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PASTURE, FORAGE AND LIVESTOCK PROGRAM

Annual Report 1988

PASTURE, FORAGE AND LIVESTOCK PROGRAM

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The International Center for Agricultural
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EXECUTIVE SUMMARY

After four years and two complete cycles of pasture and cereal the ley farming system has been successfully established on farmers' fields in north Syria. The mean size of the legume seed bank after grazing in 1987/88 (a good indicator of sustainability of the ley farming system) exceeded 200 kg/ha. Wheat yields after pasture were greater than after the farmers' alternatives, and stocking rate of regenerating pasture exceeded 7 ewes/ha. Profitability of the livestock enterprise, based on 1988 prices, was far higher than from all other options, including wheat.

Size of the seed bank of several medics and clovers is being closely monitored. In the medics, after seed softened over two summers, between 16% (M. noeana) and 56% (M. polymorpha) of the seed bank had germinated in the following autumn, while in the clovers, germination ranged from 13% (T. campestre) to 86% (T. stellatum). Possession of an impermeable seed coat (hardseededness) was the mechanism by which the seeds resisted germination. Seeds lost their hardseededness more rapidly in the second compared with the first summer after seed set, but in both years hard seed breakdown occurred most rapidly in autumn. Some species (eg M. rigidula, M. polymorpha) germinated promptly after early autumn rains, while others (eg M. rotata) resisted germination until later. Buried seeds lost their hardseededness more slowly than seeds lying on the surface.

A methodology is being developed to select pasture legumes. To begin, data on the distribution of wild species are collected, and attributes of the accessions are measured. The data show that species and accessions from dry areas are likely to have smaller seeds and be harder-seeded than when they come from wetter areas. Furthermore the species from dry areas are likely

to have more seeds/pod indicating that they are more efficient in allocating their resources to reproduction. There is less variation in the accessions from dry areas, and, within species, accessions from dry areas are likely to mature earlier. The data suggest that in dry areas Astragalus and Trigonella may be more suitable pasture species than the medics and clovers.

The next step is to measure success in the farming system for which the selections are intended - the ley farming system. The most successful species in north Syria are M. rigidula, M. noeana, and M. rotata. Within species, accessions with (in order of importance) short petioles, long peduncles, small seeds, short internodes, high mass of pods/plant, low pod retention, and high hardseededness were the most successful. The data indicate that tolerance of grazing during the pasture phase may be more important than survival of seeds during the cereal phase.

Medics resistant to root nematodes were identified, and a vetch that buries its seeds was studied. The latter is an interesting and potentially important species for improving grasslands.

Rhizobia suitable for most of ICARDA's medics have now been identified. For M. rigidula a strain (M29) has performed well in Morocco, Algeria, Turkey, Syria, France and Jordan. Introduced rhizobia have been shown to persist for several years. Nitrogen fixed by M. truncatula increased from about 20 kg/ha to nearly 80 kg/ha after inoculation, and nitrogen fixed by M. rigidula, which did not require inoculation, reached 100 kg/ha. In the experiment two methods of measuring nitrogen fixation - isotope dilution and plant difference - were compared and gave similar results.

Profitability of grazed regenerating medic pasture depended on stocking rate although, at high stocking rate (10 ewes/ha),

ewes needed a substantial amount of additional feeding. The growth rate of lambs was between 200 and 300g/day until after weaning, when it fell to about 80g/day. However the seed bank was much lower at high compared with low stocking rate indicating that in the long term the high stocking rate may not be sustainable. Cereal yields in this experient were less after medic than after fallow, and the data suggest that this was caused by a factor affecting germination or early growth.

Promising genotypes of five species of Vicia and Lathyrus were tested in microplots and nursery rows. In the high rainfall season of 1987/88 grain yields were excellent, reaching 4.9t/ha for V. narbonensis and 4.8t/ha for L. ochrus. The exception was L. sativus which, where the parasitic weed Orobanche crenata was present, produced an average of only 330kg/ha of grain. Results from three years and two sites suggest that L. ochrus may give grain yields of 750 kg/ha even where rainfall is only 250mm. In another experiment harvest index of the five species varied from 0.18 (an entry of V. sativa) to 0.36 (for V. narbonensis). All species had high quality forage and straw, although the protein content of V. narbonensis straw was less than the other species.

Herbage yield from grassland top-dressed with superphosphate was more than treble that of un-improved grassland. The response was mainly the result of better legume growth, though grass growth also improved. It was reflected in the body mass of ewes and in the amount of supplementary feeding that was necessary. At another, high rainfall site, herbage production was increased by sowing pasture legumes, and by giving the pasture some protection from grazing in spring.

Studies into the methodology of grassland research continued. Multivariate analysis was used to analyse natural variation in grasslands, and the composition of pasture was shown to be

dependent on available phosphorus, depth of soil, and stoniness of the soil surface. Presence of T. tomentosum, in particular, was closely correlated with the quantity of stones on the soil surface, presumably because the stones provided a favourable micro-environment. Native legumes varied in their response to phosphorus. The phosphorus content of leaves in many native legumes was related to soil phosphorus.

The intake of barley straw by sheep was related to its protein content, and increasing protein (by using soya bean meal) increased intake. Straw length and leafiness were confirmed as factors affecting straw quality, but environmental factors affecting these parameters were shown to be more important than genetic factors. The nylon bag technique for measuring degradability of straw was used for the first time.

The Report ends with a description of the Program's training and international collaboration. A training case study is described to help readers gain insights into the Program's training philosophy. Finally, the recomendations of a Workshop on the role of legumes in the farming systems of Mediterranean areas are presented.

INTRODUCTION

The objective of the Pasture, Forage and Livestock Program is to increase livestock production in west Asia and north Africa, an important objective as livestock account for some 30% of total agricultural revenue and constitute the wealth and primary source of income to farmers in the driest areas.

We hope to achieve this objective by increasing the availability of feed resources in two important agro-ecological zones: arable land in the cereal zone where unproductive fallows may be replaced by pasture and forage legumes, or communally owned marginal and grasslands adjacent to and within the cereal zone. In the context of ICARDA's strategic plan PFLP works with barley/livestock and wheat-based farming systems, in a rainfall band which stretches from 200mm to 350mm.

PFLP works with resources which cannot be used for producing food directly for people. These include cereal residues, non-arable grasslands, marginal lands, and fallow land which would otherwise be unproductive. We recognize that barley grain is also an important feed but, in ICARDA, barley is the subject of research in the Cereal and Farm Resource Management Programs. However, together with their work, PFLP (and ICARDA as a whole) conducts a comprehensive research program on the feed resources for livestock.

We have three other guiding principles: sustainability of natural resources and farming systems, development of low input systems, and integration of crop and livestock production. In the 1988 Report there are examples of all three. Chapter 2 shows how the ley farming system is sustained through seed dormancy, and Chapter 8 discusses the stability and productivity of grasslands. Ley farming itself is a low input system, and our

emphasis in on-farm research is on using inputs readily and cheaply available to farmers. Nearly all of our work focuses on the integration of crop and livestock production: once again our work on the ley farming system is a good example, where crop yields are being carefully monitored. The use of cereal straw (Chapter 10) is another example of research into crop/livestock integration.

Grassland research is difficult yet our 1987/88 results show ways in which grasslands may be improved. In just four years we have evidence that the degradation of centuries is being reversed: soil organic matter is increasing and the seed population (especially of legumes) has been greatly increased. Both results have been obtained through changes in management and the input of small amounts of phosphate.

Along with these principles we have two important approaches: the farming systems approach, indicated by the importance we attach to on-farm research, and an ecological approach. Our farming systems approach is discussed in greater depth in Chapter 1. Our ecological approach needs a brief explanation here.

It arises from the need for low input and stable farming systems and involves the manipulation of natural forces in the least disruptive way. Thus, in our grasslands research, the replacement of existing vegetation with new species is a low priority (though we do not exclude the possibility) and we focus on management changes instead. In our research on fallow replacement we look to the natural flora for our pasture plants, and, to help select suitable species, we study the relationship between their distribution and the climate and soil. In doing so we use the forces of that most fundamental biological process, evolution.

In 1988 ICARDA's scientific program was reviewed, the reviewers recommending that livestock and economics research be strengthened. The greatest weakness in our livestock research is in ruminant nutrition, and in particular our research into using cereal straws. As can be seen in Chapters 1, 5, 7, and 8, the need for economic analysis of our research is urgent. We look forward to strengthening these areas as soon as possible, and of other areas mentioned by the reviewers.

Our 1988 Report focuses on pasture improvement. It is rather surprising that in a region where livestock were domesticated more than 3000 years ago, there have been so few attempts to improve pastures. Perhaps the reason is that, in the beginning, the natural grasslands were of such high quality that their ability to provide livestock with feed must have seemed endless. That has changed, and with both human and livestock populations increasing, and the capacity of grasslands declining, the need for improved pastures has never been greater. ICARDA is providing a lead to the region in pasture improvement, and our Report this year highlights it.

I cannot end this Introduction without reference to the tragic death (in a road accident) of Frances Herbert, a British post-graduate student studying straw quality. Chapter 10 is a summary of her work. Everybody in ICARDA was shocked by her death, particularly the people in our sheep unit with whom she worked. They, and the rest of ICARDA, send their deepest sympathies to her parents.

Senior staff

Dr Philip Beale was posted to Rabat, Morocco, on 1 January 1988. Dr Beale joined ICARDA in September 1987, as the Pasture

and Forage Scientist for north Africa. He now forms part of ICARDA's three man team in Morocco.

In 1988/89 Dr Euan Thomson was at the University of New England (Department of Biochemistry, Nutrition, and Microbiology), in Armidale, Australia, where he spent his sabbatical leave writing up the results of 8 years' research. His work at ICARDA was supervised by Mr Faik Bahhady.

Climatic conditions in 1987/88

The following comments were supplied by the Farm Resource Management Program.

The 1987/88 season was the wettest in NW Syria since 1940/41, when seasonal rainfall totals exceeded those of 1987/88 by 10 to 20%. The average recurrence interval of seasons with the same rainfall as 1987/88 or more is estimated to be around 30 years. As the increased rainfall was due to increased cyclonic activity and, therefore, was of the advective type, the relative increase was more pronounced in the drier part of the region: Jinderess, our wettest site recieved 48% more than the long-term average is 212 mm, had 386 mm, or 18% more than "normal".

The season started early with heavy rains from 17 October to November 6. Then followed the only prolonged dry spell of the season which lasted, only interrupted by minor showers at some sites, until 4 December. This period was ideal for planting. December brought less than average rainfall at some sites, more than average elsewhere. January, February and March were wetter than average across the whole region. The last significant rains of the season fell around the middle of April. However the good accumulated supply of soil moisture allowed the crops to mature with less stress than in most seasons.

The temperature throughout the season was close to the long-term average with no extremes of note. The number of frost days was below average, in particular at the drier sites, as the frequent cloud cover reduced the occurrence of radiation frosts. Altogether the weather in Syria during the 1987/88 season laid the foundation for a bumper crop, which was widely achieved.

Definitions and abbreviations

Throughout the Report we have tried to use the common names of plants, indicating the scientific name when the species is first discussed. However it may be helpful to readers if some of the more important species are listed here, for easy reference:

vetch - various species of Vicia, including common vetch (V. sativa), narbon vetch (V. narbonensis), bitter vetch (V. ervilia), woollypod vetch (V. villosa subsp. dasycarpa), hairy vetch (V. villosa subsp. villosa), and subterranean vetch (V. sativa subsp. amphicarpa).

chickling - various species of Lahtyrus including common chickling (L. sativus), dwarf chickling (L. cicera) and ochrus chickling (L. ochrus).

forage pea - Pisum sativum

medics - various species of Medicago: of these only barrel medic (M. truncatula), snail medic (M. scutellata), strand medic (M. littoralis) and gama medic (M. ruqosa) have widely accepted common names. M. polymorpha, although often called bur medic, is referred to by its scientific name. At present we do not have a common name for M. rigidula or M. rotata.

clovers - various species of Trifolium, including subterranean clover (T. subterranean) and rose clover (T. hirtum).

We have also defined a number of commonly-used terms:

accession (acc.) - an ecotype as collected in its native habitat and used in a breeding project, or any other sample of material brought into the testing system: normally used in association with an accession number.
cultivar (cv.) - one or a group of similar genotypes, or an ecotype used in commercial agriculture, which has been officially released.

forage - is used to describe monocultures of certain legumes, namely vetch, forage pea, and chickling, or mixtures of these species with cereals. In general forages are crops sown and harvested in the same year and used for hay, straw, or grazing.

grasslands - refers to non-arable land within the cereal zone with a flora based on Mediterranean annual species. In previous Reports we have included this class of land in the term 'marginal land' (see Chapter 8).

herbage - plant material used to feed livestock

herbage yield - the mass of dry material produced. This term replaces 'dry-matter yield', which is often used elsewhere. Drying is normally at 80-90°C.

ley farming - in Mediterranean regions the farming system

in which self-regenerating pastures are grown in rotation with cereals.

Marginal land - specifically, a term for land adjacent to the steppe which, (because of low and unreliable rainfall) is risky for cultivation and crop production. Also used as a term covering all kinds of non-arable land.

pasture - a plant community which is grazed, usually referring to a regenerating population of annual legumes.

residues - herbage which remains on the land after the growing season is finished.

selection (sel.) - resulting from selection within an accession comprising more than one genotype. In its numbering system ICARDA allocates both an accession number and, where applicable, a selection number.

self-regenerating pasture - the annual pastures which establish from dormant seeds after the cereal phase of a pasture/cereal rotation.

steppe - non-irrigated land which receives (in Syria) less than 200mm of rainfall.

strain - is a general term to cover accession, selection, variety and cultivar. It is used in this Report to describe a culture of *Rhizobium* of different origin to other cultures.

straw - vegetative material (mainly stem plus leaf)

obtained from the residues of cereals or legumes which is removed from the field and stored.

stubble - cereal residues remaining in the field after harvest.

variety - we use this term both in its botanical sense, where it is a taxonomic unit beneath species, and to describe a group of genotypes used by farmers in a traditional sense, for example 'landraces'.

In the sections on ruminant nutrition the following abbreviations are used:

ADF - acid detergent fibre
CP - crude protein
DDMI - intake of digestible dry matter
DM - dry matter
DOMI - intake of digestible organic matter
IVDDM - *in vitro* digestible dry matter
IVDOM - *in vitro* digestible organic matter
MBS - metabolic body size = body mass$^{0.75}$
ME - metabolisable energy
OM - organic matter
OMI - intake/kg of metabolic body mass
NDF - neutral detergent fibre
SBM - soya bean meal
VFI - voluntary feed intake

Other abbreviations are as follows:

ACSAD - Arab Center for Studies of Arid Zones and Dry Areas, Damascus

CSIRO - Commonwealth Scientific and Industrial Organization, Australia

CIP - Cereal Improvement Program, ICARDA

FLIP - Food Legume Improvement Program, ICARDA

GRP - Genetic Resources Program, ICARDA

FRMP - Farm Resource Management Program, ICARDA

JICA - Japanese International Co-operation Agency

MIRCEN - Microbiology Resources Centres (a network sponsored by UNESCO)

NARS - National Agricultural Research Systems

ODNRI - Overseas Development National Resources Institute, London

SMAAR - Syrian Ministry of Agriculture and Agrarian Reform

UNDP - United Nations Development Program

WANA - West Asia and North Africa

Preschedules

As in previous years the report of each experiment refers to a preschedule number. These preschedules are written before the experiment begins and are the basis for discussion and criticism at our September planning meetings. Taken together the Program report and preschedules (published each November as 'Research and Training Plans') provide a complete documentation of our work and the thinking which goes into it.

Acknowledgements

In the body of the Report the scientist responsible for conducting any piece of research is acknowledged. We do not acknowledge the work of our skilled assistants and technicians.

That is not to say that they are unappreciated. In fact quite the reverse is true. I would therefore like to thank them for their work, which is of a high standard, and for their thinking, which contributes greatly to the research process as a whole.

Once again I must thank Aida Battikha and Zuka Musattat who prepared the typescript.

Finally I express appreciation to JICA, who support much of the research on animal health (not reported this year), the Government of Italy and the University of Perugia, who continue to support our work on pasture improvement, and UNDP, a major contributor to our training and workshop activities. - **P.S. Cocks**

CHAPTER 1: ADAPTING THE LEY FARMING SYSTEM TO CONDITIONS IN WEST ASIA AND NORTH AFRICA

In Chapter 1 the results of rotation experiments on farmers' fields are discussed. The experiments compare the ley farming system - a rotation of cereals and legume pasture - with other common rotations practiced by farmers in Syria. The Chapter illustrates the Program's systems approach.

The essential concepts of farming systems research (FSR) are two-fold: firstly, and most importantly, farmers must be involved, and secondly, because farms are complex biological units, scientists of different disciplines must collaborate. These concepts are especially important in livestock research where there are complex interactions between soils, plants, animals, and, of course, farmers.

Central to FSR is "on-farm research with a farming systems perspective". According to Simmonds (1986) this aspect of FSR was developed by the international agricultural research centers, although it has undoubtedly been a component of agricultural research and extension in many developed countries for decades. It is the commonsense approach to farming systems research, ignoring the deep analysis of FSR sensu strictu. In brief there are four steps:

- description of the farming system and diagnosis of problems;
- scientist-managed on-farm (and, if necessary, on-station) research;
- farmer-managed on-farm research; and
- extension of the results and monitoring of the impact.

In our on -farm research the first step, description of the farming systems and diagnosis of the problems, was brief. Indeed the main problem, shortage of feed for sheep, was taken for granted and the answer, replacement of fallows with self-regenerating pastures, was already available. Most of our on-farm research is step 3 - farmer managed on farm research - and step 4 - assessment of impact. The Chapter therefore describes the concept of using pasture legumes, the farming community with which we work, the farmer-managed research, and, briefly, why we believe our research to have been successful.

Ley farming and pasture legumes

Before describing our on-farm research it is helpful to briefly discuss ley farming, its origin, and where it might fit into farming systems in the Mediterranean basin.

The use of self-regenerating legume pastures originated in southern Australia (Puckridge and French 1983) in 'ley farming', the word 'ley' referring to the year of spontaneous pasture. Ley farming has been so successful that, for many years, almost all the wheat or barley produced in southern Australia was grown after pasture, the latter comprising either Trifolium subterraneum or Medicago polymorpha (on acid soils), or several other species of Medicago (medics) on alkaline soils. As will be seen later use of medics is the basis of ICARDA's on-farm research with ley farming.

The concept of ley farming is to replace the weeds in weedy fallows with pasture legumes, the legumes being more productive than weeds because they are independent of soil nitrogen. Any legume can be used provided, like a weed, it has the ability to persist without re-seeding. Because they produce 'hard' seeds

(which are not permeable to water) many wild Mediterranean legumes have this capacity, and it is common to see such species as Coronilla scorpioides, Scorpiurus muricatus and Medicago polymorpha in the weed flora of fallows. The concept of a 'seed bank' containing hard seeds of the pasture legumes, is central to the use of self-regenerating pastures (Fig. 1.1).

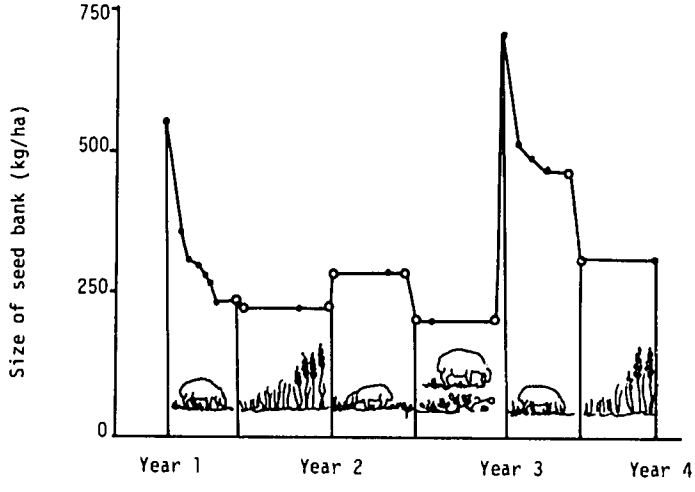


Fig.1.1. Size of the seed bank during the cereal and pasture phases of the ley farming system. The figure shows that the seed bank falls while pasture residues are grazed in summer, and as a result of germination during the cereal phase. It is replenished during the spring of each pasture phase (data obtained from Expt 3.2.). The vertical lines represent (approximately) May and December each year, beginning May 1985 and ending May 1988.

It has been estimated (Carter 1978) that there are approximately 30 million ha of fallow in west Asia and north Africa. In Syria alone there are 2 million ha, mainly where rainfall is between 200 and 350 mm (Table 1.1). This huge area, which is either left bare or used for low quality grazing, is potentially the most important source for increasing feed supplies for livestock.

Table 1.1. Land use in Syria

Climatic zone	Rainfall (mm)	Cultivated area (ha X 10^6)	Fallow area (ha X 10^6)	Percentage fallow
1	350-600	1.47	0.14	9.3
2	300-350	1.97	0.94	47.7
3	250-300	0.90	0.42	46.5
4	200-250	0.95	0.48	50.1
5	<200	1.02*	NA	NA

* cultivated on a seasonal basis.
NA Not applicable.

Ley farming is an inexpensive strategy to replace fallows. In the Mediterranean basin the target area is where it is too dry for lentils (less than 300 mm): lentil and other legumes are used to replace fallows in wetter areas. However much of our early work has been inside the lentil area (including the work described in this Chapter), a strategy which, by reducing climatic risk is justified by the range of socio-economic problems which face the ley farming system.

To introduce ley farming however requires consideration of all its components: pastures, livestock, cereals, soil fertility and, perhaps most importantly, the farmers themselves. Critics of early attempts to introduce ley farming claim that there has been a lack of consideration of socio-economic conditions, and an excessively academic approach to the technical problems (eg Springborg 1983). While the latter is probably not true - there are many serious technical problems - the former is certainly true, and for this reason we consider essential our work on farmers' fields.

The farming community

In the beginning the focus of the project was the village of Tah, in Idlib province of northern Syria. Since 1984/85 the project has widened to include 11 villages, mostly near Tah, but also in Jazira, Houran and Hama provinces (Table 1.2). The new villages are in areas both wetter and drier than Tah, which receives an average of approximately 350 mm rainfall: as Table 1.2 shows rainfall in 1987/88 was much more than this.

Tah was chosen as the focus of the project because of the presence of a farmer who himself had identified pasture legumes

Table 1.2. Rainfall in 1987/88 in representative project fields.

	Rainfall (mm)
Idlib province	
Tah (2)*	489
Deir Sharki (2)	521
Jarjanaz (2)	425
Saiyaddy (2)	410
Senjar (3)	395
Houran province	
Izra'a (2)	323
Nahta (3)	292
Al Jazira province	
Kamishly (1)	697
Smeihan (2)	385

* The number in parenthesis refers to the climatic zone in which the village occurs (see Table 1.1).

as a means of resolving feed deficiencies. He manages a 4 ha field of native M. polymorpha which attracts wide interest in the community as a whole. It was therefore a simple matter to interest other farmers in the project which, among other objectives, aims to provide seed to help them implement what they perceive to be a useful innovation.

A survey of farming practices in Tah and nearby villages was conducted in 1984/85 (Nordblom 1987). The survey was constrained to include only livestock owners, as ley farming is applicable only to these farmers. In Tah itself, we found that farmers use rotations including both wheat and barley (on the better and poorer soils respectively) in mainly three-course rotations with lentils and watermelon. In areas drier than Tah (250 - 350 mm) the most common rotations are cereal/fallow, while in wetter areas (350 - 600 mm) rotations are diverse, always including however, either wheat or barley. Suprisingly, cereal/fallow rotations are more common in the wetter areas than in Tah itself.

Sheep diets at Tah are based on cereals and the grazing of common land, the latter during spring. Cereal grains and the straws of cereals and lentils dominate winter diets, while the grazing of cereal residues dominate diets in summer and autumn. The grazing of almost mature cereals in late spring is a common alternative to harvesting the crops, especially on poor soils in poor years.

Of the rotations at Tah Nordblom (1987) found that a two-course rotation of cereals and lentils was the most profitable (though not the most widely used). Therefore, to be successful at Tah, medic pastures would need to be more profitable than lentils, and so displace lentils and watermelons on part of the land.

Scientist-managed research

There is a history of unsuccessful attempts to introduce ley farming to west Asia. Cocks (1986) considers that the reasons are fourfold: lack of adapted pasture legume cultivars, lack of resident rhizobia, inability of farmers to manage grazing, and lack of acceptable economic evaluation. The first two of these problems are being resolved by on-station research (Chapters 3 and 4) and the latter two are the subject of on-going research (Chapter 5).

The approach to selecting adapted cultivars was to use indigenous material (Cocks 1985) and to select within the ley farming system itself (see Chapter 3). An extensive survey of Syrian rangelands revealed that the species from which the Australian cultivars were selected are either rare (M. truncatula) or occur only in coastal or high rainfall mountain regions (T. subterraneum, M. scutellata, M. rugosa, and M. littoralis). Widespread in the cereal zone are M. rigidula, and M. rotata. The one exception to the absence of species giving rise to Australian cultivar is M. polymorpha, although at the time (1984) they were not available commercially.

The value of using indigenous medics is illustrated by comparison of their tolerance to frost with the Australian cultivars (Cocks and Ehrman 1987). Frost tolerant medics form the basis of all our on-farm research in Syria.

Lack of nodulation of the Australian cultivars was often confused with lack of cold tolerance, the pinkish-yellow leaves of acute nitrogen deficiency being ascribed to the effect of low temperature. In fact there are no visible effects of low temperature except for the burnt leaves caused by frost damage, which is easily recognized. In contrast the indigenous species

are often able to nodulate with resident rhizobia. For this reason, wherever possible, legumes should be chosen which do not require inoculation - a powerful reason indeed for choosing local ecotypes.

