 0.1182BP + 1171.6

Table 3 Continue

N	R^2	C_p	MSE	Estimate intercept	Possible predictions for the different dependent variables
Digestible CP (DCP)					
2	0.6358	2.365	16.02	72.8582	DCP =-0.3646B + 0.00918MB + 72.8582
3	0.6394	4.045	16.36	73.2275	DCP =-0.3617B + 0.00878MB) - 0.00034PP+ 73.2276
7	0.6849	8.002	16.34	74.5583	DCP = 17.2456M - 0.289B - 0.1722MM - 0.01726MG - 0.1662MB - 0.01744MP - 0.00287BP+ 74.5583
10	0.7192	10.96	16.31	2613.9	DCP = -25.3344M + 220.9G - 25.6025B - 272.0P - 2.4632GG + 2.4668PP - 2.4638MG + 2.4627MP -2.4568GB + 2.4609BP +2613.9
12	0.7412	13	16.33	2851.2	DCP = -21.123B - 237.2P - 0.277MM - 0.2774GG - 0.0703BB + 2.0955PP - 0.5552MG - 0.344MB + 1.8134MP - 0.3408GB + 1.8111GP + 2.0244BP + 2851.2
Digestible neutral detergent fibre (DNDF)					
12	0.6812	13.2	33.04	43.1648	DNDF = -11.7677M + 147.5G - 74.8547B + 0.1176MM - 1.4741GG + 0.7473BB - 1.3597MG + 0.8724MB + 0.1116MP - 0.727GB - 1.4707GP + 0.735BP + 43.1648

N = The number of independent variables used to determine the different dependent variables (DCP, DNDF, etc.); MSE = Mean Square Error

The independent variables as a percentage in the pasture were: M = medics, G = grass, B = broadleaf weeds, P= pods of medics, double letters indicate the product or square of medic, grass, broadleaf weeds or pods of medics and were also used as independent variables.

C_P = Criteria used to determine the best model. Ex. Where C_p are equal or closest to the number of components used + 1is the best model.

R^2 = Correlation between pasture components and dependent variables are also an indication of the amount of variation explained by the independent variables in determination of the dependent variables.