As was stated earlier grazing management and economic evaluation are the subjects of detailed on-station research. But both topics need inputs from real-life agriculture which helps answer questions like what freedom do farmers have in choosing alternative management strategies, what are the real costs of ley farming as experienced by farmers, and what will farmers see as constraints to its introduction. These are the objectives of our on-farm research.

Farmer-managed on-farm research

Establishing the ley farming system: The first fields were sown in the autumn of 1984. Six farmers were chosen on the basis of whether or not they owned livestock and on their reliability as collaborators as judged by the village leader. Fields of one ha were sown to a mixture of Australian and local medic cultivars and the grazing was managed by farmers after close consultation with scientists. The key criterion in managing the grazing was seed set during spring, with summer grazing restricted so that approximately 200 kg/ha of seed remained in the 'seed bank' in autumn. In this first year fields were rented from farmers so that there was no question of farmers taking risks should the new ideas fail. This seemed reasonable on the basis that the system was experimental, had previously failed in farmers' fields, and that the objective of the project was to resolve problems and, at this stage, not to encourage adoption. However no further incentives were offered even though, for the system to be deemed to have worked, spontaneous regeneration of pastures in the third

year needed to be observed. We used only machinery which was available to farmers and resisted the temptation to use ICARDA's more sophisticated farm machinery.

The first useful result was the realization that fields of one ha were too small for this kind of research: the size of farmers' flocks rendered sensible grazing management in spring difficult because of high stocking rates. Fields sown since 1984 have therefore been larger: from 2 - 5 ha.

However Table 1.3 shows that the first year was successful, there being only one farm (farm 3) where the seed bank was substantially less than the targetted 200 kg/ha. After stubble grazing in the following year the seed bank increased in five of the farms due to the medics growing as weeds among the cereal.

Table 1.3. Size of the seed bank (kg/ha) for six medic pastures in the year of sowing and in the following year.

Farm	After grazing 1984/85	After grazing[1] 1985/86	After grazing[3] 1986/87
1	181	477	322
2	279	335	149
3	76	148	68
4	423	449	467
5	170	74[2]	37
6	368	769	430

(1) After grazing cereal stubble except in farm 2 which was left as second year pasture.

(2) Resown with 20 kg/ha of seed.

(3) After regenerating medic pasture except farm 2 which was sown to wheat.

The establishment phase could therefore be deemed successful. Table 1.3 also shows that the seed bank in most of these original fields continued to remain above 200 kg/ha in the two years following pasture establishment.

Given the size of the seed banks it was not surprising that regeneration after the cereal was good. In three of the five original fields seedling number exceeded 1500 per m^2, while in the other two there were 300 - 500 per m^2 (Table 1.4). In 1987/88 there were 9 farms with regenerating pasture, some of the pastures regenerating for the second time (Table 1.5). Four had more than 1000 seedlings and all but one more than 500 seedlings/m^2. Puckridge and French (1983) consider that 1000 seedlings/m^2 a highly successful re-establishment: clearly, therefore, ley farming was working in our original fields. Incidentally, the owner of farms 2, 18 and 19 have elected to have continous medic pasture instead of the cereal/pasture rotation, an indication of the acceptance of pastures.

Table 1.4. Size of the seed bank in 1985/86 (kg/ha) and regeneration of medics in autumn 1986 (seedlings/m^2) after a cereal crop in 1985/86.

Farm	Seed bank in 1985/86	Seedling number in 1986/87
1	447	1640
2	148	520
4	449	1920
5	73	390 (1)
6	769	1850

(1) Resown with 20 kg/ha of seed.

Table 1.5. Seedling number in regenerating pastures on nine farms in 1987/88.

Farm	Seedlings (/m^2)	Available herbage (10 Feb)	Herbage yield (t/ha)
2	1207	1.68	NM
7	658	0.95	NM
8	525	1.39	NM
10	550	1.54	7.91
11	1951	2.08	6.73
13	1131	NM(2)	6.96
14	344	0.41	NM
18(1)	520	NM	7.01
19	1001	NM	9.24

(1) Farms 18 and 19 were in their second year of medic.
(2) NM - not measured.

At the end of 1987/88 there were 22 farms in the project including farms in the second cereal cycle (four of the original six farms) and farms with first year pasture (four new farms). Table 1.6, which shows that the mean size of the seed banks for all groups of farms was at least 200 kg/ha, indicates that by 1987/88 ley farming had been satisfactorily established in most of our farms. Indeed, of the 22 farms only three could be considered failures, a most remarkable result given the new skills required by farmers to manage the system.

Monitoring impact of the ley farming system: Productivity of the farms is being monitored and compared with adjacent fields where the farmers are continuing their traditional practices. In the

Table 1.6. Size of the medic seed bank after grazing in the summer of 1987/88.

- after first year medic (mean of four farms)	212 kg/ha
- after two years of medic (two farms)	360 kg/ha
- after the second medic cycle (seven farms)	257 kg/ha
- after the first wheat crop (four farms)	199 kg/ha
- after the second wheat crop (five farms)	286 kg/ha

wheat phase scientists are imposing treatments to assess the reponse of crops, after both pasture and the farmers' chosen alternatives, to nitrogen and weed control. Otherwise all crops are being managed by the farmers with no assistance or advice from the scientists. More advice is given on grazing management but the ultimate decisions remain with the farmer. So are the decisions about rotations: indeed, as mentioned above, three of the farmers, all on poor soils, have decided to abandon cropping altogether. On the other hand one farmer has decided to grow two crops in succession; we await regeneration in his field with great interest as it will be the first real test of ley farmings' flexibility when farmers need to crop more frequently.

Fig. 1.2. shows the productivity of regenerating pasture (in 1986/87 and 1987/88) on farms sown to medic (in 1984/85 and 1985/86 respectively). Total productivity was between 6 and 10 t/ha, and, perhaps more significantly, for farms where the most difficult period for feeding sheep is winter, available herbage in early February was up to 1 t/ha. Total yields on some other fields are shown in Table 1.5. As can be expected with legume pasture, quality, including protein content, was high (see 1987 PFLP Report).

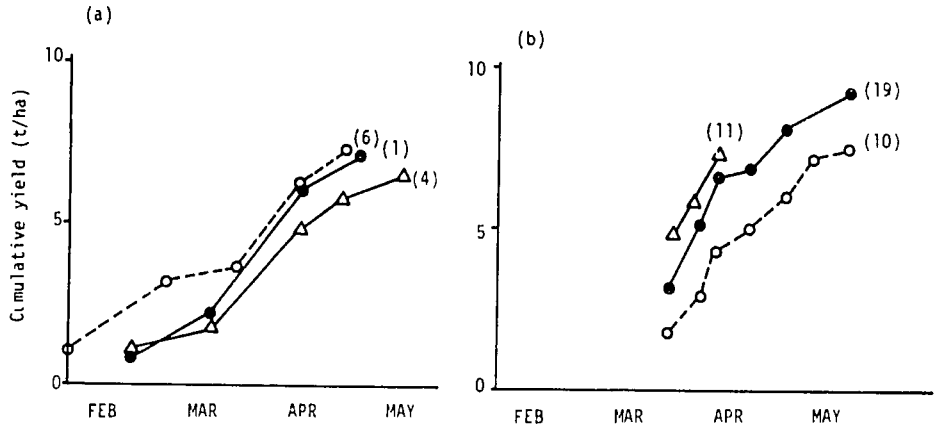


Fig.1.2. Cumulative yield of medic pasture (a) on farms 1,4 and 6 in 1986/87 and (b) on farms 10,11, and 19 in 1987/88. Farm numbers are indicated in parentheses.

On these fields average stocking rate (for all farms measured), calculated on a year round basis, was more than seven ewes/ha (Table 1.7). In fact farmers do not stock pastures continuously preferring to stock heavily from March to August, their sheep grazing green pastures until the end of April and

Table 1.7. Calculated rates of stocking (ewes/ha/year)[1] and residual seed after grazing (kg/ha) of regenerating and first year pasture.

	Number of farms	Stocking rate	Seed bank
Regenerating medic			
1986/87	5	7.8	179
1987/88	9	7.1	280
First year medic			
1986/87	5	3.5	135
1987/88	4	0.9	212

(1) the number of grazing days divided by 365

eating pasture residues (including pods), and cereal stubbles through the summer. What we believe is the effect of introducing pasture on the feed cycle of sheep is shown schematically in Fig. 1.3.

The grazing management used by farmers works well provided that grazing stops before the amount of seed in the seed bank falls too low. As was stated earlier we use a critical level of 200 kg/ha of pure seed in first year pasture: in regenerating pastures, by taking account of existing seed, the critical level of newly produced seed need only be 100 kg/ha, or even less in poor years. Assessment of this is perhaps the most difficult new skill to be learnt by farmers.

In previous years we were able to monitor milk production and liveweight changes during the period of grazing and compare the productivity of grazing ewes with ewes fed traditionally: on common land in spring, and a ration of concentrates and straw in summer. The results were repeated in several years: milk production is consistently higher on legume pasture than on the alternative feed sources. We are not sure why this is so, but it seems likely that small amounts of oestrogen-like substances occur in the leaves and residues which stimulate milk production. If present in large amounts these oestrogens will reduce ewe fertility (Braden and McDonald 1970; Francis and Millington 1965), but there has been no suggestion of infertility in our flocks.

Wheat yields after pasture and after control crops are shown in Table 1.8. Again, the 1987/88 results repeat those of earlier years in that yields after pasture were higher than after other crops. In 1987/88 wheat yields after first year pasture were not significantly greater than after the controls, although in 1986/87 even this difference was significant.

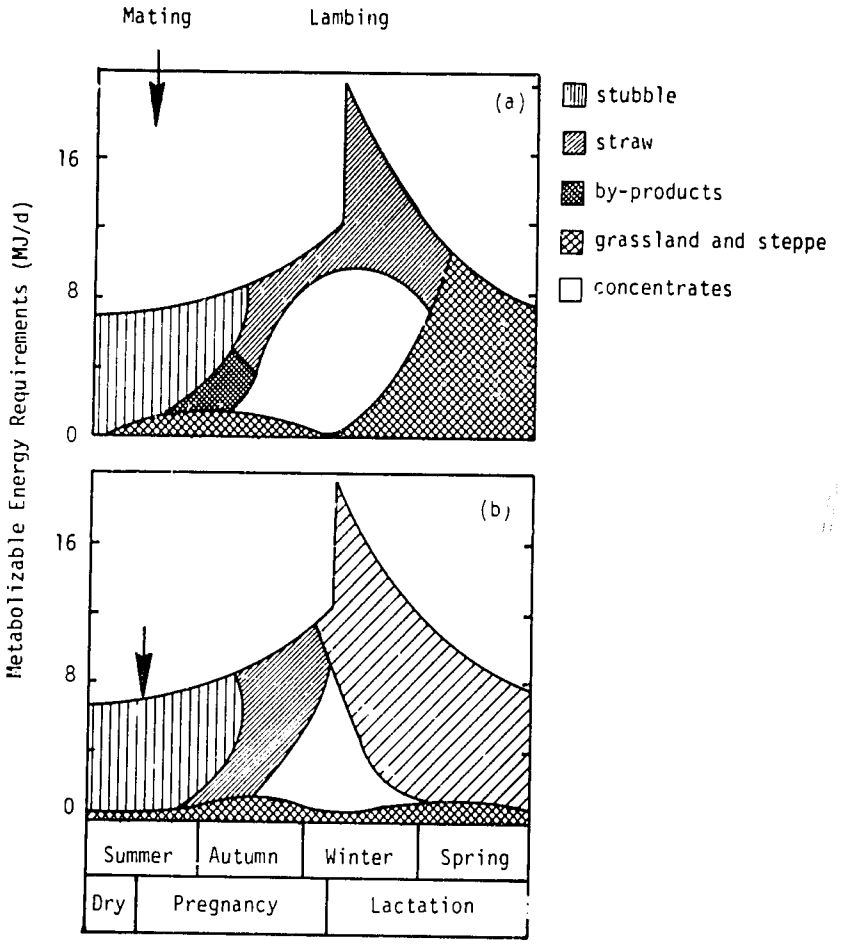


Fig.1.3. Schematic presentation of the metabolizable energy requirements of sheep and the contribution of different feedstuffs during (a) traditional and (b) improved feeding cycles in north-west Syria. Note the greatly decreased dependence on marginal lands, grasslands, and steppe in the second scenario (Data of Cocks and Thomson, 1988).

At 1986/87 prices the net returns from pasture (including depreciation and mortality costs of ewes) greatly exceeded that of the alternative crops (Table 1.9). Otherwise wheat/lentil rotations were the most profitable: since wheat yields after pasture exceeded yields after lentils, and since the profits from

Table 1.8. Wheat yields (t/ha) after first year and regenerating medic compared with wheat yields in traditional rotations.

	First year		Regenerating	
	Medic	Control	Medic	Control
1985/86	1.29	1.24 (2)	NA	NA
1986/87	1.40	1.08 (1)	NA	NA
1987/88	1.95	1.64 (2)	2.67	1.77 (1)

NA - not applicable: the first crops sown after regenerating medic were in 1987/88.

(1) Difference between after medic and after control significant at $P<0.05$

(2) Difference between after medic and after controls not significant.

Table 1.9. Estimated profitability from alternative forms of land use (1986/87 prices).

Crop	Profit (SYP/ha)
Pasture[1]	6800
Lentils	2660
Watermelon	2600
Cumin	4000
Wheat	2020

[1] Pasture, lentils, watermelon, and cumin are grown in rotation with wheat (Cocks and Thomson, 1988).

pasture were nearly three times that of lentils, the wheat/pasture rotation, at 1986/87 prices, was the most profitable. What we have not calculated is the effect of including pasture on risk, nor have we calculated threshold prices, beyond which the rank of profitability of the various rotations will change.

What has been achieved and what comes next?

We see the achievements after four years of on-farm research as follows:

- most importantly, the ley farming system is successfully being managed by farmers;

- pastures grown on arable land appear to be the property of farmers even though, like weeds, they spontaneously regenerate;

- at the very least wheat yields are maintained and, in most cases, increased in a ley farming system compared with traditional rotations;

- in Syria, ICARDA's new medics have resolved the problem of lack of adapted cultivars;

- use of indigenous medics has partially resolved the rhizobia problem, and a wide range of adapted rhizobia strains are available for areas where nodulation remains a problem;

- preliminary economic evaluation shows that, at current prices, ley farming is the most profitable land use system.

For Syria there are two remaining constraints, both of which are institutional: lack of seed production, and lack of an extension methodology. Outside Syria excessively deep tillage (more than 15cm) will pose problems if the seed bank is buried beyond a depth from which seeds can emerge. For countries other than Syria adapted medics still need to be selected.

Our research will now be used to assist in extending the ley farming system within Syria, and as a resource for training scientists and extension workers from outside Syria. We hope to hold workshops attended by extension workers, scientists, and farmers to develop an extension methodology which initially establishes a working example of the system in any area, and uses that example as a focus for further extension.

In the existing project we will provide (and later sell) seed to interested farmers, with a view to monitoring problems which become evident when farmers are working without continuous access to expert advice - in fact a continuation of the fourth stage of the farming systems process. The existing farms will continue to be monitored to gain long term data on sustainability and economic benefits.

Finally, and briefly, we list the main reasons which have led to the success of the project:

- the scientists in charge of field operations were Syrian nationals and therefore understood the language, customs, and needs of the farming community;

- the project was based on an innovation developed by a farmer, and this provided a focus for the project;

- the major technical constraints were recognized and resolved before the project began;

- scientists were open-minded about how the innovation should be managed, appropriate management being developed on a colleagial basis with farmers;

- apart from seed the project used only resources normally available to farmers, even though research station equipment would often have been more efficient; and

- local research and extension workers were involved from the beginning and, as far as possible, received credit for the project's success both within the farming community and within government and scientific circles. - P.S. Cocks, H. Sawmy Edo, and B. Mawlawi (Syrian Ministry of Agriculture)

CHAPTER 2: UNDERSTANDING LEGUME SEED BANKS IN LEY FARMING AND IN MEDITERRANEAN GRASSLANDS

In Fig. 1.1 the importance of seed banks in the ley farming system was illustrated. The survival of dormant seeds in years when cereal is grown, and their germination in pasture years, is central to the concept of ley farming. The dormancy mechanism whereby the seeds survive is hardseededness: the seed coats are impermeable to water and the seeds will therefore not germinate. In all other respects the seeds are viable, and if the seed coat is damaged to allow water to enter (the seed becomes soft) germination will promptly proceed.

It is known that in natural conditions hardseeds become permeable by the action of fluctuating summer temperatures on the integrity of the seed coat (Quinlivan 1971). At the soil surface temperatures can reach 60°C during a summer day and fall to below 20°C at night. Presumably, through the effect of expansion and contraction, the seed coat cracks and becomes soft. It is believed that such a change in hardseededness is permanent, and that seeds cannot revert to their earlier, hard, state: however there is some evidence that in very dry climates the seed coat may be able to heal (Cocks 1988).

How does hardseededness and its breakdown affect the success or failure of pasture legumes? Ideally medics in the ley farming system would not germinate in the year after the seed was set (the cereal year), would remain dormant during periods when rain is likely to be followed by drought, would germinate after reliable rains in the pasture year, and a significant proportion (which would need to remain viable for several years) would remain in the seed bank to buffer the system against future disasters. It is unlikely that such an ideotype exists, but amongst the countless Mediterranean populations of medics (and

related species) there is undoubtedly variation along these lines.

The seed bank concept is equally important in Mediterranean grasslands. The leguminous flora of these grasslands is of great diversity (see Chapters 3, and 8), and abundance of legumes is surprisingly high. As is explained in Chapter 8 we see this natural resource as a key to improving the productivity of grasslands. Again the survival mechanisms of seeds provide the key to developing management systems which encourage and sustain productivity. Seasonal changes in a typical seed bank of a Mediterranean grassland, prepared from data obtained at Tel Hadya, are shown in Fig. 2.1.

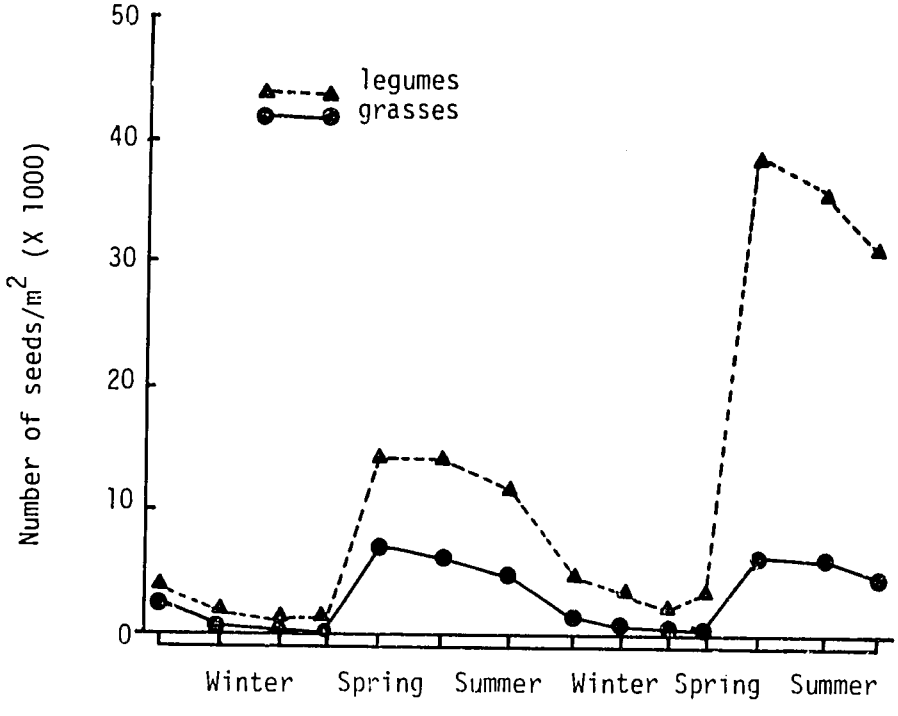


Fig.2.1. Size of the seed bank in grassland at Tel Hadya (Data from Expt 8.1).

The objectives of our work on hardseededness are eight fold:

- to explore variation in seed dormancy among native legumes;
- to measure the longevity of legume seeds in the soil;
- to observe the pattern of hardseed breakdown both within and between years;
- to assess the effect of some management practices on seed dormancy;
- to measure the size, seasonal variation, and change in botanical composition of seed banks;
- to determine the effect of interactions between genotype and environment on seed dormancy;
- to develop cultivars and mixtures of cultivars which will maintain a continuous germination over several years from a single seed set; and,
- finally, to increase the sustainability and productivity of pasture - based farming systems.

Hardseed breakdown in the ley farming system

Expt 2.1: Longevity of medic seeds (Preschedule M28)

The objective of Experiment 2.1 (which is continuing) is to measure the longevity of seeds in the soil, and to monitor the pattern of hardseed breakdown.

In this experiment use is made of plots established in 1986/87 (see page 126 of the 1987 Program Report) where seven medic species were sown at two densities. Less than half the plot area was used in the earlier study, the remainder being available to measure rate of hardseed breakdown, and the seasonal pattern of germination during autumn and winter in the following

three years. The plots were tilled after the first summer, and thereafter will remain undisturbed, the soil being sampled each year to measure seed populations at various depths.

The following seven medics were grown at low (10 kg per ha) and high (200 kg per ha) densities (see experiment 3.4. in the 1987 Report):

M. polymorpha, variety Tah
M. rigidula, sel. 1900
M rigidula, sel. 716
M. noeana acc. SA 15845
M. noeana sel. 1938
M. rotata sel. 2123
M. truncatula cv. Jemalong

There were four replicates in a randomized complete block. After completion of the 1986/87 experiment the size of the remaining plot was 2 X 6 m. Further seed set is being prevented by spraying with herbicides at flowering time.

The following data are being collected:

- seed yields of each ecotype (as part of the 1986/87 data);
- hardseededness by soaking intact pods in water for 14 days, counting the emerging seedlings, drying and threshing the pods, and counting the remaining seeds. Viability of the seeds is being tested after scarification; and
- size of the seed bank in March each year. Mass of seeds in a core 15cm deep is being measured in 5 strata each 3cm deep. Ten cores are extracted from each plot.

Table 2.1 was presented in the 1987 Report and is included here because it provides the base data for subsequent results. M. noeana sel. 1938 failed to set seed at high density and has been excluded from this year's data. Apart from M. noeana seed set was good ranging from 2700 seeds/m^2 (low density of M. truncatula) to 34,800 seeds/m^2 (high density of M. polymorpha).

Table 2.1. Seed yield (kg/ha), mean seed size (mg/seed), seeds/pod, and number of seeds ($N/m^2 \times 10^3$) for the seven medics at low and high density.

	Seed yield		Seed size		Seeds per pod		Number of seeds	
	Low	High	Low	High	Low	High	Low	High
M. noeana sel. 1938	266	0	2.46	NA[2]	4.1	NA[(2)]	10.8	0
M. noeana acc. SA 15845	478	320	3.32	2.29	4.4	3.8	14.4	14.0
M. polymorpha Tah	306	801	2.70	2.30	2.9	3.1	11.3	34.8
M. rigidula sel. 1900	397	199	2.94	2.28	8.2	7.4	13.5	8.7
M. rigidula sel. 716	516	374	4.41	3.48	6.4	5.8	11.7	10.7
M. rotata sel. 2123	446	418	5.09	4.77	4.2	4.1	8.8	8.8
M. truncatula cv. Jemalong	83	472	3.07	2.70	6.2	8.8	2.7	17.5
Mean[(1)(3)]	356	369	3.59[3]	2.97[3]	5.4[3]	5.5[3]	10.4	15.8
LSD (P<0.05) (any two)	107[1]		0.24	0.60[1]				
LSD (P<0.05) (between densities)	NS		0.05	NS				

(1) Significant (P<0.05) species X density effect for both seed yield and seeds/pod.
(2) Not applicable (no seeds of M. noeana sel. 1938 produced at high density).
(3) Means and analysis of variance did not include data of M. noeana sel. 1938.

The patterns of hardseed breakdown varied between years (Fig. 2.2). In 1986/87 the seeds remained hard until mid-September, seeds from low density plots then falling to about 70% hard by early November. At high density the seed population remained hard in November but had fallen to approximately the same level as at low density by March 1988 (the soft seeds had germinated by

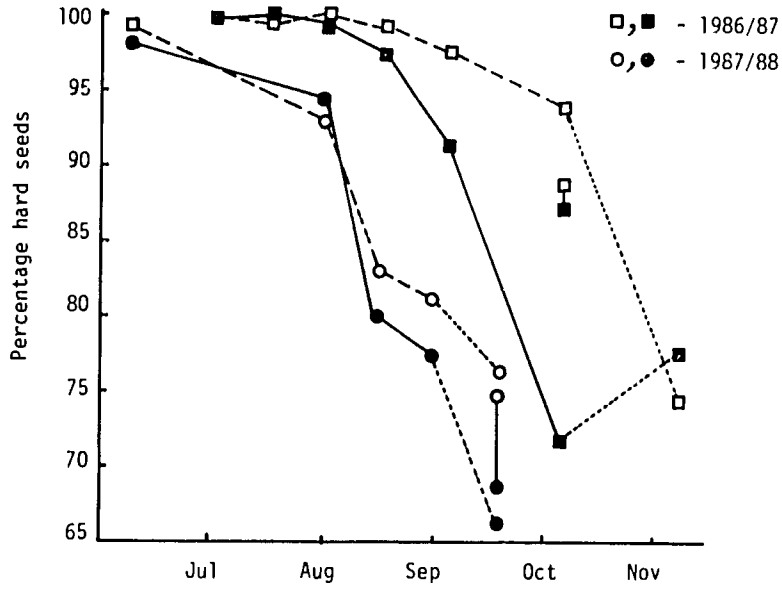


Fig.2.2. The effect of age of seed and density on the hardseed breakdown of the medics in Expt 2.1. The open squares and circles are of seed produced from low density pastures, and the closed squares and circles from high density pastures. The vertical bars are LSD's ($P<0.05$) between densities.

then, of course). In Fig. 2.2 the level of hardseededness in December is presumed to be the same as in March, it being unlikely that seeds softened between December and March.

In 1987/88 the 12-month old seeds began to soften as early as July, and by mid October hardseededness had reached a similar level to that achieved in the previous year almost two months later. Again low density seeds lost their hardseededness more rapidly, but the difference was less than in 1986/87. The data obtained on October 15 is an estimate: the amount of soft seeds were calculated by adding the change in number of seeds/pod between September and October to the soft seed present in October. This calculation was necessary because rains which fell in early October germinated the soft seeds which were then present (see later).

The dynamics of changes in hard seed populations are shown for two of the species in Fig. 2.3. Both species lost more of their hardseededness (in terms of seed numbers) at low density than at high density, in M. noeana (low density) the seed loss being greater in the first year than in the second compared with the reverse for M. rotata and the high density of M. noeana. In fact, as Table 2.2 shows, the M. noeana pattern is typical of the low density populations of all species except M. rotata. At high density however four of the six species germinated better in the second than in the first year, even in absolute terms (Fig. 2.2).

In terms of the original seed population, with the exception of M. polymorpha at low density, less than half of the seeds had germinated in two years (Table 2.3). At low density between 2000 and 12000 seeds remained in the seed bank, while at high density between 5000 and 23000 seeds remained. It is clear that, in the conditions of Tel Hadya at least, an adequate seed bank will remain in the soil for more than the single season required by a cereal/pasture rotation.

Data from Experiment 2.1 also indicates that small seeds within an accession are more likely to be hard than large seeds, at least for some species. For example, in our data mean seed size of Jemalong and M. polymorpha fell after the first year indicating that the larger seeds had germinated (Table 2.4). Such data is in line with the concept that seeds germinate from the proximal to distil ends of the pod, seed at the proximal end usually being larger than those at the distil end.

Difference in seed size may also explain the difference in hardseededness between the low and high density treatments: for all species seeds at high density were smaller than those at low density (see Table 2.1). Here difference in seed size was probably associated with greater environmental stress during seed

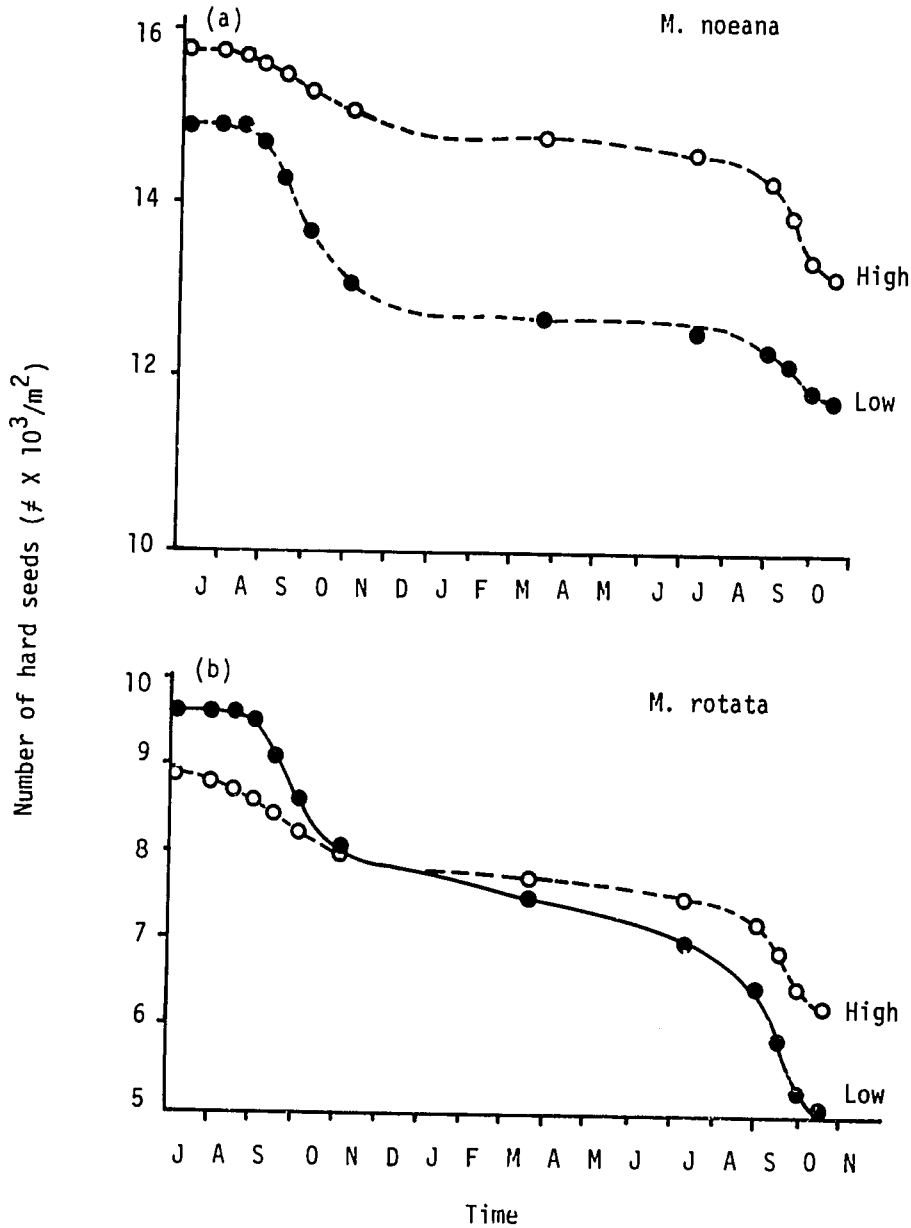


Fig.2.3. Change in the number of hardseeds with time of (a) M. noeana acc. SA15845 and (b) M. rotata sel. 2123 in Expt 2.1. Pastures represented by open circles were sown at high density, and those by closed circles at low density. Each interval on the x-axis represents a month between July 1987 and October 1988. The curves were fitted with time series functions using Daniell weighting.

Table 2.2. Seeds germinated in 1986/87 and 1987/88 as a percentage of the total seed number at the beginning of summer in each year (calculated from curves smoothed using Daniell weights - see Bloomfield 1976).

	Low density		High density	
	1986/87	1987/88	1986/87	1987/88
M. noeana	14.8	5.5	6.0	11.0
M. polymorpha	38.8	27.6	24.1	27.0
M. rigidula sel. 1900	30.4	20.6	20.6	9.8
M. rigidula sel. 716	28.7	14.4	11.5	12.3
M. rotata	21.7	31.9	13.1	17.9
M. truncatula	25.9	8.5	25.8	12.1

Table 2.3. Number of seeds germinated, number of dormant seeds remaining and percentage of the original seed population which had germinated ($N/m^2 \times 10^3$) after two summers ($N/m^2 \times 10^3$).

	Low density		Percentage of original seed	High density		Percentage of original seed
	Germinated	Dormant		Germinated	Dormant	
M. noeana	3.10	11.83	21	2.58	13.22	16
M. polymorpha	7.42	5.90	56	17.80	22.11	45
M. rigidula sel. 1900	6.10	7.51	45	2.23	5.61	28
M. rigidula sel. 716	4.64	7.26	39	2.37	8.23	22
M. rotata	4.48	5.11	47	2.34	6.32	27
M. truncatula	0.97	2.05	32	6.13	11.49	35
Mean			40			29

Table 2.4. Weight of individual seeds (mg) at maturity in 1987, and during spring of 1988 after the germination of soft seeds.

	6/7/87	23/3/88
M. noeana	2.79	2.77
M. polymorpha	2.49	2.32
M. rigidula 1900	2.61	2.64
M. rigidula 716	3.96	4.02
M. rotata	4.95	4.99
M. truncatula	2.99	2.50

LSD ($P<0.05$) between any two = 0.20 mg

formation as a result of more intense inter-plant competition. If this is so, it would appear to be in conflict with the conclusion of Quinlivan (1971) who, in subterranean clover, observed that seeds from the earliest produced inflorescences were harder than from inflorescences produced later when the plants appeared to be under moisture stress.

Between species differences in seed size apparently had no effect on hardseededness, the small seeds of M. polymorpha being softer than the larger seeds of M. rotata. However, as will be seen in Chapter 3, it seems likely that, in general, seed of small seeded species are harder than those of large seeded species and more likely to occur in arid environments. In view of its possible link with the impact of stress during seed production, the relationship between seed size and hardseededness needs further study.

When the first rains are early (as in 1988 when more than 10mm fell on 5 October and again on 20 October), the continuing decline in hardseededness should result in a series of germinations. Fig. 2.4 indicates that such is the case, the first germination (measured on 18 October) being substantially less than the second (measured on 25 October). This pattern has continued with further small germinations on 1 and 8 November and, in the case of M. rotata, a further substantial germination on 15 November. Not surprisingly seedling number and the number of seeds which germinated are closely related ($r^2 = 0.89^{**}$), the data in Fig. 2.5 indicating that 60 - 70% of the seeds lived to become seedlings.

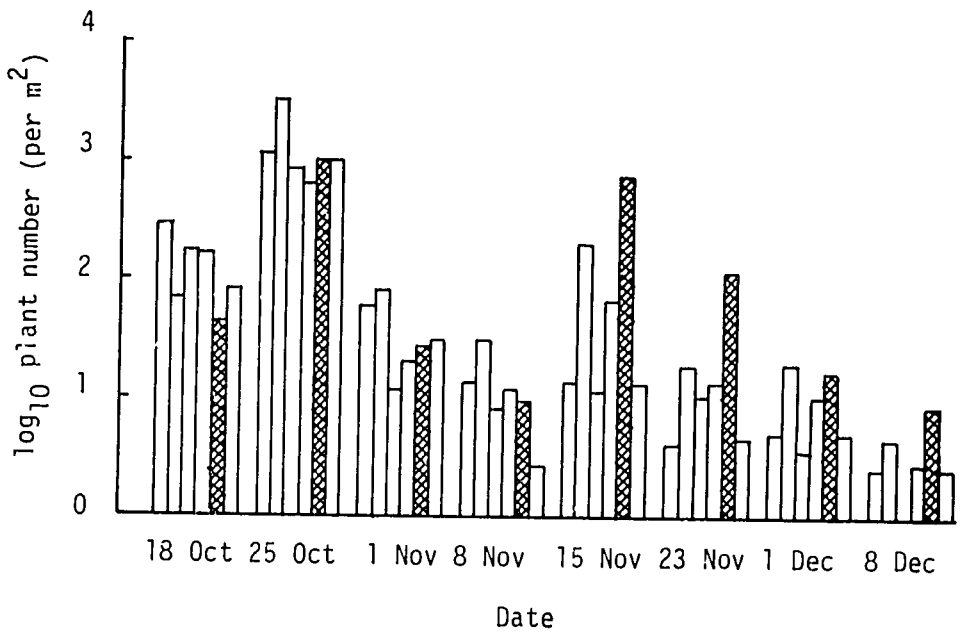


Fig.2.4. The pattern of emergence for the six species of medic (from left to right at each date - M. noeana, M. polymorpha, M. rigidula sel. 1900 M. rigidula sel. 716, M. rotata, and M. truncatula) used in Expt 2.1. The shaded column is M. rotata.

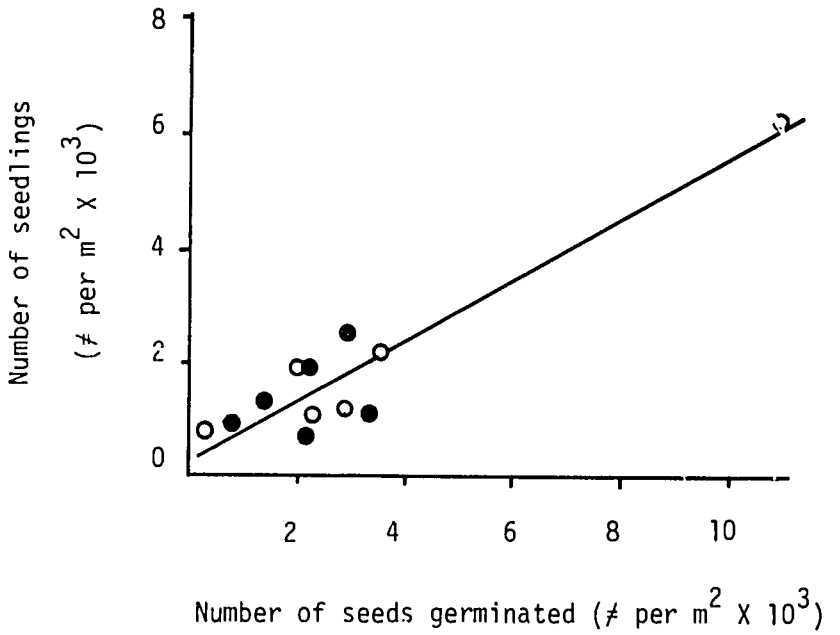


Fig.2.5. The relationship between the number of seedlings which had emerged by 1 November 1988 and the number of seeds which had germinated ($r^2 = 0.89^{***}$). Open circles represent high density, and closed circles, low density at sowing time in the previous year (see text).

Indeed M. rotata is the closest species to the ideotype mentioned at the beginning of this Chapter. Its germination is greater in the second year after seed set than in the first, and a significant proportion of its population resists germination after early rains: enough germinates early however, to take advantage of early rains should there be follow-up rains (as in 1988). Even after two years more than half of its seed remains in the seed bank as an insurance either against drought or the decision by a farmer to have consecutive years of crop. Use of M. rotata, at least in mixtures with other species (see later discussion), should increase the sustainability of the ley farming system. -- P.S. Cocks

Expt 2.2: Genotype X environment effects on hardseededness (Preschedule M27)

The objective of Experiment 2.2 is to monitor the hardseededness of an array of medic species and ecotypes in environments typical of those where medics are likely to be important. The experiment uses data generated by the international network of medic selection experiments which PFLP is establishing (see Chapter 3).

In 1986/87 and 1987/88 experiments A and B respectively were established at Tel Hadya (average rainfall 340 mm), Breda (280 mm) and Salamieh (220 mm). Experiment A (1986/87) was also sown at Mashakar (450 mm), near Amman, in Jordan.

At each site and year plots of 5 X 4 m were sown in November at a rate of $3g/m^2$. Seed was inoculated (not always successfully) with rhizobia and grassy weeds were controlled by spraying with Fusillade. The seed bank was sampled in June in two quadrats of 1 X 1 m, the unthreshed pods being returned to the quadrat area. In experiment A the plots were sown to cereal in 1987/88 (wheat at Tel Hadya and Mashakar, barley at Breda and Salamieh). All medics which germinated as weeds were sprayed with herbicide, the few plants surviving being removed by hand.

Seed populations were further sampled at intervals during the summers of 1986/87 and 1987/88. In Experiments A and B the seed remained on the soil surface in 1986/87 and 1987/88 respectively, while in the cereal year of experiment A it was buried to about 10 cm. Hardseededness was measured in pods to prevent any suggestion that it was affected by threshing. At all sampling times the number of seeds/pod was recorded in order to monitor total seed population (total seed number = pod number at harvest X seeds/pod).

Ecotypes present in the experiment varied between years of sowing (Tables 2.5 and 2.6) although there was a core of 14 ecotypes common to both years.

Tables 2.5 and 2.6 show the seed yield of each species at each site in 1986/87 and 1987/88 respectively. In both years M. polymorpha sel. 1035 produced the highest mean seed yield overall, and in all but one site (Mashakar, where it was the second best). Other ecotypes of M. polymorpha (Tah and Circle Valley) yielded almost as well at most sites (especially in 1987/88) indicating the wide adaptability of this species.

Table 2.5. Seed yield of 15 medic ecotypes at four sites in 1986/87.

	Breda	Mashakar	Tel Hadya	Salamieh	Mean
M. rigidula sel. 716	433	233	623	265	388
M. rigidula sel. 1865	283	202	459	291	309
M. rigidula sel. 1919	347	288	658	290	396
M. rigidula sel. 1902	136	164	280	17	149
M. rotata sel. 2123	401	384	706	239	432
M. rotata sel. 1943	428	485	658	196	442
M. rotata sel. 2119	483	550	873	517	606
M. noeana acc. SA 15485	311	104	587	126	282
M. noeana sel. 1938	25	101	157	14	74
M. noeana acc. 2351	218	111	495	146	243
M. polymorpha sel. 1035	621	548	805	666	660
M. polymorpha 'Tah'	459	125	522	373	370
M. polymorpha cv. Circle Valley	451	82	556	313	350
M. truncatula cv. Jemalong	326	263	202	301	273
M. scutellate cv. Robinson	461	599	547	452	515
Mean	359	282	542	280	
	Sites(S)***		Species(S)***		S X S***
LSD (P<0.05)	21		82		164

All figures are rounded to nearest kg/ha

*** Effects significant at P<0.001.

Table 2.6. Seed yields (kg/ha) of 21 medic ecotypes sown at three sites in 1987/88.

	Breda	Tel Hadya	Salamieh	Mean
M. rigidula sel. 716	851	882	350	694
M. rigidula sel. 1865	824	888	513	742
M. rigidula sel. 1919	942	1230	527	900
M. rigidula sel. 1902	622	873	478	658
M. rigidula acc. 2860	804	951	412	722
M. rotata sel. 2123	1095	1111	390	865
M. rotata sel. 1943	967	1245	337	850
M. rotata sel. 2119	1242	1297	756	1098
M. rotata acc. 2532	970	1000	291	754
M. noeana acc. SA 15485	804	1026	373	734
M. scutellata cv. Robinson	766	193	733	564
M. noeana acc. 2351	742	990	311	681
M. noeana sel. 2124	554	862	255	557
M. polymorpha sel. 1035	1513	1659	1411	1528
M. polymorpha 'Tah'	1295	1448	901	1215
M. polymorpha cv. Circle Valley	1282	886	761	976
M. truncatula cv. Jemalong	697	250	352	433
M. truncatula cv. Paraggio	601	299	579	493
M. truncatula acc. 2083	781	626	454	620
M. turbinata sel. 1991	617	795	285	566
M. aculeata sel. 1999	843	875	455	724
Means	986	923	520	
	Sites***	Species***	S X S***	
LSD (P<0.05)	25	112	193	

*** Effects significant at P<0.001.

The survival of seeds from maturity in 1987 until the spring of 1988 are shown in Table 2.7. There was virtually no germination of M. noeana (all three accessions) and of M. rigidula sel. 1902: indeed, according to the data, there were more seeds present in the spring than had been produced in the previous year. This is clearly a sampling error, but the Table indicates the high level of seed dormancy which can exist in the medics. Of the remaining entries there was less than 20% germination of seven ecotypes, between 20 and 30% of two ecotypes, and more than 50% germination of M. polymorpha sel. 1035 and M. scutellata cv. Robinson.

Table 2.7. Mean survival (at four sites) of seeds of all species in Exp 2.2 through to the spring of 1987/88.

	Survival (%)
M. rigidula sel. 716	87.4
M. rigidula sel. 1865	87.5
M. rigidula sel. 1919	88.7
M. rigidula sel. 1902	100.5
M. rotata sel. 2123	81.1
M. rotata sel. 1943	79.0
M. rotata sel. 2119	87.5
M. noeana acc. SA 15485	101.4
M. noeana sel. 1938	103.5
M. noeana acc. 2351	110.7
M. polymorpha sel. 1035	42.6
M. polymorpha 'Tah'	78.3
M. polymorpha cv. Circle Valley	86.6
M. truncatula cv. Jemalong	83.2
M. scutellate cv. Robinson	49.5

Table 2.8 shows that, although the mean hardseededness reached the same level by March 1988, the pattern of hardseed breakdown over the summer and autumn of 1987 was markedly different at the three sites. Even on 3 November, by which time the first rains had fallen, the seeds at Salamieh were 97% hard compared with 87% at Tel Hadya. Beyond 3 November there was no further breakdown of hardseeds at Tel Hadya, in contrast to Breda and Salamieh where almost all breakdown occurred after early November. At Mashakar, where measurements were less frequent, total hardseed breakdown was markedly greater than at the other three sites (Table 2.9).

As in Expt. 2.1 hardseed breakdown occurred more rapidly when seed was one year-old compared with fresh seed (Fig 2.6). The last sampling in Fig. 2.6 was in early October, and so substantial further softening during the autumn of 1988 is likely. It will be of great interest to compare the final amounts of hardseed breakdown in this experiment where, in contrast to Expt. 2.1, fresh and one year-old seed are compared in the same summer.

Both Table 2.9 and Fig. 2.7 (which shows the hardseed breakdown of three species at Tel Hadya) show general agreement with the results in Figs 2.2 and 2.6: there is rapid breakdown of hardseededness in October and November. M. polymorpha sel. 1035 illustrates this perfectly: on 6 October it was 98% hard compared with only 75% hard at the beginning of November and only 48% hard during the growing season. This point is stressed because of the profound difference in this pattern compared with that in Australia, where Crawford (1983) observed that between 50 and 70% of total hardseed breakdown had taken place by the end of summer.

The pattern of hardseed breakdown makes it important that, when screening germplasm for hardseededness, sampling is at the

Table 2.8. Hardseededness (mean percentage of original population of all species) from June 1986 until March 1987.

	Salamieh	Tel Hadya	Breda
12 June 1986	99.9	100	99.8
28 July 1986	100	99.6	100
11 August 1986	100	99.7	100
25 August 1986	100	99.7	99.9
8 September 1986	99.9	99.3	99.8
22 September 1986	100	95.5	99.7
6 October 1986	99.0	94.9	99.4
21 October 1986	99.8	92.6	95.0
3 November 1986	96.8	86.9	96.7
20 March 1987	87.2	88.6	85.9

Table 2.9. Relationship between hardseeds measured in October/November (1987) and hardseeds present in March (1988) of the following year.

	Correlation coefficient	Mean (Oct/Nov)	Mean (March)
Salamieh	0.60***	96.8	87.2
Mashakar	0.04 NS	98.2	76.4
Tel Hadya	0.79***	86.9	88.6
Breda	0.53***	96.7	85.9
		(0.9) (1)	(3.1) (1)

(1) LSD ($P<0.05$).

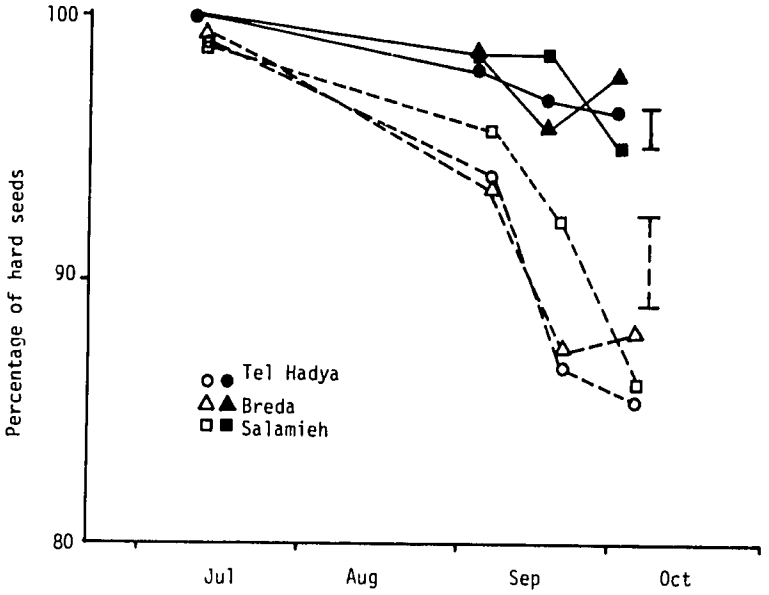


Fig.2.6. Change in percentage of hardseeds with time in the summer of 1988 at Tel Hadya, Breda and Salamieh of seed produced in 1987/88 (closed symbols) and 1986/87 (open symbols). The vertical bars represents LSD's ($P<0.05$) between times and sites (Expt 2.2).

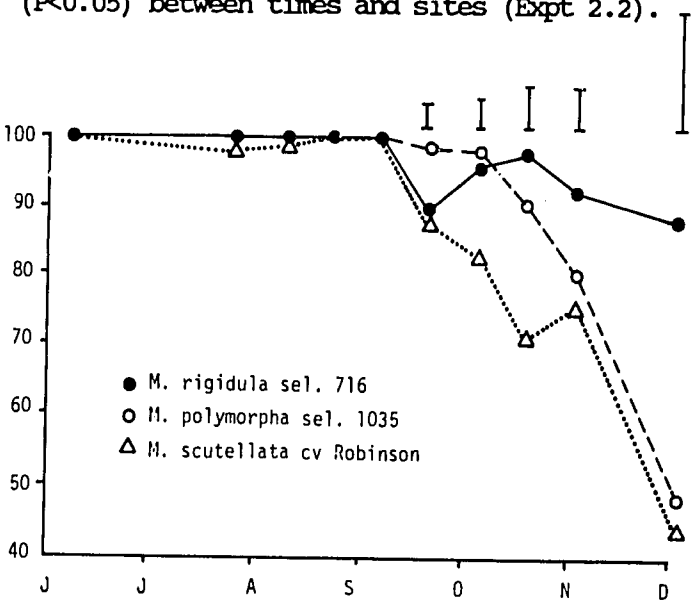


Fig.2.7. Changes in hardseededness of fresh seed of M. rigidula sel. 716, M. polymorpha sel. 1035 and M. scutellata cv Robinson during the summer and autumn of 1988 (Expt 2.2). Letters on the x-axis represent June, July, August etc.

latest possible time in autumn. In Fig. 2.8 the relationship between the amount of seed which actually germinated (measured in March) and the predicted amount based on hardseededness tests during summer and autumn is shown not to be significant until the end of September, and to continue to improve until 2 November. At sites other than Tel Hadya predicting germination is even more difficult (Table 2.9.), and impossible at Mashakar (where the last test however, was conducted in October compared with November at the other three sites).