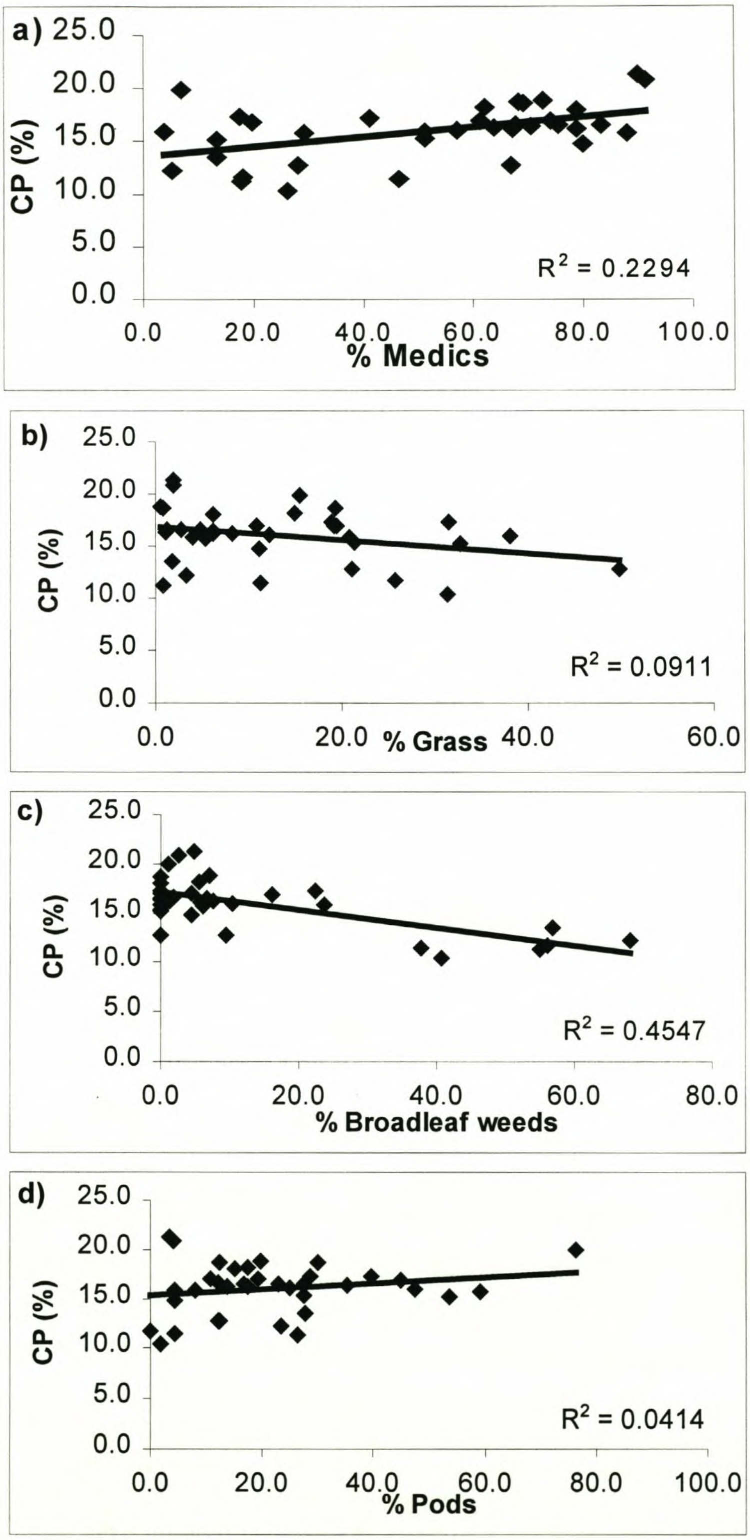

Figure 1 (a-d) The effect of different pasture components on the CP content (%)

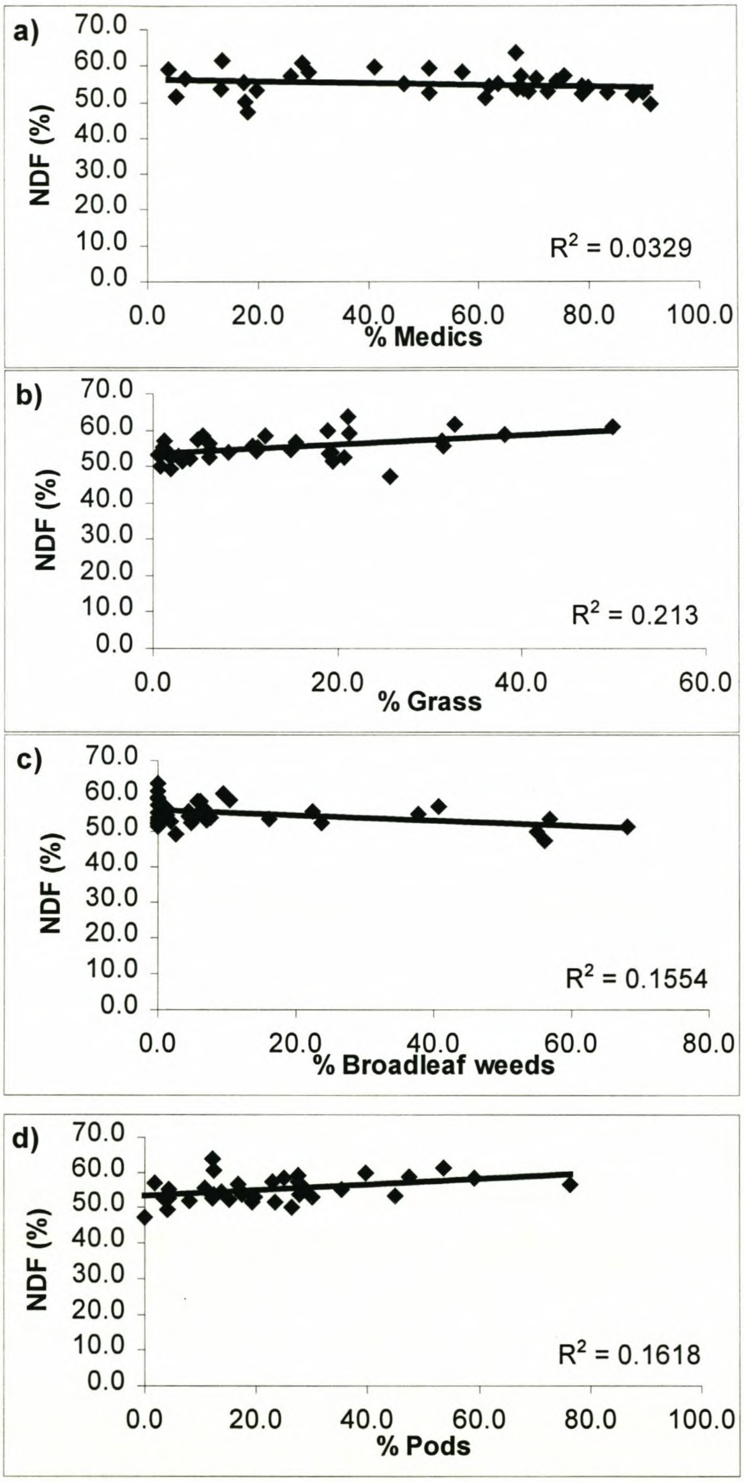

Figure 2 (a-d) The effect of different pasture components on the NDF content (%)

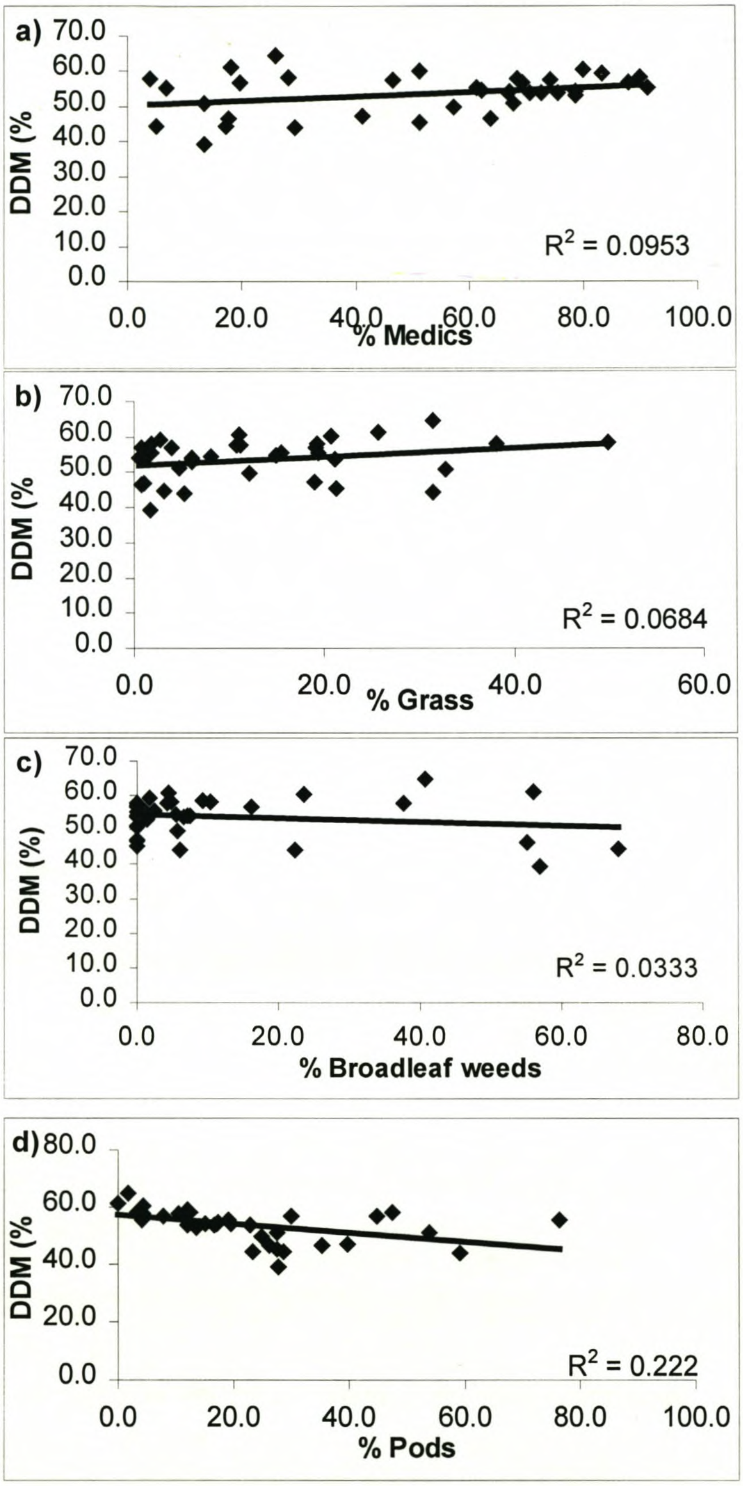

Figure 3 (a-d) The effect of different pasture components on the digestibility of DM (%)