At the two wetter sites (Tel Hadya and Mashakar), as with M. truncatula and M. polymorpha in Experiment 2.1, the largest seeds tended to germinate before the smallest (Table 2.10) - **P.S. Cocks.**

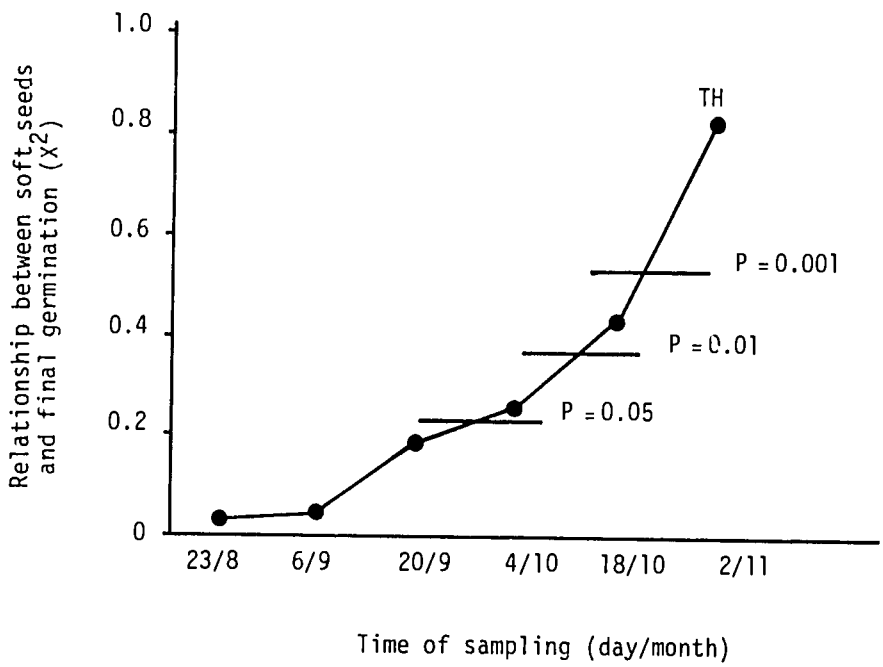


Fig.2.8. Increase in value of r^2 (correlation coefficient) with time of the relationship between total gemination of seeds at Tel Hadya in 1987/88 and that predicted by tests for hardseeds from 23 Aug to 2 Nov 1987.

Table 2.10. Mean weight of individual seeds (mg) at maturity in 1986/87 and of ahrd seeds in the seed bank after the germination of soft seeds in the autumn of 1987/88.

Sites	Seed size (at maturity)	Seed size (after germination)	Significance
Breda	4.78	4.83	NS
Mashakar	4.78	4.41	***
Tel Hadya	4.71	4.49	***
Salamieh	4.53	4.51	NS

NS, not significant
***, $P<0.05$

Hardseed breakdown in Mediterranean annual-type grasslands

Mediterranean annual-type grasslands occur within the cereal zone of the Mediterranean basin and are dominated by annual species. The flora comprises grasses, legumes and numerous other broad-leafed species: in particular the legumes are widespread and often abundant. Their survival mechanisms are of great interest to ICARDA as it attempts to devise management systems which will reverse the trend towards degradation and improve productivity.

The experiments described in this section are part of our broad strategy for improving these grasslands. The strategy includes studies of seed production under grazing, the removal of mature seeds and their survival in the digestive tract of grazing ruminants, changes in the size of the seed bank both within and between seasons, and the survival of seedlings.

Expt. 2.3: Long term seed dormancy in two legumes and a grass (Preschedule ML10)

The objective of Expt. 2.3 was to compare the seasonal germination of two annual clovers (Trifolium campestre Screb., and T. stellatum L.) with an annual grass (Bromus sp.).

A large quantity of seeds (around 100,000) of each species was divided into lots of 200, placed in terylene bags, and, in August 1987 buried at 2-3 cm. On 10 February and 20 March 1988 enough bags for 2400 seeds were retrieved, the germination which had previously occurred was assessed by counting the number of seeds still in the bags, and the germination of the remaining seeds was tested in the laboratory as described below.

For the legumes scarified and unscarified seeds were tested at two constant (10°C and 20°C) and one alternating temperature (10/20°C for 8/16h) in the presence and absence of light. The treatments were combined in a factorial design with four replicates each of 50 seeds. For the grass no seed remained in either February or March indicating that dormancy in Bromus, if it exists at all, is short term and not likely to result in the survival of seeds from year to year.

In February dormant seeds of T. campestre and T. stellatum were respectively 66% and 49% of the original 200. In March both species showed a further slight decrease (59% and 46% of the original seed respectively), the decrease being significant in T. campestre ($P<0.05$).

The scarified seeds of both clovers germinated in a few days (99.6% and 98.4% in February and 100.0% and 98.7% in March, for T. campestre and T. stellatum respectively). Darkness and low temperature (10°C) increased the rate of germination of T. campestre, as did darkness and high temperature (20°C) for T.

stellatum, but neither temperature nor light had any effect on the final germination. If seeds were soft and able to imbibe they germinated.

Unscarified hard seeds germinated poorly: 4.5% and 1.9% in February and 6.7% and 2.8% in March, for T. campestre and T. stellatum, respectively, even after 42 days.

It is clear that hardseededness is entirely responsible for the prevention of germination in the two clovers - L. Russi.

Expt 2.4: Hardseed breakdown of six wild pasture legumes

The objective of Expt 2.4. was to study hardseed breakdown of six wild legumes of importance in grassland ecosystems. The species, which were all collected in Syria, were:

M. orbicularis, (L.) Bart.
M. rigidula, (L.) All.
M. rotata, Boiss.
T. stellatum, L.
T. campestre, Schreb.
T. tomentosum, L.

The seeds were scarified, inoculated with rhizobia, and sown in 4 X 2.5m plots in a randomized complete block with three replicates.

The plots were sown in November 1986 and managed for maximum seed production. Growth was good for all species except T. stellatum where the seedlings were seriously damaged by birds.

In June 1987 the dry residues were removed by hand and, from two quadrats (20 X 105cm), medic pods or mature clover

inflorescences were cleaned from the soil, counted and weighed. In M. rotata, six groups of 100 randomly selected pods were weighed, and the single pods threshed by hand to assess the average number of seeds per pod. The remaining pods were then returned to the plot.

After maturity the plots were subdivided into three sub-plots each of $2m^2$ surrounded by a border of $4m^2$. To monitor changes in hardseededness during the first summer pods were collected from the border area and tested for germination. The first test was in June 1987 based on duplicate sets of 100 seeds per plot.

Five small quadrats (20 X 20cm) were fixed in the first of the $2m^2$ subplots and at intervals from October 1987 until April 1988 the number of seedlings were recorded and removed. In March the vegetation was killed with a dessicant herbicide to avoid further seed production. In April the seed bank was assessed in the same five quadrats.

In July 1988 pods were collected again to assess the breakdown of hardseededness of the remaining seeds. In September the five quadrats were moved to a new subplot ($2\ m^2$) in order to count and remove seedlings which germinated in 1988/89.

A second experiment with the same treatments was sown in the 1987/88 season to examine differences in hardseededness caused by varying seasonal conditions.

Fig. 2.9 shows the breakdown of hardseeds during the summer of 1987. There were no changes until late August when the seeds of M. rigidula began to soften ($P<0.05$). Two weeks later mean hardseededness had decreased from 98% to 89% (M. rigidula was down to 80%, T. stellatum, 73%, and T. tomentosum, 92%). Hardseededness of these species continued to decline: quickly in T. stellatum (28% hardseeds on 4 October), more slowly in T.

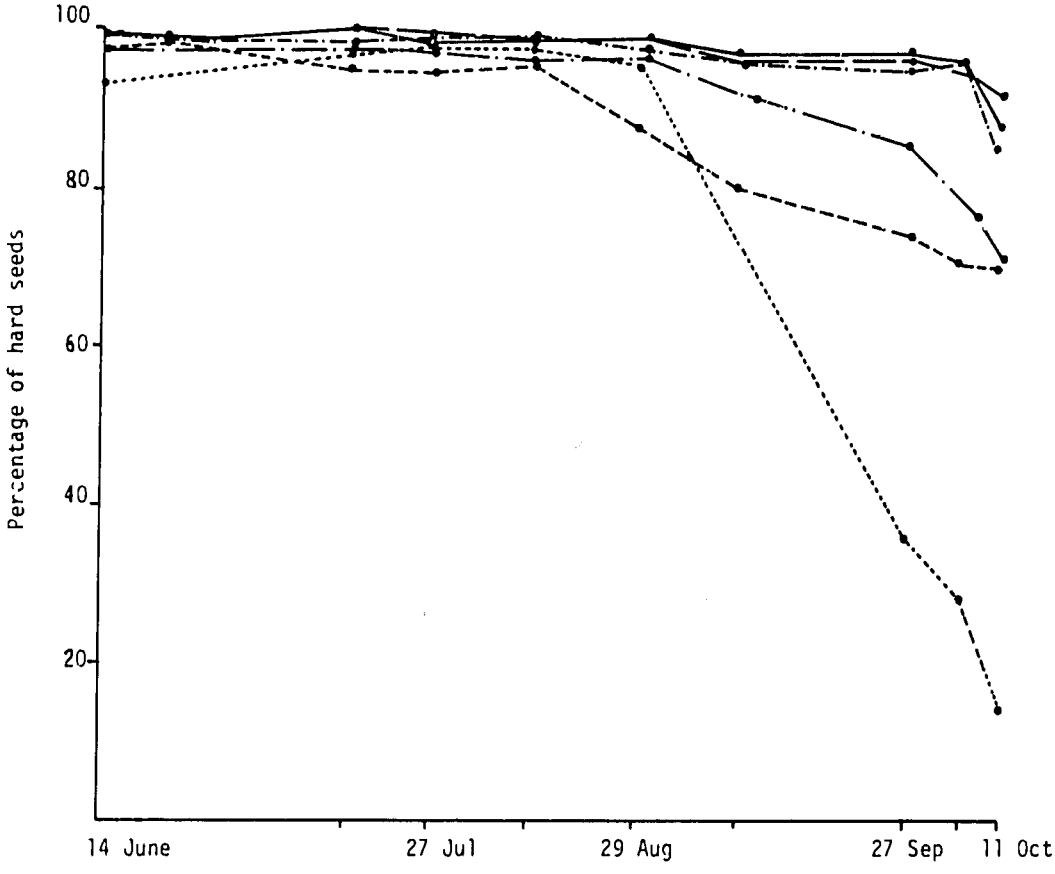


Fig.2.9. Change in hardseededness in the summer of 1988 of (from top to bottom) M. orbicularis, T. campestre, M. rotata, T. tomentosum, M. rigidula and T. stellatum. Seeds were produced in 1988.

tomentosum (78%) and M. rigidula (71%). Hardseededness of the other species did not decline until early October.

Table 2.11 shows hardseededness on 11 October (before germination), the percentage (of the total seed production) which emerged as seedlings, and the percentage of seeds remaining in the seed bank in April 1988. In all species most emergence had occurred by the end of November, although, except in M. rigidula, seedlings continued to emerge until the end of March.

Table 2.11. Cumulative seedling emergence in 1987/88, seed bank in April 1988, and hardseededness in October 1987, in six legumes.

	Initial seed population	Cumulative seedling emergence Oct 26 1987	Nov 5 1987	Nov 12 1987	Nov 24 1987	Mar 24 1988	Seed Bank April 1988	Hardseededness Oct 1987
M. orbicularis	100.00	2.29	4.85	5.00	5.07	5.26	94.74	91.5
M. rigidula	100.00	9.47	20.42	21.11	21.11	21.11	78.89	69.5
M. rotata	100.00	0.44	1.58	1.69	1.73	1.80	98.20	84.3
T. stellatum	100.00	1.62	30.64	60.64	71.71	73.23	26.77	13.7
T. campestre	100.00	0.06	2.59	9.27	13.99	15.78	84.22	87.5
T. tomentosum	100.00	2.80	7.82	19.46	22.84	25.62	74.38	71.0
Average	100.00	2.78	11.32	16.01	22.74	23.8	76.[illegible]	69.5

Measurement of hardseededness in October was a reliable indicator of actual germination and emergence, and, in contrast to the data in Table 2.9, hardseededness in October over-estimated subsequent germination. This appears to have been due to inadvertent softening of a few seeds during the threshing process: in October, when the amount of hardseeds of threshed seed was compared with imbibition of seeds in the intact pods, the latter was 4% less than the former.

Fig. 2.10 shows the rate of hardseeded breakdown in the second summer. As in the earlier data (Figs 2.2 and 2.6) hardseed breakdown in the second year commenced earlier than in the first year.

The data in Fig. 2.11, which represents the second sowing, further supports this conclusion: in the same summer, two year old seed (Fig. 2.10) broke down more rapidly than one year old seed (Fig. 2.11). Table 2.12 shows the percentage of hardseeds in October 1987 and 1988 from seed set in 1987 and 1988

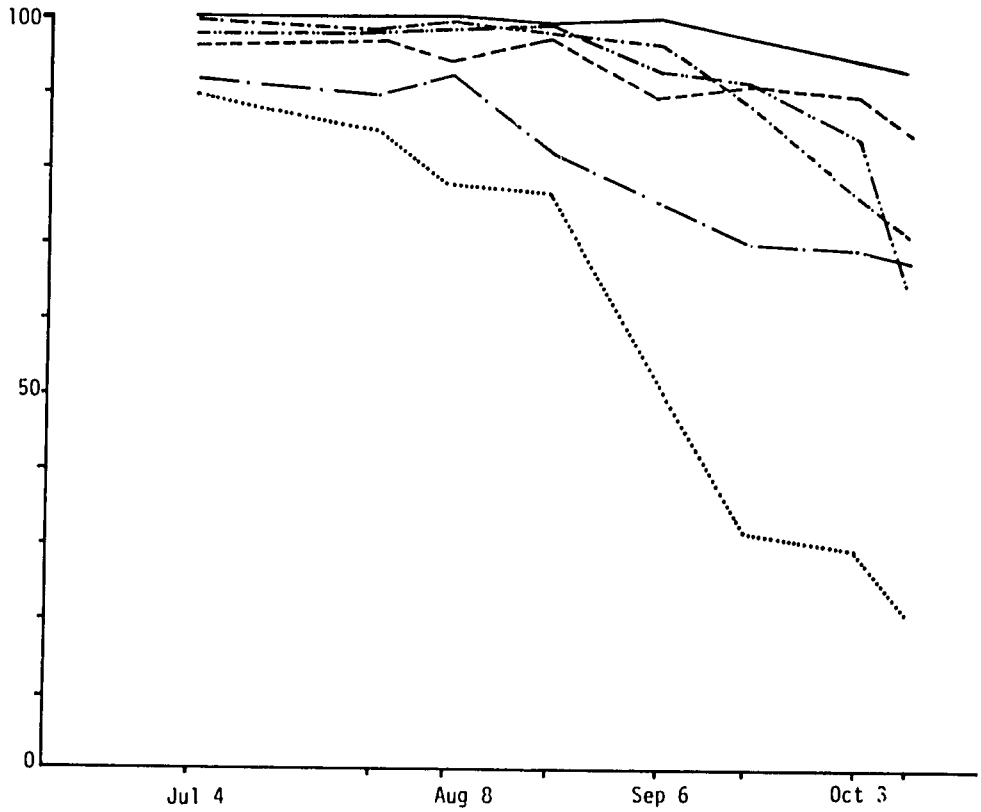


Fig.2.10. Change in hardseededness in the summer of 1988 of (from top to bottom) M. orbicularis, M. rotata, T. tomentosum, M. rigidula, T. campestre, and T. stellatum. Seeds were produced in 1987 and the percentages are those of the population as it was in June 1988.

respectively. The difference between years is significant ($P<0.05$), but the most striking differences are those between species ($P<0.001$). T. stellatum is shown to be extremely softseeded, and would be unsuitable for the ley farming system. In contrast M. orbicularis is very hardseeded. There was a significant species X year interaction due to the contrasting behaviour of some species: M. orbicularis, M. rotata, and T. stellatum were relatively harder in 1988 ($P<0.05$) than in 1987, while T. campestre and T. tomentosum were relatively softer ($P<0.05$). - L. Russi

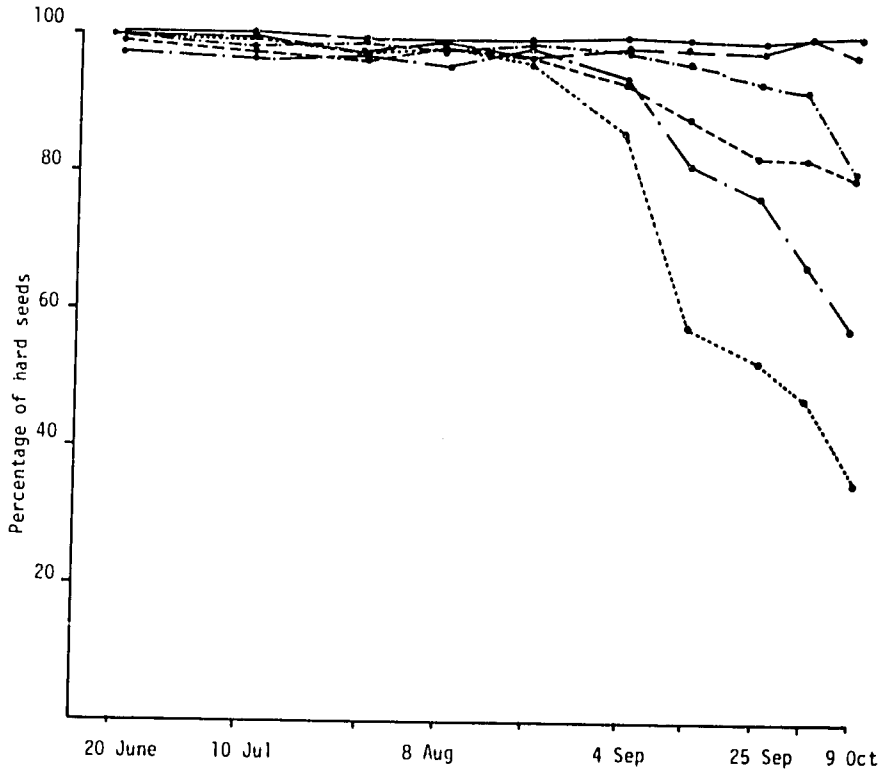


Fig.2.11. Change in hardseededness in the summer of 1988 of (from top to bottom) M. orbicularis, M. rotata, T. campestre, M. rigidula, T. tomentosum, and T. stellatum. Seeds were produced in 1988. Compare this figure with Fig.2.10.

Expt. 2.5: Hardseed breakdown of seeds buried in the soil at different depths

The objective of Expt. 2.5 was to relate hardseed breakdown with depth of seed burial.

In the ley farming system seeds are buried during cultivation and so account must be taken of the effect of burial on hardseed breakdown. In grasslands too, seeds are often buried (though less deeply) by the action of treading, insects, and the incidence of cracks in the soil.

Table 2.12. Hardseededness on 11 October 1987 and 9 October 1988 two seed populations (set in 1987 and 1988 respectively).

	Year of seed set			
	1987	1988	Difference	Mean
M. orbicularis	$91.5^{bc(1)}$	99.7^{a}	$+8.2^{*}$	95.6^{A}
M. rigidula	69.5^{fg}	79.3^{def}	$+9.8^{*}$	74.4^{CD}
M. rotata	84.7^{cde}	97.0^{ab}	$+12.7^{*}$	90.7^{B}
T. stellatum	13.7^{i}	34.7^{h}	$+21.0^{*}$	24.0^{E}
T. campestre	87.5^{cd}	80.0^{def}	-7.5^{*}	83.8^{C}
T. tomentosum	71.0^{ef}	57.0^{g}	-14.0^{*}	64.0^{D}
Mean	69.6^{B}	74.6^{A}	+5.2	72.1

* Difference between years significant ($P<0.05$).

(1) Values followed by different letters of the same case (upper or lower) are significantly different (see text).

It is known that burial insulates seeds against fluctuating temperatures. For example in Australia, Taylor (1984) showed that the normally soft-seeded subterranean clover (T. subterraneum) remains hard when buried to a depth of only 6 cm, and Taylor and Ewing (1988) showed that medics responded to burial in a similar (though lesser) way. The work of Taylor and his colleagues is of such importance in understanding the nature of seed banks that ICARDA has designed two experiments to see whether their results apply to our species in our environments. The first of the experiments is reported here.

The same species as in Expt 2.4 were used in Expt. 2.5 (see Table 2.13). The seeds, in terylene bags were placed on the soil surface, or buried at 5cm and 10cm depths. Seeds were collected

Table 2.13. Hardseededness in six legumes buried in June 1988 at different soil depths and measured on 16 October 1988.

	Surface	5 cm	10 cm	Mean
M. orbicularis	$99.3^{ab(1)}$	99.7^{a}	99.3^{ab}	99.4^{A}
M. rigidula	82.0^{g}	92.7^{def}	95.7^{bcd}	90.1^{C}
M. rotata	99.3^{ab}	99.7^{a}	99.7^{a}	99.6^{A}
T. stellatum	47.0^{h}	95.7^{cde}	96.0^{cde}	79.6^{D}
T. campestre	91.7^{ef}	97.3^{bcd}	96.3^{cde}	95.1^{B}
T. tomentosum	86.3^{fg}	96.0^{cde}	97.7^{abc}	93.3^{BC}
Mean	84.3^{B}	96.8^{A}	97.4^{A}	92.9

(1) Values followed by different letters of the same case (upper or lower) are significantly different (see text).

on 14 September and 2 October 1988: further collections will be taken later. Hardseededness was measured by soaking seeds in Petri dishes for 15 days.

Seeds on the surface softened more rapidly than those at 5 or 10 cm depth (Table 2.13). There was a significant species X depth interaction ($P<0.05$): some species were still nearly 100% hardseeded even on the surface. It is clear that, as in Australia, burial protects seeds from the effects of fluctuating temperature and so prevents hardseed breakdown. - **L. Russi, and Prof. E.H. Roberts (Universitu of Reading, U.K.)**

Towards a hardseed ideotype

The productivity of pastures depends, above all, on the number of seedlings which germinate. For example in comparing 23

lines of M. rigidula, 92% of variation in productivity was accounted for by variation in seedling number (Abd El Moneim and Cocks 1986). Seedling density, governed by the pattern of hardseed breakdown, is therefore of overwhelming significance in pasture production, whether in the ley farming system or in grasslands.

But in the ley farming system it is seedling density in the second year after seed set which is important. Seeds which germinate in the first or cereal year are lost to the seed bank and contribute nothing to productivity. Therefore we need to understand not only the pattern of hardseed breakdown in the first summer (as Crawford (1983) suggests) but also the between season pattern of hardseed breakdown. Moreover there needs to remain in the seed bank enough seed to sustain the system in the event of natural or man-made disasters.

Fig. 2.12 helps to conceptualize these ideas. On the y-axis size of the seed bank after two seasons is plotted against, on the x-axis, the amount of seed germinating in the second or pasture year. The three curves represent (from left to right) what would happen if twice as much seed germinated in the first (cereal) year compared with the second (pasture) year, equal proportions germinated in the two years, or twice as much germinated in the second (pasture) year, compared with the first (cereal) year. The amount of seed which germinated increased from the top of the graph, where no seed germinate, to the bottom, where it all germinated. Fig. 2.12 is based on a seed bank of 200 kg/ha, which is representative of a real life ley farming system (see Chapter 1).

The data from Expt. 2.1 have been plotted in Fig. 2.12. As expected density affects the position of the various species, affecting M. noeana and M. polymorpha most. M. rotata is always

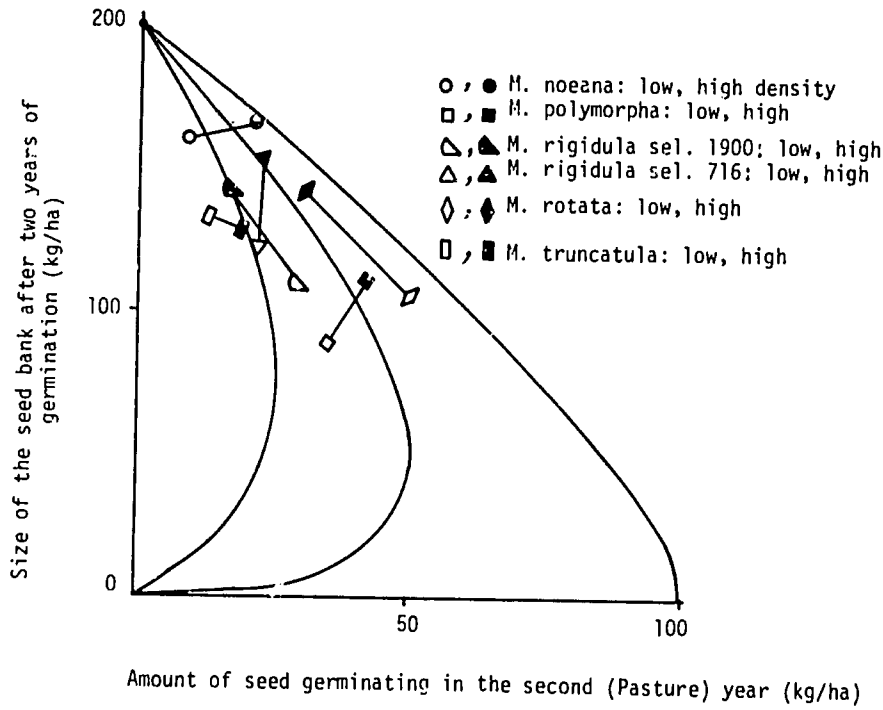


Fig.2.12. Idealized relationship between size of the seed bank after two seasons of germination and amount of seed germinating in the second (or pasture) year. The curves represent (from left to right) the case where twice as much seed germinates in the first compared with in the second year, equal amounts germinate, and twice as much germinates in the second compared with the first year. The points represent data from Expt 2.1, the open and closed cicles representing low and high density respectively (see text).

in that part of the Figure which indicates greater germination in the second year. Jemalong, on the other hand, has a most undesirable pattern which results in far less seedlings in the second year than would be predicted from its hardseed breakdown in the first year. If the criteria for selecting an ecotype were at least 30 kg/ha of germinating seed in the second year and a seed bank after the second year of at least 100 kg/ha, only M. rotata (at both densities) and M. polymorpha (high density) would be selected.

If, however, as suggested by Puckridge and French (1983), 1000 seedlings per m^2 defines successful re-establishment (along with a seed bank of 100 kg/ha) then only M. polymorpha at high density could be considered sucessful, although three other combinations of species and densities would exceed 900 seedlings/m^2: M. rotata at low density (980 seedlings), M. rigidula sel. 1900 at low density (980 seedlings), and M. noeana at high density (920 seedlings). There is a consistency between the two sets of criteria (M. rotata and M. polymorpha would be selected in both cases), but the data point out the biological complexities of selecting genotypes on the basis of hardseed breakdown and, indeed, of the whole process of pasture reproduction.

Therefore it is unlikely that an ideotype will be found. This will be especially so if ley farming is to be sustained on farms where economic changes force farmers to alter their crop sequences. For example if the price of wheat or lentils were to rise and the price of livestock fall many farmers would want to crop their land for 2, 3 or even 4 years in succession. Conversely high livestock prices might stimulate several consecutive years of pasture. In either of these circumstances it is desirable for there to be a constant release of seeds for periods of 5 or 6 years without further seed set.

This could be achieved by using mixtures. Let us assume that there are four ecotypes where seeds soften in the patterns illustrated in Table 2.14(a). If the seed bank in year 1 is 200 kg/ha, comprising 50 kg of each ecotype, there would be an almost uniform germination of seed for at least 6 years with 57 kg/ha of seed still in the seed bank at the end (Table 2.14(b)). Note that the botanical composition of the pasture would have changed from dominance by ecotype A in the first year, to dominance by ecotype D in the sixth year.

Table 2.14. (a) The interseasonal variation in hardseed breakdown of four hypothetical medic ecotypes (see text), and (b) its effect on total germination and botanical composition in each of six years after the four ecotypes are sown in a mixture.

(a)	Germination percentage					
	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
Ecotype A	40	25	10	5	5	5
Ecotype B	15	15	15	15	15	15
Ecotype C	5	15	45	50	55	60
Ecotype D	1	1	5	10	25	40

(b)	Amount of germinating seed (assuming a seed bank of 200kg/ha in Year 1)					
	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
Ecotype A	20.0	7.5	2.3	1.0	1.0	0.9
Ecotype B	7.5	6.4	5.4	4.6	3.9	3.3
Ecotype C	2.5	7.1	18.2	11.1	6.1	3.0
Ecotype D	0.5	0.5	2.5	4.7	10.5	12.6
Total	30.5	21.5	28.4	21.4	21.5	19.8

Our data suggests that this scenario is possible. Examples of ecotype A are M. scutellate cv Robinson, and M. polymorpha sel. 1035; of species B are most ecotypes of M. rigidula; of species C are M. rotata and probably M. noeana; and of species D probably M. orbicularis (this is speculative because our experiments have only now entered their third year). Note that

although the botanical composition of the seed mixture would change, all ecotypes would still exist in the seed bank even after six years.

Of course the viability of 6 year old seed is unknown, but hardseeds are normally very long lived. For example Quinlivan (1971) quotes Ohga (1926) who found that viability of 1000-year old hardseeds of Nalubium speciosum was almost 100%. In the medics Taylor and Ewing (1988) found that virtually no seeds of M. truncatula cv Cyprus died after four years in the field, and few seeds of T. subterraneum.

One final point - regarding seed size. For most medics it can be assumed that seed eaten is seed lost (see the 1987 PFLP Report). For smaller species however seed survival after ingestion is higher - up to 20% for small seeded medics and up to 60% for the smallest seeded clovers. It may, in fact, be easier to maintain a satisfactory seed bank if the pasture species is small seeded. - P.S. Cocks

CHAPTER 3: DEVELOPING A METHODOLOGY TO SELECT MEDIC ECOTYPES SUITABLE FOR THE LEY FARMING SYSTEM

In Chapter 2 we discussed an ideotype for medic hardseededness. We saw that it was possible to select medics which could be sustained for several years in pasture under a variety of adverse conditions. But hardseededness is only one of many attributes that plant breeders take into account when selecting pasture plants.

One of the objectives of our medic selection is to identify attributes which can be measured in nursery rows and used to predict the success of ecotypes in difficult environments. We recognize that such a task is likely to be long term, arduous, and the results not always reliable. In the meantime, since we know that commercially available medics are not adapted to the environments and farming systems with which we are working, there is a need to develop a reliable methodology for selecting new medics.

We have decided on an evolutionary approach which relies heavily on natural selection. The approach uses the relationship between habitat and distribution of plants - the result of natural selection over thousands of years - and success in mixtures subject to grazing in the pasture phase and cultivation in the cereal phase of the ley farming system. Success is being related to attributes measurable in nursery rows.

The first step is to study the relationship between distribution and environment. Some of the results were reported in the 1986 Program Report and also by Cocks and Ehrman (1987). Briefly, seeds were collected from 207 sites throughout Syria, meteorological data was collected from each site, and the soil sampled. The results suggest that the distribution of annual legumes is affected by the incidence of frost, amount and

distribution of rainfall, and pH and lime content of the soil. Of particular interest were the species present where ley farming is likely to be introduced: M. rigidula, M. rotata, M. polymorpha, M. radiata, and M. orbicularis. Absent from these areas were, with the exception of M. polymorpha, the species from which the Australian medics were selected: M. truncatula, M. rugosa, M. littoralis, M. scutellata, and M. tornata. By contrast, a more recent survey in Morocco (Chapter 11) reveals that the most frequent species are M. polymorpha, M. truncatula, M. laciniata, M. aculeata, and M. orbicularis.

The second step is to study the distribution of plant attributes, and some results of this research are reported in Expt 3.1. Expt 3.2 monitors natural selection in species mixtures in medic/wheat and medic/barley rotations at Tel Hadya and Breda respectively, and Expt 3.3 explores ways of extending this concept to national programs. Again plant attributes are being related to survival in both experiments. In Expt 3.4 we survey the reaction of a collection of medics to root knot and cyst nematodes. In Expts 3.5 and 3.6 we report on studies of an interesting new pasture species, Vicia sativa subsp. amphicarpa, subterranean vetch, a species which, as its name suggests, possesses the important attribute of being able to bury its own seed.

Although the experiments are aimed at developing methodologies we hope to illustrate their success by identifying medic ecotypes adapted to ley farming in Syria.

Expt 3.1: Co-adaptation and geographical distribution of reproductive attributes in Syrian pasture legumes (Preschedule M5)

As part of understanding the natural distribution of pasture

legumes it is important to understand the distribution of their attributes, especially reproductive ability. The objective of Expt 3.1 was therefore to relate some reproductive attributes - seed size, seeds/pod, hardseededness, flowering time, and seed and pod production/plant in nursery rows - with the geographic origin of the ecotypes.

The seeds were collected from throughout Syria (Cocks and Ehrman 1987) and grown in nursery rows at Tel Hadya. Briefly, they were sown into 'Jiffy pots' in a greenhouse and, after hardening, the seedlings were transplanted into the field in rows 1.5 m apart, with 50 cm between plants within rows. There were two collections: in the summer of 1984 and the summer of 1985, and these were grown in 1985 and 1986 respectively.

Analysis of the 71 species (more than 1000 accessions) reveals interesting patterns of co-adaptation and distribution. Fig. 3.1 is a three dimensional graph which shows the relationships between seed number/plant (x-axis), seed size (y-axis), and hardseededness (z-axis). There is a strong hyperbolic relationship between seed size and seed number (giving a correlation after log transformation of -0.78 ($P<0.01$)), and levels of hardseededness are related to both of these attributes as shown in Fig. 3.1. These relationships are particularly strong at both ends of the spectrum. For example at one end lie species with few, large, soft seeds (eg. Onobrychis spp. and Medicago scutellata); at the other are species with numerous, small, hardseeds (eg. several species of Trifolium, Trigonella and Astragalus). As seeds become smaller and more numerous so their levels of dormancy rise. The middle of the spectrum displays a wider range of attribute combinations than is found at either end. There are some exceptions: Scorpiurus muricatus and Trifolium clypeatum, though large seeded, have higher levels of dormancy than predicted. Trifolium subterraneum and T.

pauciflorum, by contrast, have higher seed numbers than would be predicted on the basis of seed size and dormancy. Even so, linear regression of hardseededness on seed size and seed number gives a multiple R-square value of over 0.5, indicating that a high proportion of the variance is accounted for by the relationship in Fig. 3.1.

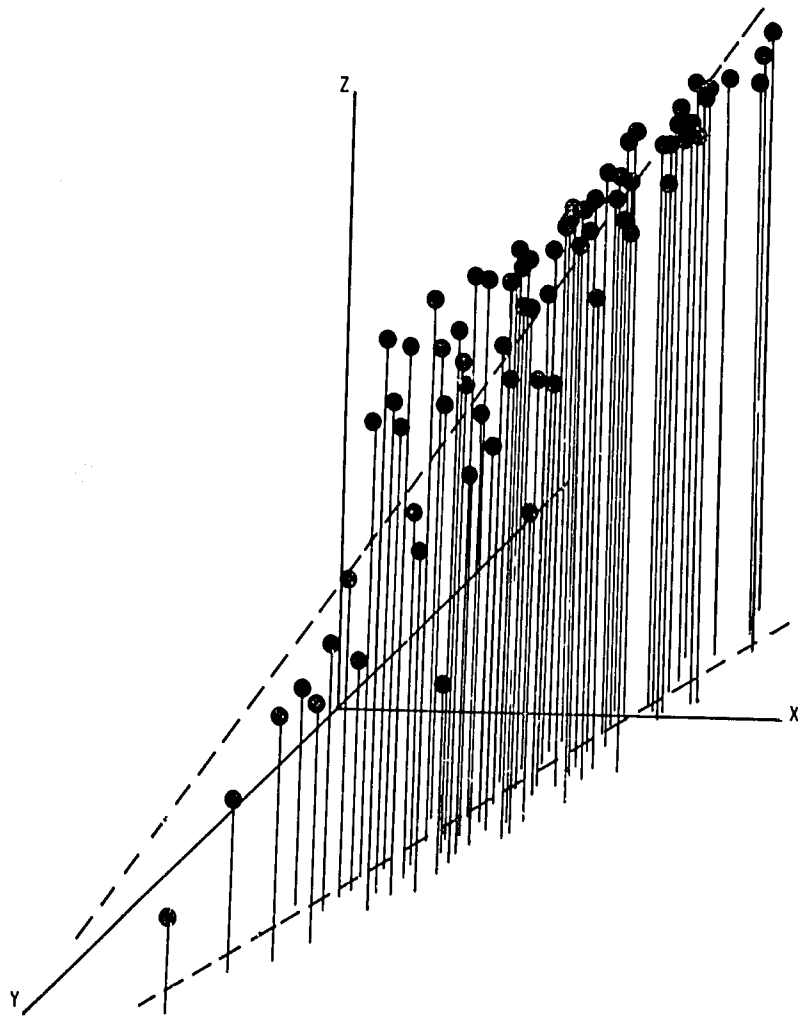


Fig.3.1. A three dimensional graph showing the relationship between log10 seed number/plant (x-axis), log10 seed size (y-axis), and percentage hardseededness (z-axis) of annual pasture legumes collected in the grasslands of Syria and grown in nursery rows at Tel Hadya.

Geographical distribution of reproductive attributes: The geographical distribution of reproductive attributes was analyzed by firstly conducting principal component analysis on the attributes themselves - flowering time, seed number/pod, pod number/plant, seed number/plant, seed size, and hardseededness - and secondly by plotting the geographical origins of the populations against the first two components.

The first two axes (components) account jointly for 65% of total variance, normally regarded as an acceptable level. Seed size and number of pods have high loadings on the first axis, while number of seeds/pod and flowering time contribute most strongly to the second axis, as shown in Table 3.1. Seed number/plant and hardseededness contribute more weakly, the latter contributing to the first two axes. Populations are distributed along these two axes in the shape of a triangle. The attribute combinations characterizing each of the three corners of the triangle are explained in Fig. 3.2, as are the geographical relationships of accessions in relation to the two axes. Two facts are noticeable. First, the range along the first axis - comprising pods/plant, seed size, seed number and hardseededness - is greatest in coastal areas. These strategies become increasingly constrained (the range becomes narrower) in drier, inland areas. Secondly, accessions from inland areas are displaced higher up the second axis relative to those from areas near the coast.

This implies the following. First, populations from inland areas are earlier flowering than those from coastal areas. Second, the proportion of populations with high levels of dormancy rises further inland, as does the average seed to pod ratio. Lastly, populations characterized by large, soft seeds, (eg. Onobrychis) or by production of numerous flowers and pods (eg. clovers) become increasingly rare in drier areas.

Table 3.1. Loadings for the first two principal component axes of an analysis of variation in a collection of Syrian pasture legumes (see text).

	Axis 1	Axis 2
Pods/plant	0.789	0.000
Seed size	-0.699	0.000
Seed number	0.651	0.000
Hardseededness	0.629	0.504
Seeds/pod	0.000	0.771
Flowering time	0.000	-0.615

Axis 1 positive end indicates populations with small, hard seeds and many pods/plant.
negative end indicates populations with large, soft seeds and few pods/plant.

Axis 2 positive end indicates early flowering populations with a large number of seeds/pod.
negative end indicates late flowering populations with a small number of seeds/pod.

The last two points indicate, among other things, that in wetter areas seed yield is maximized by high pod production, whereas in drier areas it is governed more by a high seed to pod ratio. Various species of Trifolium, Trigonella and Astragalus, for instance, produce very large quantities of small, hard seeds. The clover species adopt the first of these strategies (high pod production) and are entirely restricted to areas receiving over 300 mm rainfall. The Trigonella and Astragalus species adopt the second strategy (high seed to pod ratio) and predominate in zones

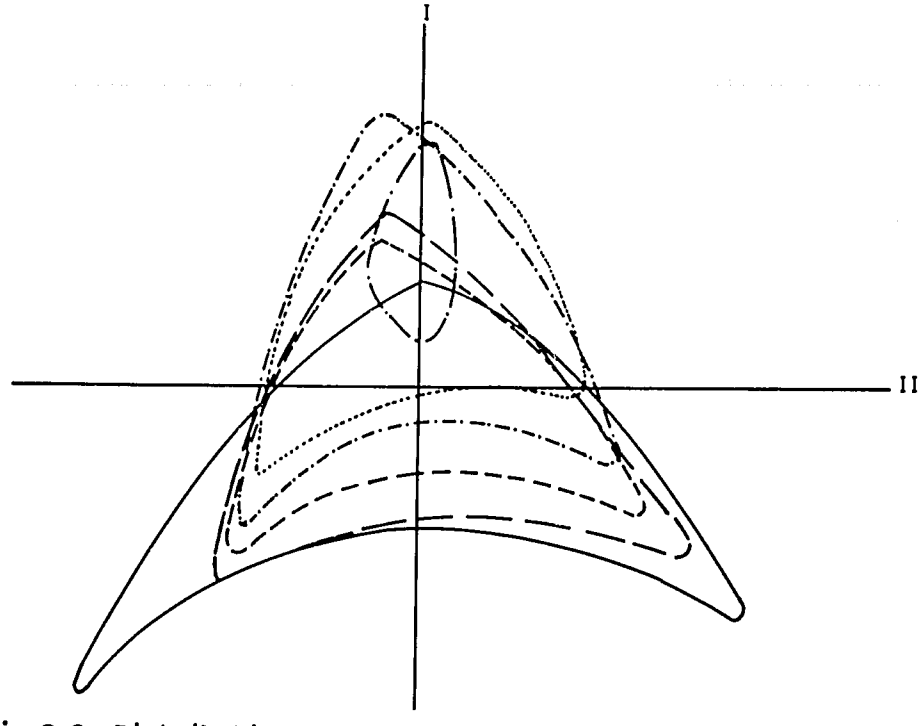


Fig.3.2. Distribution of populations along the first two axes of a principal component analysis of the reproductive attributes of annual pasture legumes collected from Syrian grasslands. Populations from coastal areas are enclosed in the broad - based 'triangle' with solid lines, and those from the steppe in the much narrower 'triangle' enclosed by alternate dots and long dashes. Populations from Mediterranean areas (rainfall more than 500mm), the southern mountains, the wheat belt, and the barley belt are intermediate, the base of the triangle becoming progressively narrower as rainfall declines.

receiving between 150 and 300 mm rainfall. One explanation may lie in the relationship between the number of flowers produced and the number of flowers aborted. Increasing the number of seeds/pod represents an increasingly economic method of reproductive packaging in terms of maternal investment per seed. This is due to a decrease in the degree of vascular supply to reproductive structures (every pod but not every seed has an

independant vascular supply). The consequences, in environments where water and nutrients are limited, would arguably entail a higher relative degree of investment in each flower and lower rates of abortion.

The other main feature of interest is the virtual absence of species with large, soft (non dormant) seeds in arid regions. Numerous models have predicted a close relationship between levels of dormancy and degree of climatic uncertainty. Dormancy provides the most efficient means of offsetting the adverse effects of year-to-year climatic fluctuations. The lack of species with low dormancy levels in such environments therefore comes as no surprise. In fact the only two large-seeded species which are regularly found in arid areas are Onobrychis crista-galli and Vicia sativa ssp. amphicarpa (subterranean vetch). Both are characterized by dimorphic seeds (seeds with two shapes or sizes). In regions where the selective advantages of dormancy are less pronounced seed size provides an alternative survival strategy, in that it promotes early growth and establishment. The reason why species with numerous, large, hard seeds are not found among annual legumes presumably relates to internal constraints or 'trade-offs' governing allocation of resources between vegetative and reproductive functions.

Reproductive attributes and species distribution patterns: Turning to the influence of reproductive attributes on distribution patterns, Fig. 3.3 shows the mean values of individual species in relation to the first two principal component axes. For the sake of clarity, only three 'classes' of species are shown: those species restricted to coastal regions, those species restricted to the barley belt and steppe, and widely distributed species (found in all climatic zones). As expected, species restricted to coastal areas are widely

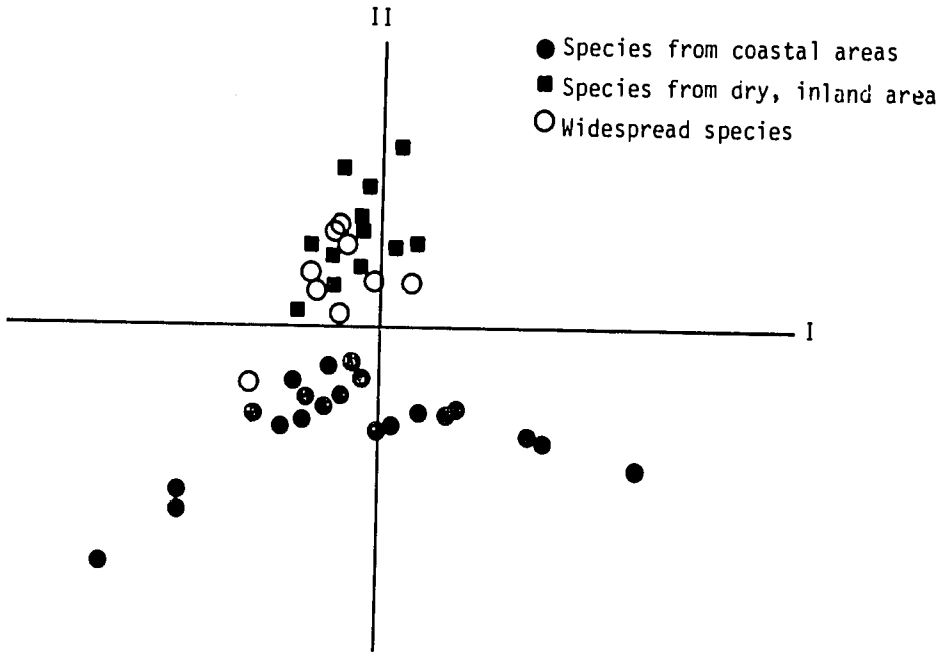


Fig.3.3. Distribution of the mean values (of species) for scores of the first two components of a principal component analysis of reproductive attributes. The closed circles represent species collected only in coastal areas, the squares, species collected only in dry inland areas, and the open circles, those species that are widespread.

distributed along the first axis and have mean values well below zero on the second axis. As species become progressively more widely distributed so their mean values shift higher up the second axis and become increasingly constrained along the first axis. The most widely distributed species have a tightly clustered distribution of mean values. They also occupy a similar, though less extreme, part of the spectrum to species restricted to arid, inland areas. Provided that levels of within-species variance are not commensurate with levels of between-species variance - which they are not - then it appears that reproductive strategies associated with more arid environments are better pre-adapted to exploiting better

environments than vice-versa. The relationship between reproductive strategies and climatic amplitude is thus asymmetric. From an analysis of infraspecific differentation (results not presented here) it seems that a shift towards late flowering is the major mode of adaptation needed for any one of these species to spread into wetter areas.

Future studies need to consider the population-dynamic consequences of different reproductive strategies and their sensitivity to climatic fluctuations and density effects. In order to understand how such strategies are related to niche selection and community structure, experiments should also be conducted on the relationships between reproduction, growth and dispersal within communities of varying complexity.

The results of this research raise the question of which species are most appropriate for improving grasslands in dry areas. Genera like Astragalus and Trigonella have been largely overlooked and preference given to Medicago and Trifolium. In view of appropriate reproductive strategies this may have been a mistake. The work also suggests that the most likely source of desirable hardseed patterns - a breakdown period of several years (see Chapter 2) - for inclusions in mixtures is most likely to be found in the arid areas, even though, in this instance their use would be for wetter areas. - **T.A.M. Ehrman (University college London) and P.S. Cocks**

Expt 3.2: Selection of medic ecotypes for the ley farming system (Preschedule M4)

The objective of Expt 3.2 is to follow changes in the composition of a mixture of medic species and ecotypes growing in a cereal/pasture rotation with a view to selecting adapted ecotypes.

In earlier research Abd El Moneim and Cocks (1986) have reported that herbage productivity of regenerating medics is directly proportional to the number of seedlings (see also Chapter 2) regardless of ecotype. In other words the genetic attributes which affect the growth and development of seedlings are far less important than those which affect reproduction. It follows that if we select ecotypes which survive in the greatest number under the conditions in which they will be used our ultimate objective of increased productivity will be achieved. If the selection process is long enough then the successful ecotypes will also be those best buffered against extremes of the environment.

Such an approach also gives us the opportunity to relate success to early generation selection in nursery rows. As discussed in Chapter 2 we now have a much better idea of the required pattern of hardseed breakdown. But of the other reproductive attributes, some of which are discussed in relation to plant distribution in the previous section, we know little of their value in predicting success in the ley farming system.

In 1983/84 part of the two-course rotation experiment managed by FRMP became available for our work. The 2-course rotation experiment comprises seven rotations of wheat with an alternative: lentils, chickpea, vetch, fallow, summer watermelons, continuous wheat, and medic pasture. The pasture area is large enough to be grazed and therefore can take into account all aspects of the ley farming system. The experiment has two phases so that both medic pasture and wheat are present each year.

The initial medic sowings failed, but in 1984/85 a mixture of 84 ecotypes was sown at a rate of 40 kg/ha becoming Phase 1 of the experiment. In 1985/86 Phase 2 was sown with an identical

Table 3.2. Species sown in Expt 3.2 and the percentage of each species (by mass) in the mixture at sowing time.

Species	Number of ecotypes	Percentage
M. aculeata	17	14.6
M. blancheana	1	4.5
M. constricta	2	2.7
M. littoralis	1	4.5
M. noeana	4	7.2
M. polymorpha	8	2.4
M. rigidula	19	26.6
M. rotata	11	10.7
M. rugosa	1	0.5
M. scutellata	1	4.5
M. truncatula	9	10.6
M. turbinata	10	9.2

mixture. Both sowings were successful. Table 3.2 indicates the species composition of the mixture at sowing time.

To monitor changes, the seed population was sampled at the beginning and end of summer in each pasture phase and during the cereal year. Thus in Phase 1 we have samples of the population at the end of the first growing season in June 1985, when sheep were removed from the plots in September 1985, during the cereal year in March 1986, at seed set of the regenerating pasture in June 1987, and at the conclusion of grazing in September 1987. Sheep grazed the pasture during winter, spring, and summer each year and so influenced the population of the mixture at the vegetative, reproductive, and dormant stages of its life cycle. As can be seen in Fig. 1 1 (Chapter 1), grazing of seeds during

summer significantly depleted the seed bank and was therefore a powerful selection agent. Sheep were removed when the seed population fell to approximately 200 kg/ha.