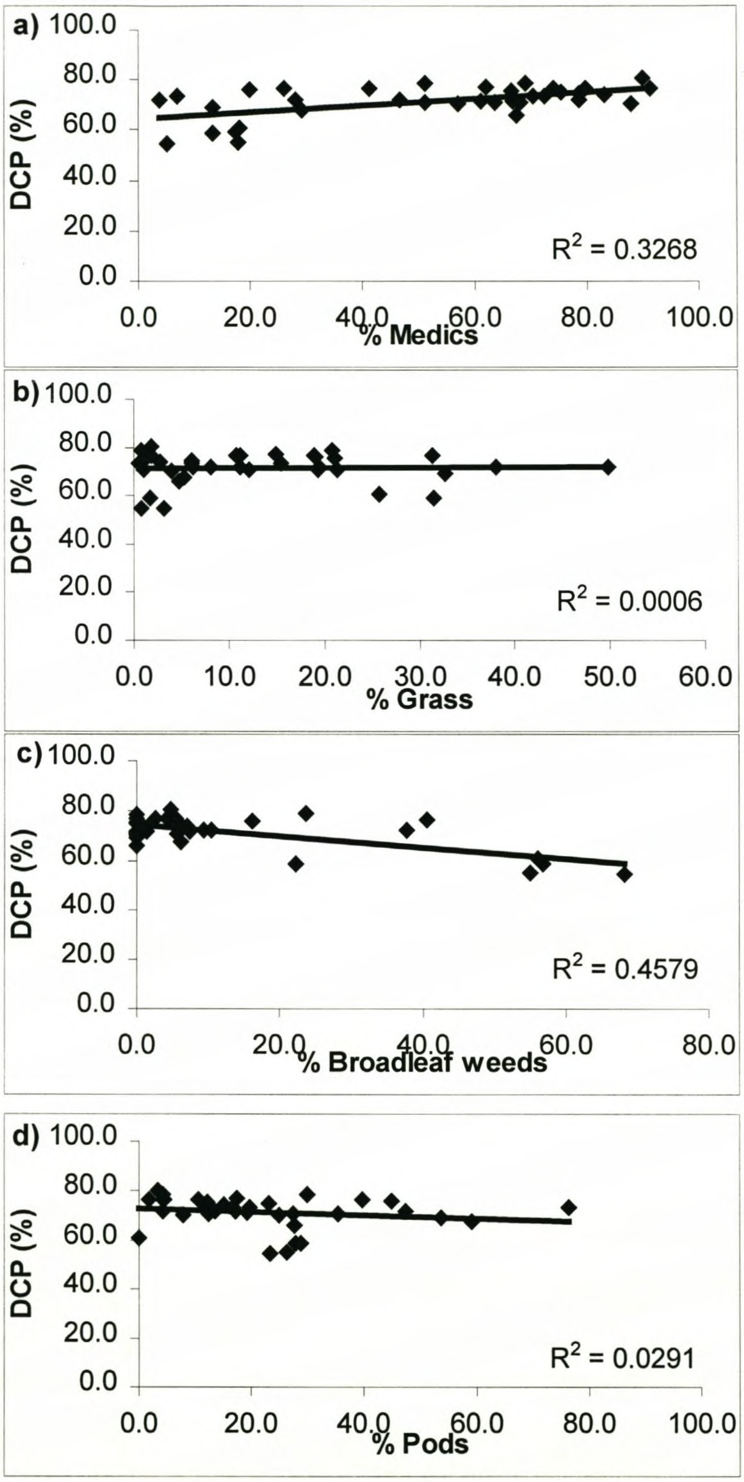

Figure 4 (a-d) The effect of different pasture components on the digestibility of CP (%)

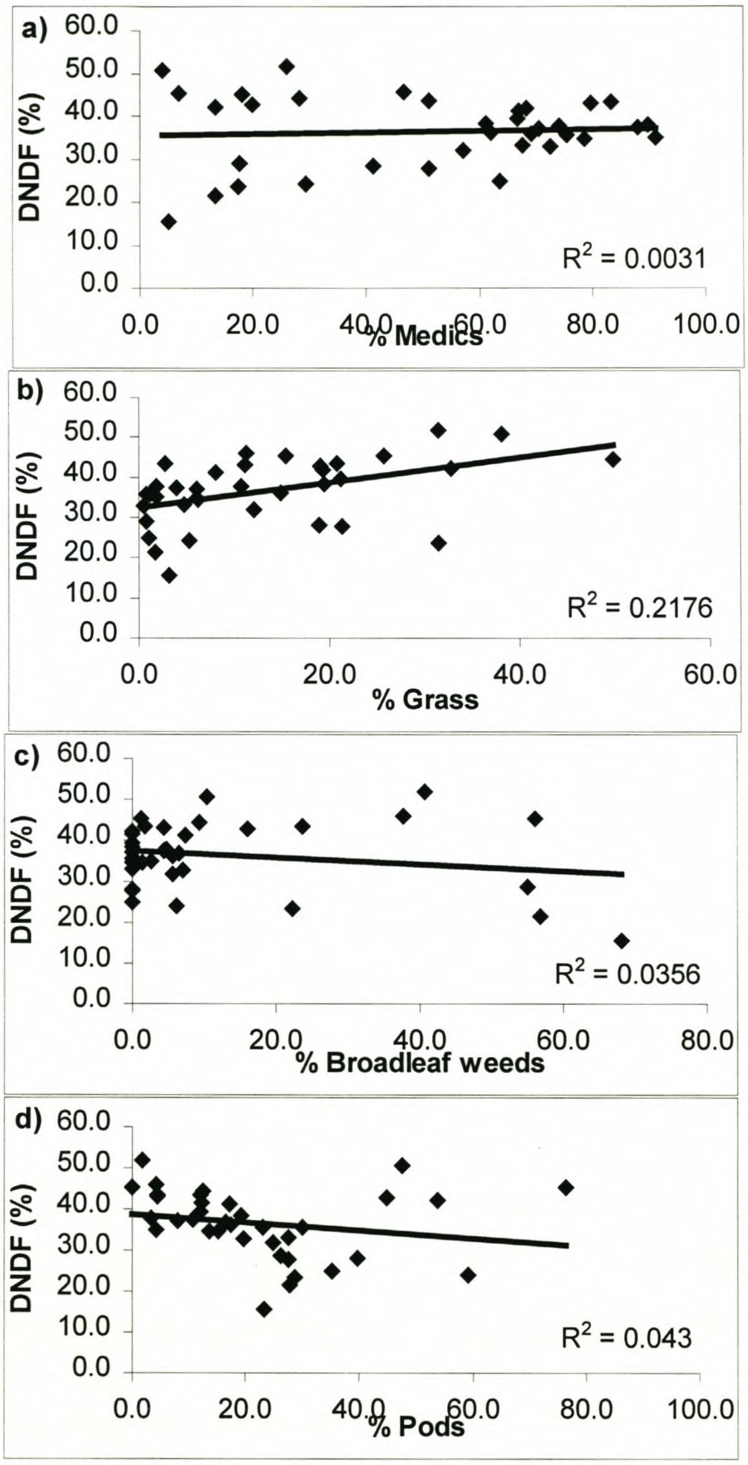

Figure 5 (a-d) The effect of different pasture components on the digestibility of NDF (%)

The relative small variation in PCP, PNDF, DDM, DCP and DNDF can be explained by the pasture components. Minimal differences in PCP, PNDF, DDM, DCP and DNDF occurred between different grass, broadleaf weed, pods and to a lesser extend medic species. Differences between weed species in their *in vitro* digestibility, acid detergent fibre, acid detergent lignin and CP content was detected by Marten and Anderson (1975).

Figures 1-5 shows the general tendencies for the different pasture quality parameters as it is influenced by different pasture components. These tendencies have a low R^2 value and therefore a low correlation, as with the model. The relationship between pasture quality parameters and components will for this reason not be discussed.

Conclusions

During sampling in October 1998 the cultivar Paraggio produced the most DM while Serena produced the least. IMI led to a higher production in medic DM, broadleaf weeds and pods compared to HAL, which led to a higher grass production of the two herbicides. HAL precipitated a significant higher DDM and DNDF in the pasture compared to IMI.