During the cereal year the population was sampled to 10 cm depth in 300 cores of 10 cm diameter. In the regenerating phase seed was obtained from the surface and so represents seed production in that year only. In Fig. 1.1 however the residual seed (seed present in the cereal year) has been added to the new seed to indicate the tottal size of the seed bank.

After sampling, the medic pods were separated from other residues and soil, and then separated into species. The pods were threshed, and a sub-sample of the seeds, the size of which was proportional to the number of ecotypes of the species in the original mixture, were individually scarified. The scarified seeds were sown into 'Jiffy pots' in a greenhouse, and at the second trifoliate leaf stage, the seedlings hardened in the open air before transplanting into a field at Tel Hadya. As in Expt 3.1 there was 1.5 m between rows of plants, and 50 cm within rows.

The ecotypes were identified by comparison with nursery rows of the original populations. We found comparison of pods to be most useful in the identifications, although leaf markers, growth habit, and flowering time were also useful. In 1987/88, 14 attributes of the 84 ecotypes were measured in the nursery rows, and the success of the ecotypes in the mixtures related to the nursery row evaluation. The attributes measured were: flowering time, petiole length, peduncle length, internode length, leaf area, the node at which flowering began, the number of flowers/node, the percentage of flowers surviving to set pods, pod mass, seed mass, seeds/pod, hardseededness in October, pod mass/plant, and pod number/plant.

Success itself was measured as the change in proportion, in terms of seed numbers, from the original seed mixture to the seed population at times 1 to 5. Success (S) is expressed as:

$$S = \log \frac{(P\ (t_1))}{(Pt_0)}$$

where $P(t_0)$ is the proportion of an ecotype in the mixture in the original population (Table 3.2), $P(t_1)$ is the proportion of an ecotype in the population at the first sampling, and so on.

The expression is logged to give it a normal distribution.

Fig. 3.4 shows the frequency distribution of 'S' at time 5 (September 1987) in Phase 1 of the rotation. Only a small proportion of the ecotypes (18 out of 84) showed a positive value of S; that is had increased as a proportion of the population. M. rigidula was easily the most successful species, 11 of the 19 ecotypes having positive S values. The other successful species were M. rotata (four ecotypes out of 11) and M. noeana (three ecotypes out of four).

However there was a striking difference between years. Throughout Phase 2 M. rotata has been more successful than it was in Phase 1 and indeed more successful than M. rigidula (Table 3.3). The difference between years appears to be associated with initial establishment: for Phase 1 there were good following rains after the first seasonal rains and so emerged seedlings survived. For Phase 2 the new sowings experienced several light showers which were followed by periods of drought. Seeds of M. rigidula germinated after the early rains and the seedlings died during the subsequent drought whereas the seeds of M. rotata resisted the early rains and germinated after the later, heavier

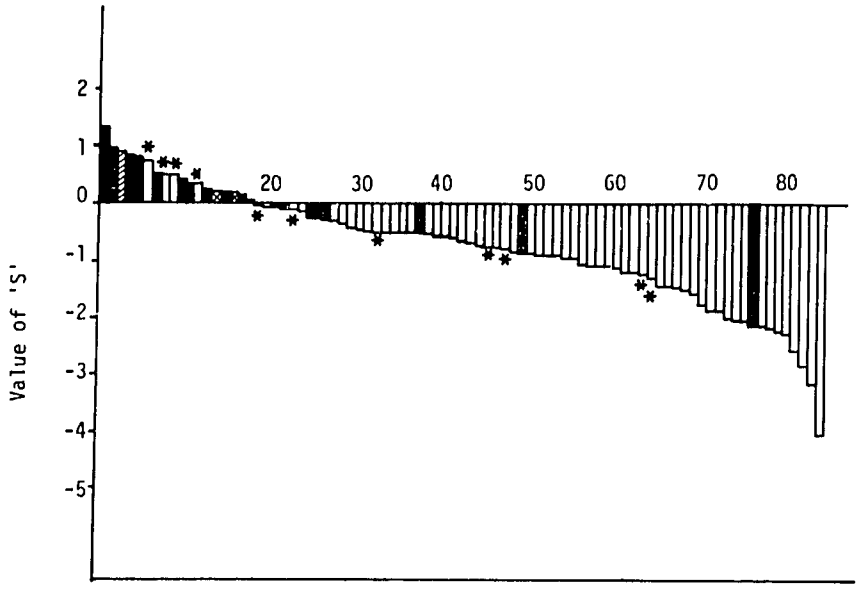


Fig.3.4. The frequency distribution of 'S', the success index (see text) of 84 medic ecotypes sown in a mixture in 1984/85 and collected from the mixture in September 1987, the mixture being subject to the pasture and cereal phases of the ley farming system. Solid shading of the histograms represent ecotypes of M. rigidula, those with a star above or below them represent M. rotata, and hatched shading represents M. noeana.

rains. As is seen in Chapter 2 this pattern of germination in M. rotata appears typical of the species, both in new sowings (as here) and in regenerations. It is a valuable attribute.

Principal component analysis of the S values at each time and for each ecotype reveal some interesting patterns. Table 3.4 shows the first three normalized component coefficients for the five S values. Component 1 appears to be positively associated with S at each sampling, but components 2 and 3 reveal that many of the ecotypes are more successful in some phases of the rotation than in others. For example ecotypes with high values of component 2 perform poorly in the year of sowing but well

Table 3.3. Identity of the top ten medic ecotypes (in order of success) in Phase 1 and Phase 2 of a cereal/pasture rotation[1].

Phase 1	Phase 2
M. rigidula sel. 1304	M. rotata acc. 2475
M. rigidula sel. 716	M. rotata sel. 2123
M. noeana acc. 2351	M. rotata acc. 2688
M. rigidula acc. 2844	M. rotata acc. 2532
M. rigidula sel. 2038	M. rotata sel. 2116
M. rotata acc. 2532	M. rotata sel. 2119
M. rigidula acc. 2860	M. rotata sel. 2118
M. rigidula sel. 1865	M. rotata acc. 2752
M. rotata acc. 2752	M. rigidula sel. 1304
M. rigidula sel. 1295	M. rigidula sel. 1865

(1) The phase 2 list is the result of sampling in the cereal phase, while the phase 1 list comes at the end of grazing the regenerating pasture (both in 1987).

Table 3.4. Normalized component coefficients calculated from principal component analysis of the success indices (S) of the 84 ecotypes at five times in Phase 1 of the cereal/pasture rotation.

	Component 1	Component 2	Component 3
S(t1)	0.251	-0.443	0.349
S(t2)	0.212	-0.699	0.042
S(t3)	0.233	0.194	-1.336
S(t4)	0.256	0.414	0.455
S(t5)	0.253	0.428	0.459

during the cropping phase (resist germination) and in the regenerating pasture phase. Other species perform well in both pasture phases, but poorly during the cereal phase: these have high values of component 3. M. rigidula is an example of the former - performing better in regenerating years, and M. aculeata and M. scutellata examples of the latter - soft-seeded species the seeds of which die in the cereal phase.

In Fig. 3.5 the distribution of five species - M. rigidula, M. rotata, M. noeana, M. aculeata and M. polymorpha are shown in relation to components 1 and 2. The most successful ecotypes are plotted in the upper right part of the Fig., and the least successful in the lower left. Note that the Australian cultivars are among the least successful: M. rugosa cv. Paragosa, M. scutellata cv. Robinson and M. truncatula cvs Jemalong and Cyprus all occuring at the extreme left.

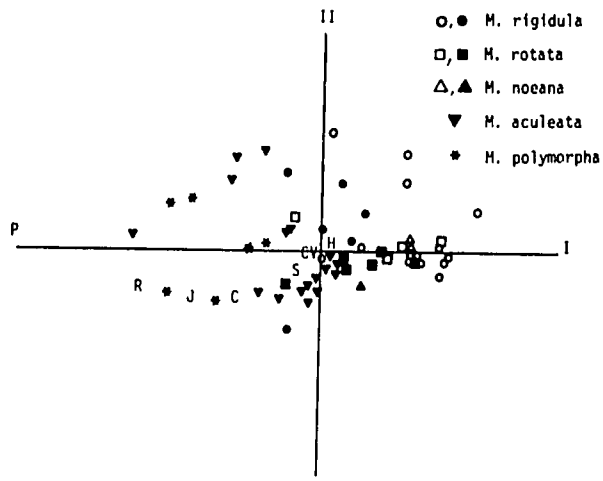


Fig.3.5. The distribution of five medic species in relation to the first two components of a principal component analysis of 'S' values of all 84 ecotypes in Expt 3.2 from all five harvests. The open circles, squares, etc, represent ecotypes with positive 'S' values. The letters P (cv. Paragosa), R (cv. Robinson), J (cv. Jemalong), C (cv. Cyprus), S (cv. Serena), and CV (cv. Circle Valley) represent the positions of some of the Australian medic cultivars.

The correlation matrix of S values and nursery row attributes are shown in Table 3.5. Success appears to be positively correlated with high values of hardseededness, long peduncles, late flowering and short petioles. The value of hardseededness is clear enough: soft-seeded species will disappear during the

Table 3.5. Correlation coefficient (r) between success (S) of each ecotype in the mixture at five times [1] in a cereal pasture rotation and 14 attributes of the ecotypes measured in nursery rows (n=84).

	S (t1)	S (t2)	S (t3)	S (t4)	S (t5)
Days to flowering	0.335	0.296	0.523	0.441	0.390
Internode length	0.148	0.087	0.233	0.228	0.141
Petiole length	-0.239	-0.105	-0.215	-0.214	-0.342
Peduncle length	0.384	0.160	0.416	0.509	0.420
Leaf area	0.039	0.067	-0.015	-0.050	-0.115
Node number of first flower	0.374	0.303	0.488	0.439	0.392
Pod retention[2]	-0.119	-0.100	-0.151	-0.153	-0.192
Pod mass	-0.070	-0.178	-0.268	-0.184	-0.169
Seeds/pod	-0.055	0.024	0.138	0.113	0.160
Seed mass	-0.126	-0.269	-0.455	-0.263	-0.252
Pod mass/plant	0.055	-0.012	0.054	0.080	0.021
Pod number/plant	0.098	0.109	0.191	0.141	0.090
Hard seeds[3]	0.278	0.316	0.398	0.457	0.426
Flowers/node	0.034	0.040	0.114	0.074	0.056

(1) At pod maturity in year 1 (t1), after grazing finished in year 1 (t2), during the cereal phase in year 2 (t3), at pod maturity in year 3 (t4), and at the end of grazing in year 3 (t5) - see text.

(2) The percentage of the total number of flowers produced which survived to four mature pods.

(3) The percentage of hardseeds in October in the year of seed set.

cereal phase. The value of short petioles may be associated with ability to escape grazing in the vegetative phase. The value of late flowering is possibly associated with ability to recover from grazing, the value of long peduncles being associated with late flowering.

Step-wise multiple regression gives a similar though slightly different picture (Table 3.6). Petiole length (negative) and peduncle length, (positive) enter the regression followed by seed mass (negative), internode length (negative), pod mass/plant (positive), pod retention (negative), and hardseededness (positive). It is too soon to discuss the meanings of these relationships, but it is clear that many of the nursery row attributes may prove of value during early selection.

A new experiment was established this year at Breda with the objectives (1) of measuring the productivity of medic pasture at Breda and (2) selecting successful medic ecotypes within a mixture of medics at this lower rainfall (280 mm) site.

Table 3.6. Summary of the step-wise multiple regression relating success of medics (see text) in a cereal/pasture rotation with attributes measured in nursery rows. Success was assessed at the end of grazing of regenerated pasture.

	Step	Multiple r^2	F to enter	Slope	Sig. of slope
Petiole length	1	0.44	64.6	-1.05	0.0002
Peduncle length	2	0.53	16.6	1.13	0.0009
Seed mass	3	0.59	11.2	-0.34	0.055
Internode length	4	0.60	2.9	-0.73	0.057
Pod mass/plant	5	0.62	2.7	0.34	0.108
Pod retention	6	0.63	2.8	-0.63	0.018
Hardseededness	7	0.65	4.1	0.65	0.043

The first year, a year of good rainfall (400 mm), resulted in good pasture establishment of Phase 1 of the 2-Phase entry experiment. Medic seed yield was nearly 1 t/ha, which exceeds that of either Phase in Expt 3.2. Even after grazing, the seed bank contained nearly 600 kg/ha.

Species in the mixture are M. aculeata (1 ecotype), M. noeana (1 ecotype), M. polymorpha (3 ecotypes), M. rigidula (5 ecotypes), M. rotata (1 ecotype), M. scutellata (1 ecotype) and M. truncatula (1 ecotype). In contrast to Tel Hadya the most successful species at Breda so far is M. polymorpha. However it is far too early to draw conclusions about the suitability of M. polymorpha at Breda where moisture stress in regenerating years is more likely to be a constraint than at Tel Hadya.

The new experiment is a co-operative experiment with the Farm Resource Management Program. - **P.S. Cocks (and Dr M.J. Jones, at Breda)**

Expt 3.3: Extending the ICARDA selection methodology to other countries in the Mediterranean basin (Preschedule M28)

It is difficult for national programs to establish large grazing experiments in which natural selection in mixtures can be conducted. While we hope that research in ley farming will increasingly incorporate livestock we realize that in the short term that may not be possible. Nor is it realistic for national programs to screen large numbers of ecotypes as we have done in Expt 3.2. On the other hand growth of medics for a single season, even if seed yields are measured, is of little value in assessing the merits of medic ecotypes.

Our initial approach was to distribute 'nurseries' to national programs in which they subjected the ecotypes to a

pasture/cereal rotation, the main selection criteria being numbers of seedlings at the beginning of the regenerating pasture year. Results from the nurseries sown in Syria are presented in Chapter 2 (Tables 2.5, 2.6, 2.7, and 2.8), where the experiment is also being used to study the breakdown of hard seeds. - **P.S. Cocks, Mr B. Mawlawi (Syria), Dr A. Turk (Jordan), Dr G. Gintzburger (France and Algeria), Mr M. Bounjemate (Morocco), Mr. M. Missoum (Algeria), and others.**

Expt 3.4: Screening annual medics for resistance to nematodes

There are two root-infecting nematodes which may cause problems in medics. Neither are widespread in the dry areas at present, where medics are likely to be used, but we are not sure whether this is because the nematodes will not grow in dry areas or to the absence of legume hosts. If the latter is true, and because their effect can be severe, we decided to screen the more promising of our annual medics to find resistant genotypes. We believe that the root-attacking nematodes are likely to the first of the 'second generation' of problems affecting the ley farming system.

The two nematodes are the root knot nematode (Meloidogyne artiella Frankline) and cyst nematode (Heterodera ciceri Volvas, Greco et Divito), the latter being newly classified in the H. trifoli group.

In 1986/87 100 ecotypes of 11 species were screened in a heavily infested field. This screening indicated that cyst nematode is rarely a problem in medics. In 1987/88 the regenerating plots were monitored with special attention being paid to 37 genotypes which had previously been scored as resistant or tolerant to root knot nematode. The greenhouse was

used to screen the same ecotypes under more carefully controlled conditions.

The infestation level of the field is shown in Table 3.7. The high numbers are due to continually growing susceptible legumes for four years: in this way the nematode population is maintained at high levels to assist the screening program.

Results from the field revealed that four ecotypes of M. rigidula (sels 1856, 977, 1535, and 1970), two ecotypes of M. rotata (sels 1955 and 1953) and two ecotypes of M. aculeata (sels 908 and 2008) were moderately resistant to root knot nematode. This is in broad agreement with the result from 1986/87.

Table 3.7. Mean number of cyst nematodes (cysts/100g soil) and root-knot nematodes (larvae/g soil) present in the experimental field at eight sampling dates.

Sampling date	Cyst nematode+	Larva, root knot nematode++
20.10.1987	53	1.35
30.11.1987	30	1.46
22.12.1987	26	2.25
31.01.1988	29	3.06
3.03.1988	36	2.02
1.04.1988	27	4.59
26.04.1988	33	4.82
Mean	33	2.79

+ One cyst contains approximately 700 eggs.

++ Second stage juveniles.

Under heavy artificial infection (20 larvae/g soil), no medic ecotype was found completely free of root knot nematode although M. rigidula sels 1870, 1535, and 1856 had few galls and could be classified as resistant or moderately resistant. Of the advanced selections M. rotata sel. 1953, and M. noeana sels 2124 and SA 15485 were also moderately resistant.

The average number of galls/g of root in the greenhouse experiment was 796, varying from 240 on M. aculeata sel. 918 to 1620 in M. rotata sel. 1946, while in the field the average was 623, varying from 161 in M. noeana sel. SA 15485 to 1637 in M. rigidula sel. 1533.

The ecotypes were also tested using different infection rates - 20, 40, 60, 80, 100, 120 second stage juveniles/g soil. The results indicate that M. rigidula sels 1856, 1553, 1870, M. rotata sel. 1933 and M. noeana sel. 2124 were moderately resistant up to a level of 80 larvae/g soil (Fig. 3.6). These results confirm those obtained in the field and under the standard artificial conditions of 20 juveniles/g soil. M. rigidula sels 1856 and 1953 were moderately resistant up to levels as high as 100 juveniles/g soil.

Several of our most promising ecotypes - M. rigidula sels 716 and 1919, M. rotata sel. 1943 and M. polymorpha variety Tah are susceptible to root knot nematode.

Our results show that annual medics vary widely in their response to root knot nematode. Resistant and tolerant ecotypes have been identified and will be used to produce resistant cultivars. In 1987/88 our first crosses were made to introduce resistance into the ecotypes which we know are well adapted to ley farming. Even though there have been no reports of root knot nematode attack on any of our farmers' fields we feel confident

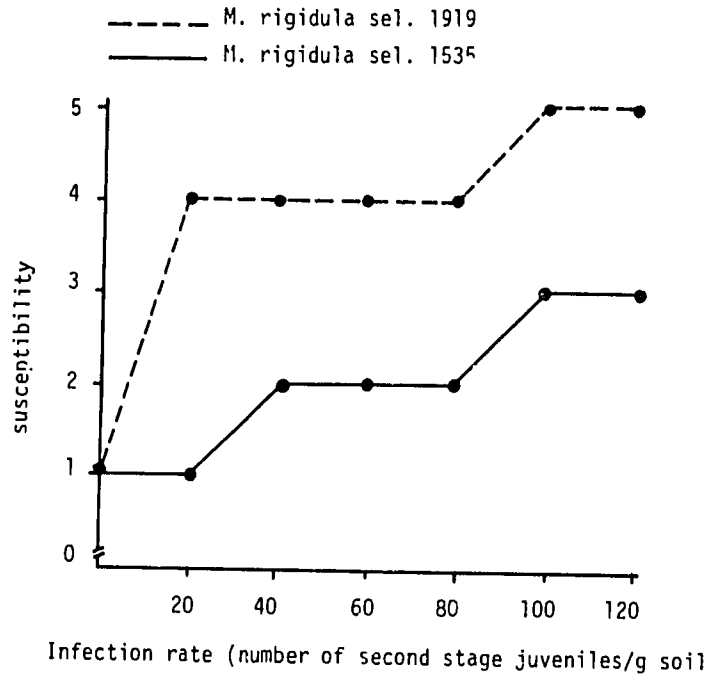


Fig.3.6. Reaction of two ecotypes of M. rigidula to infection at seven levels of root knot nematodes (Meloidogyne artiella). Susceptibility to the nematode increases from score 1 to score 5.

that, if and when should they become a problem, we will be prepared with resistant cultivars. - **Ali Abd El Moneim, Gawdal Feddoul, Damascus University Yassin Swedan, of Forage Section ARC, Douma**

Subterranean vetch - a new pasture species which buries its seed

We have already discussed the importance of the seed bank in pasture-based farming systems (see Chapters 1 and 2). One method by which plants protect their seeds from overgrazing is the production of small seeds which are not digested by grazing animals. Another is their ability to bury seeds.

The best known example of seed burial in pasture plants is subterranean clover (T. subterraneum). This species is geocarpic, which means that after pollination the peduncles reflex towards the ground and exert pressure on the soil surface, the seeds becoming buried to a depth of about 1 cm. Geocarpism works best in the sandy soils to which subterranean clover is well adapted. In addition to protecting the seed from grazing geocarpism places them at a depth which is ideal for germination and emergence. Among the medics M. aculeata is geocarpic - the peduncle reflexes after pollination - but it does not appear able to exert sufficient pressure on the soil for the pods to be buried. Factorovskya aschersoniana, a species which has been tentatively renamed Medicago hypogaea (Small and Brooks 1984), is another Mediterranean annual which is geocarpic.

Another mechanism by which a species buries its seed is amphicarpism. Amphicarpic species produce two kinds of flowers - aerial and subterranean. In these species the subterranean flower is initiated under the ground and remains under the ground for its whole life. The seeds of such species would seem to be even better protected against grazing than those of geocarpic species.

One of the vetches - Vicia sativa subsp. amphicarpa (subterranean vetch) - is amphicarpic. We normally consider the vetches to be forage or grain legumes (Chapter 6) but an amphicarpic vetch would clearly be useful as a pasture legume. Its usefulness in ley farming will depend on its hardseededness but even if it proves to be too soft-seeded for ley farming it could be a valuable species for improving permanent grasslands (see Chapter 8).

Subterranean vetch is a native of the Mediterranean basin (Rumbaugh 1979). It grows wild in hills and mountains and

generally prefers stony soils and good aeration. We have also found it in fallows in north Syria and in grassland at Tel Hadya. It would seem therefore to be not only of theoretical interest but also of practical value.

In 1987/88 we conducted two preliminary experiments: to observe aspects of the phenology of the species, and the effect of clipping on herbage and seed production. We used local seeds and also seeds collected from the Anatolian plateau of Turkey.

Expt 3.5: Growth and development of subterranean vetch

In the green house, scarified seeds, obtained from subterranean pods and sown in Jiffy-pots, germinated in 2-4 weeks, and unscarified seeds in 7-10 weeks. In contrast 90% of unscarified seeds from aerial pods germinated in 1-2 weeks indicating a low level of hardseededness. These observations suggest that dormancy of subterranean seeds is greater than that of aerial seeds, that hardseededness is probably the mechanism involved, but that seeds are much softer than seed of the annual medics. This will be examined in more detail in 1988/89.

The growth rate of subterranean vetch appeared lower than of common vetch. The populations appeared variable but this depended partly on the time of germination: earlier germination resulting in more rapid growth.

The subterranean stolons start to grow at the same time as secondary stems. They develop from cotyledonary buds and buds situated at the basal nodes just above the root-collar. The stolons are clorotic, rather delicate, rarely branched and bear reduced scale-like leaves. They consist of a few long internodes, the one near the apex recurving to protect the apical bud as it penetrates the soil. We observed that in compact soil,

short stolons developed whereas in loose soil the stolons were longer and more numerous. When stolons were exposed to day-light they became green, the leaves enlarged, and they behaved in all ways like aerial stems.

Flowering time ranged from 15 March to 1 May. Flowering of both aerial and subterranean flowers occurred simultaneously, though subterranean flowers continued to be produced after all aerial pods had matured. The flowers and pods are distinctly dimorphic, the aerial flowers being typical of common vetch and the subterranean flowers, developing in the axils of the tiny leaves, producing pods with fewer (1-2) seeds. The natural fertility of the subterranean flowers is usually high: 91% compared with 81% in aerial flowers. Since this cannot be attributed to differences in genotype it is likely that the subterranean flowers are less exposed to environmental factors affecting gametogenesis and fertilization.

Fruit setting of subterranean and aerial flowers is simultaneous but maturation takes longer under the ground, possibly due to the larger seed size. Morphological differences between aerial and subterranean seeds and pods are summarized in Table 3.8.

Although we had expected that they would be closely correlated the correlation between aerial and subterranean flowers was, in fact not significant. The ratio of subterranean/aerial pods varied from 0.5 to 10.0 (Fig. 3.7), the variation depending mainly on genetic variability. Probably diseases affecting either above or below ground parts will also contribute significantly to the aerial/subterranean pod ratio. -
Ali Abd El Moneim

Table 3.8. Comparative morphology of aerial and subterrranean pods and seeds (sample of 25 plants).

	Aerial	Subterranean
Pods		
Size	3-4 x 0.5-7cm	1.5 x 0.6cm
Shape	Linear-compressed to sub-cylindrical	Oblong
Colour	Green or black, some times brownish	Whitish
Seeds		
Number per pod	4-9	1-2
Diameter	2-5 mm	5-7 m
Weight (100 seeds)	1.5-2.5g	3.1-5.5g
Hardseededness	10-25%	60-80 %

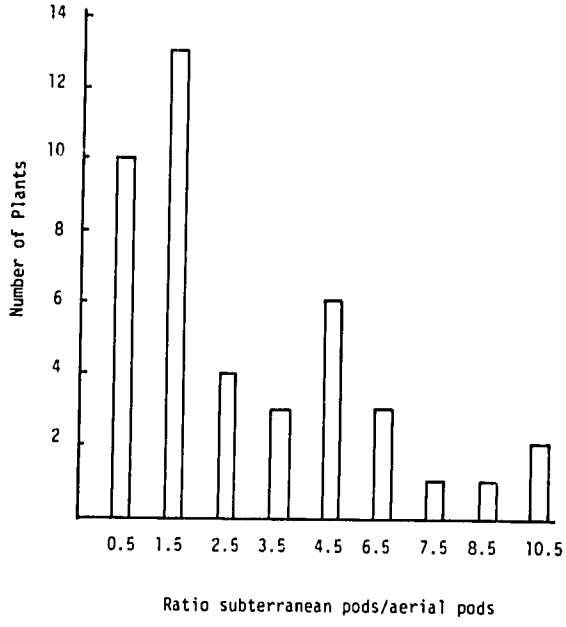


Fig.3.7. Frequency distribution of the subterranean to aerial pod ratio in 43 plants of subterranean vetch.