Using regression analysis, pasture medic, medic pods, grass and broadleaf weed content can be used to predict the digestibility, CP and NDF content. The regression between the pasture components and the pasture quality parameters however only explains part of the variation in the CP, NDF and the DDM of the pasture. The reason for this is possibly due to a more complex relationship between the pasture components and the quality parameters used in this trial and further study should lead to a refinement in the regression equations. By using growth prediction curves and pasture quality predictions it might be possible to improve animal production management.

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CHAPTER 6

General conclusions

The aim of this study was to determine the effect of nine different medic cultivars, haloxyfop-R-methyl ester and imazamox herbicides, as well as method of tillage during the planting of wheat on the regeneration, dry matter production and quality of medic pastures.

Regenerative ability of the different cultivars under these conditions depends on the amount of seeds that are produced in a growing season. In January 2000, after a pasture and a wheat year, Sephi (410.7) and Paraggio (400.3) produced the most seedlings in the germination trial while Caliph (189.2) and Parabinga (145.7) produced the least seedlings/m^2. As expected, all the cultivars except for Orion (105.0) and Caliph (121.1) produced more seedlings/m^2 after two pasture years and where no wheat has been planted compared to where wheat has been planted. Cyprus (691.7) produced the most seedlings where no wheat has been planted. The ability of a cultivar to produce enough seed with a certain degree of dormancy is a very important characteristic of medics because the intervention of wheat in the rotation system causes a year in which very little or no seed are produced. Some of the cultivars (e.g. Caliph, Serena, Parabinga and Santiago) however, have a very high degree of dormancy in their seeds and might also be suited for winter rainfall areas such as the Southern Cape which receive some summer and early autumn rain (November - February).

The susceptibility of cultivars to herbicides used to control broadleaf weeds, is another factor that should be kept in mind for it can result in poor regeneration of the pasture due to a small amount of seeds produced. In this trial the cultivar Orion proved to be very sensitive to an imazamox spraying with the result that this cultivar produced the lowest number of seedlings as well as dry matter during pasture years.

The control of broadleaf weeds in the pasture by imazamox (which controls mainly broadleaf weeds) caused an increase in the average seed production in medics compared to the haloxyfop-R-methyl ester (which controls only grassy weeds) treatment. This result makes it therefore an important aspect to consider when there is a possibility of poor pasture regeneration due to competition from weeds.

Tine tillage, compared to no tillage, caused an increase in the number of medic seedlings in the pre-season germination trial but this was not the case in the on-site seedling counts.

Both the herbicides reduced the number of seeds of the respective weed species which they are registered for in the pre-season germination trial.

Tine tillage caused a significant higher number of grass weeds seedlings, while no tillage caused a higher number of broadleaf weed seedlings.

Dry matter production by the different medic cultivars differed during the growing season. At 7 July and 15 August 2000 little difference were however found between cultivars except for Orion, which produced very little dry matter through out the season due to its sensitivity to the imazamox treatment. At both dates Parabinga produced the highest amount of dry matter, but at sampling on the 2nd of October 2000, Caliph out yielded all the other cultivars, which is probably due to later germination due to the relative high degree of dormancy in Caliph's seeds.

As expected, haloxyfop-R-methyl ester gave better control of grassy weeds, while imazamox gave better control of broadleaf weeds.

The analysis of pasture samples taken in October 1998 showed no differences between the herbicide treatments in so far pasture composition are concerned.

The correlations, in the modelling procedure, used to predict the pasture quality parameters (crude protein and neutral detergent fibre content, digestible dry matter, -neutral detergent fibre and -crude protein) by using the pasture components as independent variables differed widely and a further improvement on this model might be possible. Accuracy (R^2) of the different regression functions differed between 49 and 74.1 %.

It seemed like the pod and broadleaf component of the pasture had the largest influence on the neutral detergent fibre digestibility and digestible dry matter content of the pasture.

It might be possible to use this model in on farm experiments to improve animal production and management but further refinement of this model is necessary.

The best cultivar, herbicide and tillage combination for a sustainable wheat/medic pasture rotation and high pasture quality under these conditions, seemed to be any of the cultivars except for Orion and Cyprus, the imazamox herbicide and a shallow tine tillage treatment at planting of wheat. This is because of Orion's sensitivity to imazamox and Cyprus's low dry matter production late in the growing season, imazamox's ability to control unpalatable and low digestible broadleaf weeds as well as some grass species and the fact that the shallow tine tillage treatment caused a higher medic seedling number in the pre-season germination trial.