Expt. 3.6: The effect of clipping on herbage and seed yield of subterranean vetch

The objective of Expt 3.6 was to make preliminary observations on how subterranean vetch might respond to grazing.

Two experiments were conducted. In the first, four genotypes (Table 3.9) of subterranean vetch were planted in split-plots the main-plot being the four genotypes, and the sub-plots being clipping treatments (early March, early April and no clipping). Plot size was 3 rows of 3m, there being 45 cm between rows and 30 plants/row. The plants were clipped at 5cm above the soil surface at each clipping. Herbage was dried at 70°C for 24 hours to determine herbage yield, and aerial and subterranean seed yields were assessed.

Table 3.9(a). Effect of clipping time on herbage production (g/plant) in four genotypes of subterranean vetch.

		Clipping Time		
	Origin	Early March	Early April	No clipping
sel. 2614	Turkey	3.7	13.0	10.2
sel. 2660	Turkey	5.7	25.0	12.6
sel. 2647	Syria	3.2	15.3	10.5
sel. 2650	Syria	3.9	23.2	14.6
Mean		4.1	19.2	12.0

L.S.D ($P<0.05$) (treatments) = 4.5

L.S.D ($P<0.05$) (entries) = 9.9

Table 3.9(b). Effect of clipping time on seed production (g/plant) of aerial (A) and subterrenean (S) seeds in four genotypes of subterranean vetch.

	Clipping Time					
	Early March		Early April		No clipping	
	A	S	A	S	A	S
sel. 2614	0.00	0.12	0.00	0.34	0.31	0.16
sel. 2660	0.02	0.22	0.00	0.53	1.00	0.26
sel. 2647	0.06	0.23	0.00	0.42	0.15	0.29
sel. 2650	0.01	0.29	0.00	0.68	2.07	0.87
Mean	0.02	0.22	0.00	0.49	0.89	0.39

L.S.D ($P<0.05$) (treatments - aerial) = 0.20
L.S.D ($P<0.05$) (entries - aerial) = 0.47
L.S.D ($P<0.05$) (treatments - subterranean) = 0.12
L.S.D ($P<0.05$) (entries - subterranean) = 0.26

In the second experiment, the same genotypes were used, with the same basic experimental design, but with different treatments in the sub-plots: at 50% flowering the plots were clipped at 5, 7.5, and 15 cm above the soil compared with no clipping. Herbage yield and aerial and subterranean seed yields were assessed.

The plants clipped in early March produced less herbage than those clipped in April (Table 3.9a), the plants which were not clipped producing an intermediate amount. The plants clipped in early March produced few seeds (Table 3.9b), either aerial or subterranean, while those clipped in April produced less seeds than those not clipped. Late clipping prevented aerial seed production (the flowers were removed) and the plants were able to partly respond by increasing the yield of subterranean seeds.

Severe cutting (5cm) prevented the production of aerial pods and severely restricted the production of subterranean pods. Moderate clipping (7 cm) resulted in few aerial pods while light clipping (15 cm) resulted in less aerial pods but as many subterranean pods as no clipping.

The results sufficient promise for the research to be continued. The production of subterranean flowers continues even under severe clipping, and it is likely that considerable variation within the species will exist for this attribute. Hardseededness may be insufficient but screening of an enlarged germplasm pool is likely to produce more desirable genotypes.

Subterranean vetch is only one of a huge pool of Mediterranean species which may ultimately be used as pasture plants. Another is Trifolium balansae (balansa clover) which, in 1988/89, will be tested on farmers' fields in Morocco. - **Ali Abd El Moneim and Elyas Fayad (Tchreen University).**

CHAPTER 4: NITROGEN FIXATION - SELECTION OF RHIZOBIA, INOCULATION OF SEED, AND AMOUNT OF NITROGEN FIXED BY PASTURE LEGUMES

One of the attractions of the ley farming system is its independence of nitrogen fertilizer. When associated with the concept of self-regeneration, the ability of pasture legumes to fix nitrogen and to transfer it to cereals makes ley farming a truly low input system. It also makes it simple for farmers to operate, while significantly increasing its biological complexity.

In line with our ecological approach we prefer to use legumes which do not need to be inoculated. Thus at our Tel Hadya farm M. rigidula grows well without inoculation while most other medics do not: M. rigidula is therefore the preferred species. In contrast, at our on-farm site at Tah, M. polymorpha does not need to be inoculated and is therefore our preferred choice. Because of these interactions we are conducting research (not reported in the 1987/88 Report) which attempts to understand the relationship between environment and the need to inoculate. But, whatever the results of this research, we know that there are many environments where it is inevitable that, to initiate the ley farming system, inoculation of the seed with an effective and adapted strain of rhizobia will be necessary.

It is somewhat surprising that there should be soils with inadequate populations of Rhizobium meliloti, the bacteria which nodulate Medicago, Melilotis, Trigonella, and Factorovskya, since the Mediterranean basin appears to be the centre of origin of all four genera (Lesins and Lesins 1979). The reason appears to be the long period of cultivation, extending in some cases for several thousand years, during which the annual legumes have been viewed by farmers as weeds which should be destroyed. Indeed,

when this long period is taken into account, the frequent survival of rhizobia rather than its absence, is remarkable. This ability to survive for long periods underscores the point that inoculation of medics is likely to be necessary only when the ley farming system is first established: thereafter the rhizobia should survive in the soil.

In re-introducing rhizobia (where it is necessary to do so) one of the main problems is mortality of rhizobia on the seed coat immediately after inoculation. Simple inoculation with peat-based inoculants often fails even though the rhizobia strain is known to be effective. This is especially so when seed is sown dry - which farmers are forced to do when the opening rains are late - but occurs also, with disturbing frequency, in more favourable circumstances. There needs to be a 'fail-safe' method of inoculation which does not require a high level of skill by farmer-inoculators. Research to this end is reported in Experiments 4.1 and 4.2. Experiment 4.3 describes our selection of adapted strains leading, in Expts 4.4 and 4.5 to a consideration of indigenous rhizobia and the status of our rhizobia collection. The persistence of introduced rhizobia is examined in Experiment 4.6 and the Chapter ends with an estimate of nitrogen fixation by medic pasture, and a brief look into the future of our research into nitrogen fixation.

Exp 4.1. Testing adhesives and coatings to improve the efficacy of inoculation (Preschedules M21 and M22)

The objectives of Expt 4.1 were to (1) determine whether coating the seeds after inoculation extends the life of rhizobia, (2) evaluate different adhesive agents used to glue the inoculant to the seed, and (3) measure the effect of coating and adhesive treatments on plant growth.

The experiments were conducted at four sites: Tel Hadya, Breda, Senjar (all in north Syria) and Ramtha (in Jordan). Choice of medic species and rhizobia strain were based on previous experience and were as follows:

- at Breda (mean rainfall 280 mm) Tel Hadya (340 mm), Senjar (220 mm), and Ramtha (250 mm) M. rigidula sel. 716 with strain ICARDA M28;

- at Breda and Senjar M. polymorpha cv. Circle Valley with strain ICARDA M38;

- at Tel Hadya M. polymorpha cv. Circle Valley with strain CC169;

- at Breda and Senjar M. truncatula cv. Jemalong with strain CC169;

- at Tel Hadya M. truncatula cv. Jemalong with ICARDA M28; and

- at all four sites M. rotata sel. 1943 with ICARDA M28.

To test adhesives a slurry was made of the peat inoculant and the following compounds: (1) gum arabic, (2) methyl (gum) cellulose, (3) beet molasses, (4) polyvinyl pyrrolidone (PVP-360 T), and (5) water. Non-inoculated controls (with and without 60 kg/ha of nitrogen) were added to the experiment which had three replicates. A uniform dressing of 18 kg/ha of P_2O_5 was applied and herbage was measured at the end of the growing season.

Of the four species only M. rigidula responded to inoculation: strongly at Senjar and Ramtha, and weakly at Breda (Table 4.1). At Tel Hadya, although M polymorpha responded to

Table 4.1. Response of M. rigidula to inoculation with rhizobia strain M28 using five different adhesives (t/ha of herbage).

	Tel Hadya	Breda	Senjar	Ramtha
Gum arabic	7.29	4.40	2.82	6.24
Methyl cellulose	7.35	4.65	2.90	7.16
Beet molasses	5.83	5.33	3.02	6.72
DVP-360T	7.54	5.32	4.21	6.10
Water	7.01	3.92	3.57	7.16
Uninoculated - N	8.02	3.86	0.57	0.76
Uninoculated + N(1)	8.08	5.13	1.16	2.49
LSD ($P<0.05$)	2.03	1.44	1.05	2.38

(1) received a dressing of 60 kg/ha of nitrogen.

nitrogen application, the plus nitrogen treatment and all inoculation treatments of the three other species had comparable yields indicating that the lack of response was because nodulation by indigenous rhizobia was effective. It was effective also at Breda but at Senjar yield of M. rigidula (3.30 t/ha) was significantly ($P<0.05$) above M. truncatula (1.20 t/ha), M. polymorpha (1.11 t/ha) and M. rotata (0.86 t/ha), and at Ramtha, where only two species were used, the yield of M. rigidula (6.68 t/ha) was significantly ($P<0.05$) above M. rotata (1.47 t/ha). These results indicate strongly that for M. polymorpha, M. truncatula and M. rotata the inoculation procedures failed. This conclusion is supported by responses to nitrogen: M. rotata responded to nitrogen at Ramtha, and at Senjar, for all species except M. rigidula, the nitrogen treatment gave the highest yield (NS).

The lack of response to adhesives at Tel Hadya and Breda may indicate simply that conditions at sowing time were so good that inoculation using water was effective so eliminating any chance of a further response to the other inoculation treatments. In previous seasons at these sites the use of organic adhesives had been significantly better than water. It is frustrating that a seasons work on the use of adhesives can be wasted simply because conditions were good.

At Senjar there appeared to be a response to the use of PVP, although since, compared with water, the difference was not significant, the response should be viewed with caution.

At the two sites where inoculation failed (Ramtha and Senjar) M. rotata did not nodulate with strain ICARDA M28 nor were the local indigenous populations able to produce nodules. In another experiment (see later) strains ICARDA M3 and M53 succeeded at Ramtha. These strains will be tested at Senjar in the coming season.

The second part of Experiment 4.1 was designed to evaluate the effect of coating the seeds after application of the inoculant. Molasses and, at Breda and Tel Hadya, gum arabic were used as adhesives. The four treatments consisted of dusting the freshly inoculated seed with (1) finely ground calcium carbonate, (2) rock phosphate, (3) activated organic charcoal, (4) a mixture (50/50) of calcium carbonate and charcoal and (5) uncoated. The four medic species were used, except at Ramtha where there were only M. rigidula and M. rotata.

As with the adhesives there was no effect of coating at Tel Hadya. At Breda all coated treatments produced higher yields (mean 4.35 t/ha) than the uncoated (2.99 t/ha), an increase of 46% (Table 4.2). However, since the uninoculated control also

Table 4.2. The response of M. rigidula to inoculation using four seed coatings and two adhesives at Breda.

Treatment	Molasses	Gum arabic
Coating agents		
Rock phosphate	3.77	3.85
Calcium carbonate	4.63	3.82
Activated charcoal	4.68	3.53
Mixture	4.33	4.70
Uncoated	2.99	2.80
Uninoculated seed		
Without nitrogen	3.88	4.00
With nitrogen[1]	3.97	4.02
LSD ($P<0.05$) treatments	1.47	

[1] received a dressing of 60 kg/ha of nitrogen.

produced more than the uncoated treatment the results are difficult to interpret. No differences at the 5% level of singificance were detected for the other species nor was there an effect of adhesive.

At the drier Senjar site, inoculation of M. rigidula again produced a significant increase in herbage (see Table 4.1). Although the coating treatments were not significantly greater, yields were somewhat higher than the uncoated control. At the other dry site (Ramtha) there was, as in Table 4.1, a large and significant response to inoculation, but, again, no significant effect of seed coating.

The experiments on seed coatings and adhesive will be repeated because the abnormally wet year probably affected the results (by reducing moisture stress). - **L.A. Materon.**

Exp 4.2. Freeze-dried oil-based inoculants (Preschedule M48)

The objectives of Expt. 4.2 are (1) to measure the storage life of freeze-dried (lyophilized) medic rhizobia and (2) to monitor the survival of lyophilized rhizobia on the surface of seeds.

Freeze dried inoculants have the advantage over peat-based inoculants in that higher rates of rhizobia can be applied. This is especially important for small-seeded legumes, where the area of the seed surface is limited, and in soils where populations of ineffective rhizobia are likely to be high. Furthermore some researchers have recently reported that oil-based inoculants (oil is used as a base for suspending freeze-dried rhizobia) extend the survival of rhizobia in dry soils (Kremer and Peterson 1982).

Table 4.3 describes some of the results obtained by our collaborator at the Boyce Thompson Institute when ICARDA strain M28 was lyophilized. Strains M28 and M38 were chosen for the Boyce Thompson research because of their effectiveness with M.

Table 4.3. Numbers of lyophilized medic rhizobia (strain ICARDA M28) recovered from ampoules and from the surface of seeds after application in an oil-base. Figures are expressed as logarithmic numbers to the base 10.

Pre-lyophilization cells/ampoule	11.49
Post-lyophilization cells/ampoule	11.18
Cells in oil, cells/ml	11.25
Inoculation on seeds, cells/seed	
1. At zero time	6.08
2. After 7 days	3.38
3. After 14 days	3.10

truncatula, the most widely used medic, and one which shows promise in north Africa.

At ICARDA the research on lyophilization includes freeze-drying and studies on the recovery of lyophilized rhizobia from either storage vials or from the seed surface.

After growing the rhizobia in yeast mannitol broth different strains were freeze-dried at -60°C and kept in a vacuum for eight weeks. Using plate counts the contents of the vials were counted at weekly intervals and expressed as the logarithmic number of living rhizobia/vial (Table 4.4). Means remained high for all strains and fluctuated only from 10^5 to 10^9 cells. These figures are comparable to those obtained with excellent quality peat inoculants during the first weeks of storage. The experiment will continue with cell counts each month. The next step will be

Table 4.4. Survival of lyophilized rhizobia in glass vials stored at room temperature. Viable rhizobia are expressed as logarithmic base 10 numbers/vial.

	Strain of rhizobia						
Week	M3	M15	M28	M38	M53	M59	M234
0	9.36	9.43	9.86	9.83	9.88	9.72	9.48
0.5	9.50	9.60	9.57	9.88	9.82	9.76	9.67
1	7.83	8.88	8.00	9.51	9.16	8.70	8.00
2	7.20	8.18	8.75	8.72	8.53	8.44	7.52
4	8.00	7.11	8.05	8.30	8.50	7.30	8.29
6	7.08	7.17	7.24	6.95	8.20	9.27	6.18
8	6.30	5.52	6.82	6.56	6.90	7.23	5.85

to suspend the freeze dried bacteria in various locally available oils and investigate their survival on medic seeds in different environments.

Returning to the Boyce Thompson Institute no differences in rhizobia survival were observed when the inoculant was suspended in Syrian olive oil compared with paraffin oil, although a steady decline in numbers was observed after the fourth week in both oils (Table 4.5). These numbers are higher than would be expected in peat-base inoculants in similar circumstances.

Table 4.5. Viability of rhizobia from oil-based inoculants on medic seed as affected by time and type of suspending oil when stored at 26°C.

Week	Log_{10} number of rhizobia per seed	
	Olive oil	Paraffin oil
0	6.62	6.30
1	5.78	5.67
2	5.49	5.33
4	5.15	4.88

The oil-based inoculation technique using lyophilized rhizobia shows promise for small seeded legumes and appears to give greater flexibility in terms of storage life. However there are still technical problems to be resolved, its efficacy in west Asia and north Africa is largely unknown, and there is a need to study the survival of rhizobia on the surface of seeds in field conditions. - **L.A. Materon and A. Eaglesham (Boyce Thompson Institute, Ithaca)**

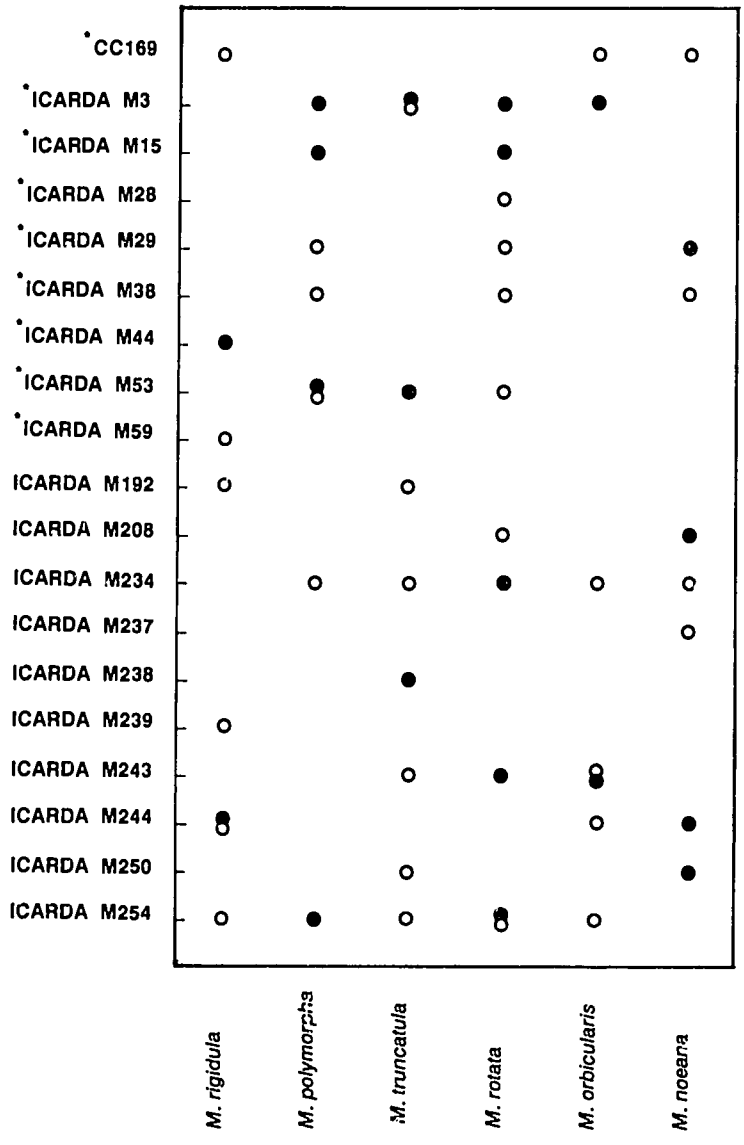
Exp 4.3. Selection of more effective strains of medic rhizobia (Preschedule M26)

The objective of this experiment was to find the most effective rhizobia strains for maximum expression of capacity to fix nitrogen.

The selection of strains is based on in vitro techniques with emphasis on nodule characteristics and plant appearance. The selected strains are tested in the field using six medic species (M. rigidula, M. rotata, M. noeana, M. polymorpha cv Circle Valley and M. truncatula cv. Jemalong) at two sites: Tel Hadya (500 mm rainfall in 1987/88) and Breda (408 mm). The experiment was a split plot design having rhizobia strains as main plots and medic species as sub plots. There were three replicates.

In 1987/88 30 strains of rhizobia were tested and compared with uninoculated controls with and without nitrogen in fields which, as far as was known, did not contain medics. Nine strains were evaluated for the second season: they appear with an asterisk in Fig. 4.1, which shows the response of the six medics to inoculation at both sites.

Fig. 4.1 is based on growth prior to flowering when, from past experience, the response to inoculation is greatest. A symbol is present when a significant response was obtained: lack of a symbol means that there was no significant response. For example the Figure shows that strain M3, being tested for a second season, was effective at Tel Hadya with M. polymorpha, M. rotata, M. truncatula and M. orbicularis, but not effective at Breda. On the other hand strains ICARDA M234 and ICARDA M254 worked well with most species at Breda but were less effective at Tel Hadya. Thus, although all three strains appeared to be effective with several species, they were specific about sites.



*Second year evaluation

Fig.4.1. Compatibility of 19 out of 30 strains of rhizobia with six medic species at Tel Hadya (closed cicles) and Breda (open circles). Presence of either closed or open circles indicates that the strain caused a significant increase in herbage yield over no inoculation: absence indicates no response. The remaining 11 strains were not effective with any medic.

Indeed, prior to flowering, there were no cases where a strain performed equally well at both sites, although, at maturity, ICARDA M15 successfully nodulated M. rotata, M. orbicularis and M. polymorpha at both sites (Table 4.6). Note that in Table 4.6 all species responded to ICARDA M254 at Breda but none did so at Tel Hadya.

Table 4.6. Magnitude of significant ($P<0.05$) responses to inoculation in herbage yield at the stage of pod maturity expressed as a ratio of the yields of plots sown with inoculated seed to those with uninoculated seed. Results are given for growth at Breda (BR) and Tel Hadya (TH) in 1987/88. Blank spots refer to non-significant responses. The table shows only the most responsive strains.

	Strain of rhizobia				
Medic host	ICARDA M15	ICARDA M53	ICARDA M234	ICARDA M253	ICARDA M254
M. rigidula		1.8BR	1.7TH	2.0BR	
M. rotata	2.6TH				1.9BR
	1.8BR				
M. noeana	1.7TH			1.5TH	1.9BR
M. orbicularis	1.7TH				1.5BR
	1.3BR				
M. truncatula	1.6TH	1.6TH	1.5BR	1.6BR	1.5BR
M. polymorpha	2.0TH				2.1BR
	2.0BR				

Fig. 4.2 illustrates the striking effect on M. rotata of several rhizobia strains at Ramtha in north Jordan. The best

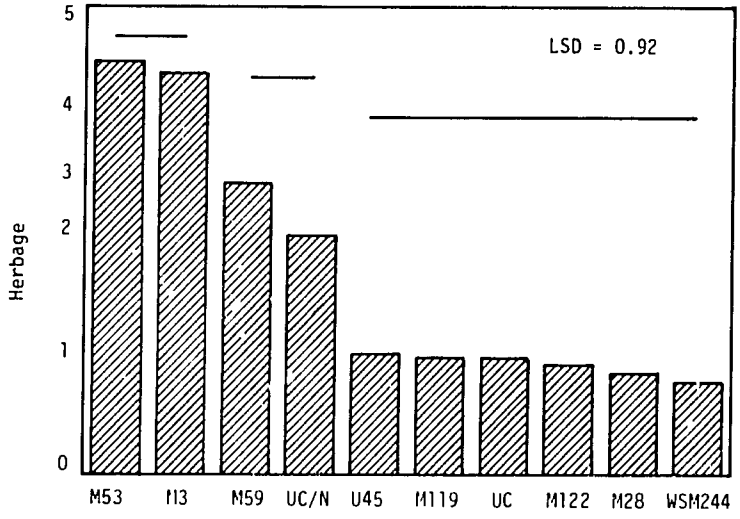


Fig.4.2. The effect of inoculating M. rotata sel. 2123 at Ramtha (Jordan) with ten strains of rhizobia. Histograms covered by the same horizontal line are not significantly different (P<0.05).

strains were ICARDA M53 and M3 which were superior to most other strains including ICARDA M28, a strain known to be successful with M. rotata in north Syria (see also Expt. 4.1). A further pool of strains from west Asia will be evaluated at Ramtha in the coming season.

Strain evaluation needs to continue until a group of elite strains are selected suitable for a wide range of environments for each commercially useful species. - **L.A. Materon**

Exp 4.4. Inoculation network experiments (Preschedule M47)

The interaction of rhizobia strain, medic species, and environment, referred to in Expt. 4.3, needs an international series of experiments to be resolved. Without such a series the recommendations emanating from Tel Hadya are likely to be

misleading when applied, for example, in Morocco. Such an international network will also increase awareness in national programs of possible inoculation problems.

In fact one of the recommendations of a workshop organized by ICARDA/UNDP on biological nitrogen fixation in April 1986 was that a series of need-to-inoculate experiments be undertaken with collaborators from the Mediterranean basin. The objectives of the network are to form closer links between national programs and to use the limited resources available to microbiologists in the most efficient manner. The network also enables ICARDA to evaluate its strains throughout west Asia and north Africa. Furthermore it will help spread information on how to conduct research on strain selection, host specificity, inoculant production, seed inoculation, and other related topics.

Table 4.7 lists the experiments conducted by members of the network in 1987/88. Most of the research was on annual medics and their rhizobia: experiments on Hedysarum coronarium and common vetch were in response to specific requests.

Highlights of the network's results were:

- strain ICARDA M29 performed well in symbiosis with M. rigidula in Morocco, Algeria, Turkey, Syria and France;

- large responses due to inoculation of M. rigidula were observed at Ramtha, Rabba and Mashakar in Jordan;

- M. noeana performed better than other medics in Turkey; and

- collaborators from Universities in Turkey, Syria and Morocco are involving graduate students in projects related to nitrogen fixation in annual medics.

Table 4.7. International network for inoculation of pasture and forage legumes in the Mediterranean area: activities during the 1987/88 season.

Legume type	Collaborative institution	Country	Number of sites*
Hedysarum	Range Management Project	Tunisia	1
Medic	Ministry of Agriculture	Jordan	2
Medic	University of Jordan	Jordan	1
Medic	Ministry of Agriculture	Jordan	1
Medic	University M. Ben Abdallah	Morocco	3
Medic	Ministry of Agriculture	Syria	1
Medic	University of Cukurova	Turkey	1
Medic	CSIRO	Australia	(1)
Medic	INRA-Montpellier	France	2
Medic	El Zaidin	Spain	1
Vetch	Ministry of Agriculture	Syria	1

* In brackets: glass house experiment, otherwise, field experiments.

The network is being extended to Iran, Iraq, Cyprus, Italy and Greece.

Exp 4.5. Symbiotic response of medics to indigenous rhizobia (Preschedule M18)

The objectives of Expt 4.4 were to collect rhizobia from soils where medics grow, obtain information on their compatibility with six species, and determine the environmental effect on the distribution of rhizobia.

It is important to define the distribution and properties of indigenous rhizobia and to establish whether or not, in any soil, inoculation is required. Soils from arable and non-arable sites in Syria (24 samples), Jordan (63), Turkey (19), Cyprus (10) and Lebanon (24) were collected and their rhizobia isolated and grown in liquid culture (yeast mannitol broth). Aliquots of 1 ml of a heavy suspension of rhizobia were used to inoculate seedlings of M. rigidula, M. noeana, M. orbicularis, M. rotata, M. polymorpha cv. Circle Valley and M. truncatula cv. Jemalong. The seedlings were grown aseptically in glass tubes containing a vermiculite-gravel mixture moistened with a nitrogen-free solution. Plants were allowed to grow for 5 to 6 weeks at which time symbiotic responses (plant appearance, plant mass, and nodule number, distribution, quality, color and vigour) were evaluated. These parameters were used to classify or rank the in vitro response of each medic to each of the isolates, and to select elite strains for further testing under field conditions (see Expt 4.2).

The results indicate that indigenous rhizobia vary significantly in their ability to nodulate the six medics. As seen in Fig. 4.3 most strains were ineffective to some degree, some even producing no nodules at all. M. rigidula was nodulated effectively by many of the strains from north Syria, but, with isolates from Jordan and south Syria, usually failed to form effective nodules. All of the medics had specific rhizobial requirements, a result which strongly supports the concept developed elsewhere (see Chapter 3) that, wherever possible indigenous populations of both plants and rhizobia should be used.

Clover rhizobia (Rhizobium trifolii) were collected in various parts of Lebanon, and the isolates used on seedlings of five clovers (Trifolium stellatum, T. hybridum, T. subterraneum,

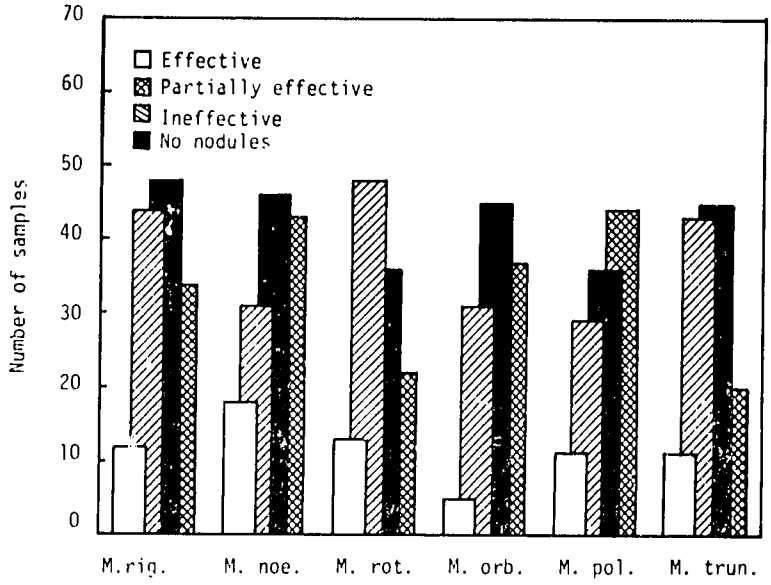


Fig.4.3. Frequency distributions of nodulation performance of 140 isolates of rhizobia with six annual medics grown in vitro. The species are (from left to right) M. rigidula, M. noeana, M. rotata, M. orbicularis, M. polymorpha, and M truncatula.

T. hirtum and T. repens). Fig. 4.4 shows that, as with medics, the clovers have specific requirements for rhizobia: only about a quarter of the isolates produced fully functional nodules on the five clovers. In the case of white clover (T. repens), only two isolates produced effective nodules and 15 out of 21 were found to be incompatible. - **L.A. Materon and collaborators**

Exp 4.6. Persistence of introduced rhizobia strains (Preschedule M23)

The objective of Expt 4.6 was to assess long-term survival of a rhizobia strain (WSM 244) which was used to inoculate three medics in 1985. The experiment consists of a split-plot design with M. rigidula sel. 716, M. truncatula cv. Jemalong and M. polymorpha cv. Circle Valley as main plots and three inoculation

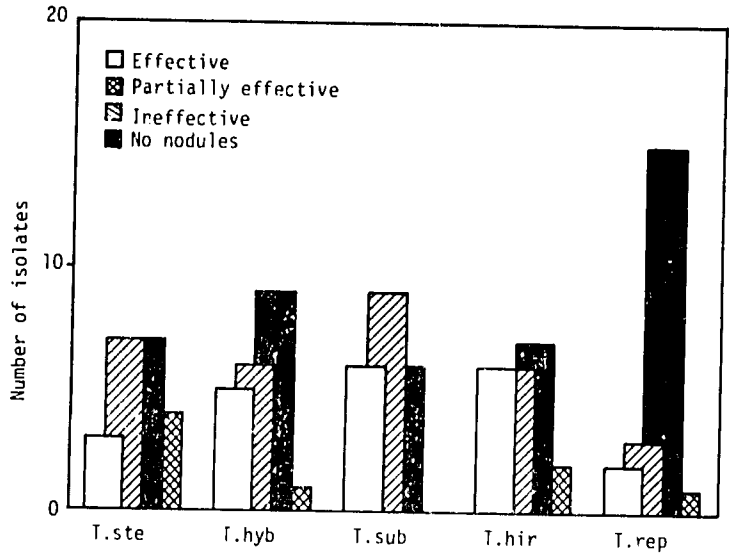


Fig.4.4. Frequency distribution of the nodulation response of five clovers from 21 isolates of R. trifolii (clover rhizobia) collected in the Beka'a valley of Lebanon. The clovers are (from left to right) T. stellatum, T. hybridum, T. subterraneum, T. hirtum, and T. repens.

rates (1x, 5x and 10x the recommended rate of peat inoculant) as subplots. The medics have been allowed to regenerate naturally each year since in 1985.

The experiment was made possible by inoculating the medics with mutant rhizobia resistant to antibiotics. By isolating the rhizobia in the years following inoculation and growing them on a medium containing antibiotics lethal to normal strains, it is possible to determine whether the mutant strain has persisted. The mutant strain in Expt 4.6 is resistant to high concentrations (150 micrograms/ml of streptomycin sulfate in yeast mannitol agar (YMA) medium) and has otherwise unaltered symbiotic characteristics. Samples of rhizobia from 100 nodules of each species were disinfected and the contents grown on medium containing the antibiotic. Table 4.8 shows the results: mutant WSM 244, a strain which originated in Iraq and was previously

Table 4.8. Nodules produced by an introduced strain of rhizobia (WSM 244) in self-regenerating medics during a third season in Tel Hadya (1987-1988).

Species	% nodules produced by: WSM 244	Native rhizobia	Mean number of nodules/ plant	Green herbage t/ha
M. rigidula	1	99	10.9	26.0
M. polymorpha	93	7	3.3	17.1
M. truncatula	97	3	4.8	8.1
LSD ($P<0.05$)			3.5	5.0

recommended for M. rigidula, failed to form nodules with that species. With M. polymorpha (on which it was originally found) and M. truncatula it produced nearly all of the nodules showing that it had established and survived in the Tel Hadya soil. This survival, though hardly surprising, is pleasing, in that it indicates that exotic strains can be introduced to new sites and maintain their integrity over several years: an important point if genetically engineered strains are ever to be introduced. - **L.A. Materon**

Expt 4.7. The status of our rhizobia collection (Preschedule M19)

The objectives of collecting rhizobia are to (1) establish a collection of rhizobia effective for pasture and forage legumes, (2) provide other scientists and institutions with rhizobia for experimental purposes and, (3) promote and encourage research on strain selection within west Asia and north Africa.

Most of the strains (comprising mainly medic, clover and vetch rhizobia) were isolated from soils supporting native pastures in Syria, Turkey, Jordan, Lebanon, and Cyprus, and from exchange with other institutions. In the case of medic rhizobia, M. rigidula, M. noeana, and M. rotata are used to "trap" the rhizobia from the soil samples. Seedlings are grown aseptically in a vermiculite-gravel mixture, containing a plant nutrient solution devoid of nitrogen. The soil sample is vigorously agitated in a reciprocating shaker for 20 minutes and a volume of 1 ml is used to inoculate the seedlings. Rhizobia are then isolated from the nodules.

At the moment there are 343 purified strains of R. meliloti in the collection, of which 42 are spontaneous antibiotic resistant mutants, 35 are strains of R. trifolii, and 48 are strains of R. leguminosarum. Next season the collection will be enlarged with material coming through cooperators from national institutions, IBPGR, MIRCENs, and ICARDA's Genetic Resource Program.

The cultures are maintained in a freeze-dried state to minimize genetic variation and prolong storage life. The lyophilized (freeze-dried) cultures are stored in small glass vials which are regularly tested for vacuum. Purified strains of rhizobia are available upon request and a catalogue is currently being prepared.

Our laboratory produces peat-based inoculants utilizing gamma irradiated peat imported from Australia. In 1987/88 we distributed a total of 367 inoculant bags to cooperators, mostly from countries in the Mediterranean basin (Table 4.9). Small amounts of peat-based inoculants are also prepared for interested scientists outside the ICARDA region. - **L.A. Materon**

Table 4.9. Peat-based inoculants for pasture and forage legumes distributed to cooperators and interested researchers during 1987/88 (in brackets pure cultures on YMA slants).

Type of legume	Number of bags or slants*	Country**
Clovers	(3)	Egypt
Clovers	2	Lebanon
Lathyrus	1 (4)	Cyprus
Medics	47	Algeria
Medics	(9)	Australia
Medics	(2)	Canada
Medics	3	Cyprus
Medics	2	Egypt
Medics	67	France
Medics	2	Greece
Medics	(6)	Iraq
Medics	8	Italy
Medics	139	Jordan
Medics	53	Morocco
Medics	3	Portugal
Medics	(3)	Spain
Medics	4	Tunisia
Medics	31	Turkey
Medics	(5)	U.K.
Medics	(13)	U.S.A.
Vetches	9	Cyprus
Vetches	5	Pakistan

* Each bag weighs 90 g and will inoculate approximately 3.5kg of small (medic-sized) seeds.

** Includes cooperative projects between ICARDA and Ministries of Agriculture.

Expt 4.8. Nitrogen fixation by two medics at three plant densities (Preschedule M23)

The objectives of Expt 4.8 were to (1) measure nitrogen fixation by M. rigidula and M. truncatula and (2) compare two methods of measuring nitrogen fixation: isotopic dilution (ID) of an enriched nitrogen fertilizer (the ^{15}N method) and plant nitrogen difference (ND).

Nitrogen fixation is one of the reasons (but by no means the only one) for growing pasture legumes. Although, in Australia, there have been many measurements of nitrogen fixation by pasture legumes (50 - 300 kg/ha/year), there are few in the Mediterranean basin. We need an indication of the amount of nitrogen fixed to provide the basis for studies into what happens to the nitrogen.

There are two methods of measuring absolute amounts of fixed nitrogen: the difference method, which is cheap and can therefore be used widely and frequently, and the isotopic dilution method which is expensive but better able to discriminate between fixed nitrogen (from the atmosphere) and nitrogen absorbed from the soil. Expt 4.8 was conducted in 1985/86, and a summary of the results appeared in the 1986 Program Report: now that mass spectrometric analyses of the ^{15}N samples is finalized, a report which incorporates the complete results, is presented.

The medics were sown at three densities: 5, 30 and 500 kg/ha. These densities represent the extreme range likely to be experienced in poor, average, and very dense pastures. The strains used were WSM 244 and CC 169: the former intended for M. rigidula and the latter for M. truncatula. Both strains were antibiotic resistant mutants which made them easy to identify (Expt 4.6). The experiment was a split-plot design with a 3 X 2 factorial in the subplots. Main plots represented inoculated and

non-inoculated treatments and were replicated 6 times. Subplots were occupied by the two species at three densities: within each subplot a nested area of $1m^2$ was treated with ^{15}N-labelled ammonium sulfate. Ryegrass (Lolium rigidum) was selected as a suitable non-nitrogen fixing species and sown at a rate of 100 kg/ha.

Ammonium sulfate labelled with 4.92 atom% ^{15}N excess was applied to the 1 m^2 areas within each subplot. For each area, 9.43g of the labelled ammonium sulfate was dissolved in 200 ml water (equivalent to 20 kg N/ha) and sprayed uniformly on the surface. Plots sown to ryegrass were similarly treated. No nitrogen was applied to the rest of the plot area.

Harvests of the untreated medic and grass were taken at regular intervals to determine seasonal growth patterns. Each sample was taken from 0.5 m^2 and oven-dried at 75°C for 48 hours. Subsamples were finely ground and analyzed for total N by the Kjeldahl method. At the advanced pod stage inner areas (0.8 X 0.8 m) of the ^{15}N-treated plots were harvested by hand clipping: these samples were also dried as described above and their nitrogen isotope ratios ($^{14}N/^{15}N$) determined in a mass spectrometer at the IAEA/FAO Agricultural Laboratory at Seiberdorf (Austria).

The percentage of plant nitrogen derived from the atmosphere (%Ndfa) was expressed by the equation:

$$\%Ndfa = \left(1 - \frac{\text{atom\% }^{15}\text{N excess in legume}}{\text{atom\% }^{15}\text{N excess in non-legume}}\right) 100$$

To calculate the total amount of nitrogen fixed from the atmosphere, this expression is inserted into the following equation:

$$\text{Nitrogen fixed (kg/ha)} = \frac{\%\text{Ndfa}}{100} \times \text{total nitrogen in legume}$$

and the result referred to as the isotope dilution method (ID). The plant nitrogen different method (ND) was assessed as follows:

Nitrogen fixed (kg/ha) = N yield of the legume - N yield of the grass

Before discussing the amount of nitrogen fixed we present Table 4.10 reproduced from the 1986 Report which shows that, although both WSM 244 and CC 169 were effective on M. truncatula they failed on M. rigidula. Nevertheless M. rigidula was well nodulated and healthy and, as will be seen below, fixed more nitrogen than M. truncatula (see also Table 4.8 which shows the survival of WSM 244 two years later).

Table 4.10. Proportion of nodules in two medics produced by two inoculants at Tel Hadya (1985/86)[1].

Species	Nodule due to	
	WSM 244	CC 169
M. rigidula	9	8
M. truncatula	92	100

[1] Rhizobia from non-inoculated plots were not able to grow on antibiotic-supplemented YMA medium.

More than 80% of the nitrogen in M. rigidula was derived from the atmosphere, regardless of plant density, and rather less than this amount (64%) in M. truncatula (Table 4.11). This suggests

Table 4.11. Measurement of nitrogen fixation of two medics (kg/ha), inoculated with two rhizobia strains and not inoculated, using the isotope dilution (ID) and plant difference (ND) methods. The medics were sown at three densities - 5, 30, and 500 kg/ha.

Strain	Density (kg/ha)	M. rigidula ID	M. rigidula ND	M. truncatula ID	M. truncatula ND
WSM 244	5	84.3	83.5	75.5	79.7
	30	72.2	70.5	29.7	28.0
	500	40.7	35.6	3.7	NM[1]
CC 169	5	98.9	102.9	57.1	62.1
	30	64.1	62.2	21.6	19.7
	500	33.9	27.9	1.0	NM
Not inoculated	5	88.1	91.0	18.7	20.8
	30	107.3	107.4	3.7	NM
	500	60.6	56.2	0.6	NM
CV		15.9	16.4	11.6	17.8
LSD ($P<0.05$)		37.1	40.4	12.8	16.8

[1] NM - not measurable

that the symbiosis of M. rigidula and native rhizobia makes M. rigidula superior to M. truncatula at Tel Hadya even though the latter was inoculated with effective rhizobia. In fact M. truncatula is probably less well adapted to Tel Hadya than the two rhizobia strains.

The coefficient of variability (CV) of the ID method the percentage of nitrogen fixed was only was only 4% for M. rigidula (not shown in Table 4.11) indicating the high precision that can be obtained by this method. In contrast, the CV for the

difference method with M. rigidula was several times higher (though still low at 13.2%), caused by variations in herbage yields. The CV of the ND method for M. truncatula could not be calculated because of negative values in the low density treatments where the grass absorbed more nitrogen than the medic could fix or absorb. This inability to estimate fixed nitrogen where low nitrogen values are encountered, is a weakness of the ND method. Nevertheless the good general agreement between the two methods indicates that, where soils are low in nitrogen, the difference method is a valuable (and cheap) technique for measuring nitrogen fixation.

One of the more striking aspects of the results is the huge increase in growth of M. truncatula after inoculation: 500% and 350% using strains WSM 244 and CC 169 respectively. In fact plants from the non-inoculated plots were yellowish and stunted, typical symptoms of nitrogen deficiency. The native rhizobia which nodulated M. rigidula have since been isolated and labelled ICARDA M29: this strain has been widely distributed to our collaborators, and it usually produces effective nodules on M. rigidula.

Table 4.12 shows the fertilizer efficiencies and uptake values for both the medics and ryegrass. The calculations were based on enriched nitrogen fertilizer and show that only a small portion of the fertilizer was used by the medics and rather more by the grass. The heavy reliance of the medics on atmospheric nitrogen is, of course, typical of soils which are low in nitrogen: in this experiment total nitrogen (Kjeldahl) was only 530 ppm and mineral nitrogen at the beginning of the season was only 7.2 ppm NH_4-N and 8.1 ppm NO_3-N (Bremmer method). - **L.A. Materon and S.K.O. Danso (International Atomic Energy Agency, Vienna)**

Table 4.12. Enriched isotopic nitrogen fertilizer uptake and efficiency in medic and ryegrass.

	Fertilizer Use Efficiency %	Total Fertilizer Uptake (TFU) kg/ha	Fertilizer Uptake Eff %
Ryegrass	17.35	1.67	13.1
M. rigidula			
WSM 244	1.75	1.27	10.0
CC 169	1.83	1.35	10.6
Mean (inoculated)	1.79	1.31	10.5
Uninoculated	1.67	1.58	12.4
M. truncatula			
WSM 244	4.20	1.87	14.7
CC 169	4.85	1.66	13.1
Mean (inoculated)	4.53	1.78	14.0
Uninoculated	7.95	1.02	8.0

Expt 4.9. Improvement of the energetic efficiency of medic rhizobia (Preschedule M48)

The objective of experiment 4.9 is to introduce genes from *R. leguminosarum*, which is energetically efficient, into the less efficient *R. meliloti*, and to test the resulting rhizobia in the field.

Biological nitrogen fixation uses up to 10% of the energy in plant material: hydrogen, a byproduct of nitrogen fixation, is lost as gas diffusing out of the nodules. However, some rhizobia

species (for example R. leguminosarum) have the capacity to recycle this hydrogen, making nitrogen fixation a less energy demanding process. The capacity to recycle hydrogen is a desirable characteristic if the rhizobia is otherwise adapted and the plants not suffering from other stresses. Recently we started a cooperative project with the Universidad Politecnica de Madrid (Spain) in which genes from R. leguminosarum will be genetically engineered into ICARDA strains M29 and M34.

The approach is to transfer the gene P Sym-hup (coding for nitrogen fixation and hydrogen uptake) located in R. leguminosarum strain 128C53 into the genome of the ICARDA strains. The plasmid has been marked by the transposon system (Tn5-mob) and transferred by bacterial conjugation into the receptors (strains M29 and M34). The strains so produced are currently being tested for genetic stability and to determine whether the alterations in behaviour are in fact due to presence of the new genes. Once these parameters have been defined and the organisms recommended for released, we will evaluate their symbiotic performance with the ICARDA medics.

ICARDA is aware that some people have reservations about the release of genetically-engineered microorganisms into the environment. While rhizobia are non-pathogenic and therefore unlikely to represent any risk, ICARDA will respect the views of organizations and countries and proceed with the release of genetically-engineered strains only when it is considered safe by responsible parties. - **L.A. Materon and T. Ruiz-Argueso (Universidad Pelitecnica, Madrid)**

Expt 4.10. Mycorrhizae for medics (Preschedule M49)

The objective of Expt. 4.10. is to (1) improve nutrient

uptake and nitrogen fixation through the use of mycorrhizae and (2) develop techniques to infect soil with the fungi. The project is in cooperation with ICARDA and the University of Granada in Sevilla (Spain).

In many semi-arid soils scarcity of available soil phosphorus is an important factor restricting the growth of legumes. Various minor elements such as molybdenun, boron, zinc, iron, copper and sulphur may also be deficient.

Mycorrhizae can improve phosphate and minor element uptake by making use of the absorbing capacity of the extensive network of external hyphae associated with the infected root. This network extends for several centimeters from the root surface and provides an effective uptake system beyond the range of root hairs, particularly for ions which diffuse slowly such as phosphate, zinc and molybdate.

The Granada team has isolated strains of mycorrhizae for M. rigidula, M. rotata and M. polymorpha which are successful in the field. The next step involves developing and evaluating techniques to infect roots with selected mycorrhizae and rhizobia. - **L.A. Materon and J.M. Barea (El Zaidin, Granada)**

CHAPTER 5: GRAZING MANAGEMENT OF MEDIC PASTURE

Chapter 5 addresses the question of how to graze medic pastures.

Grazing management involves optimisation of the growth of plant populations, their harvesting by grazing animals, growth and reproduction of the animals, and the continued use and maintenance of pasture land. The objective of good grazing management is to maximise livestock production in a manner which is relevant to the economic well being of farmers, and the capacity of the land to continue indefinitely in a stable state.

Sustainable agriculture, when it involves livestock, depends upon good grazing management. The converse, bad management, destroys the growth of plants and results in overgrazing. Unfortunately overgrazing is a daily event in west Asia and north Africa where livestock are vital to the existence of people, and where the provision of more animal feed is a high priority.

We know that the use of medic pastures will increase the capacity of land to carry livestock. However they too can be overgrazed, that is the pasture's capacity to continue to grow can be destroyed.

In all annual pastures, including medic pasture, seed needs to be produced each year to provide feed for sheep during summer and for pasture regeneration (see Chapter 2). However, the animals have to be fed every day, and cannot wait. If there is a danger of overgrazing, alternative feeds must be purchased, but such purchases kept to a minimum to avoid wasting pasture later. Grazing must control the weeds, and at the same time use them to maximum advantage. Animal needs fluctuate with the reproductive cycle, and the time when the need for feed is greatest rarely coincides with seasonal peaks in plant growth.

Our grazing management research was set up to obtain basic information to enable good grazing management practices to be extended to farmers. In so doing, the productivity of the wheat/pasture rotation is being determined and compared with other alternative forms of land use.

Expt 5.1: Measuring the optimum stocking rate of medic pasture

Medic pastures were established at Tel Hadya and are managed at three stocking rates. Pastures have now been grazed for three seasons, that in 1987/88 being the first in which regenerating pasture was available.

The experiment occupies 30 ha and compares seven treatments as follows: wheat in rotation with

- medic grazed at 4 sheep per hectare;
- medic at 7 sheep per hectare;
- medic at 10 sheep per hectare;
- fallow;
- watermelon;
- lentil; and
- vetch.

Further details are given in the 1987 Program Report (page 44).

Grazing management: The pastures grazed in 1987/88 were originally sown to medic (M. rigidula (L.) All., a mixture of cultivars dominated by sel. 716) in autumn 1985, the first phase (Phase 1) of the rotation. Second phase pastures (Phase 2), sown in 1986, were on land which rotated to wheat in 1987/88. The

sheep thus had access to green pasture during the winter, spring, and early summer of 1987/88, and dry pasture and wheat stubble for the remainder of summer and autumn.

Two rules for management were found to be essential for sustained production, one for the welfare of pastures, and the other for the welfare of animals. For pastures, the rule was to graze green pasture as long as the rate of growth was positive: the daily growth rate must be at least equal to the quantity being eaten. It was also decided not to graze during periods of heavy rain because of possible damage to soil structure when the forces induced by the body mass of animals may exceed the sheering stress of the soil.

The rule for sheep feeding is discussed in the next section.

The ewes were pregnant in December when grazing in 1987/88 began. In the summer and autumn of 1986/87 they had grazed wheat stubble and the seeds and pods of the Phase 2 medic. With the onset of autumn rain, stubbles became unattractive and the sheep began to graze volunteer wheat seedlings, avoiding the newly-emerged medic seedlings.

During winter there were periods when grazing was halted, especially during wet weather, but there was enough grazing to eliminate volunteer cereals and most of the weeds (Table 5.1).

Inevitably the day to day supervision of grazing depends on subjective assessment of pastures. This is accompanied by longer-term measurements of the quantities of biomass present, and estimates of the quantities eaten by sheep. The latter depends on two series of exclusion cages (a modification of the open and closed method), which facilitates the measurement of pasture growth rate in the temporary absence of grazing (ICARDA Technical Manual 15 En, 1987).

Table 5.1. Changes in the botanical composition of a medic pasture under grazing from December 1987 to May 1988. The percentage of medic, volunteer wheat and weeds is given in terms of herbage present in the total aerial biomass, as a mean for three rates of stocking.

	Medic	Wheat	Weeds
December	78	20	2
January	85	11	4
February	87	6	7
March	94	2	4
April	96	1	3

The plant-animal interface: The quantity of available pasture was measured throughout the year, and estimates were made of the quantity grazed. Fig. 5.1 shows that the initial quantities at each stocking rate (SR) were low, but that there was rapid growth in spring to a peak of herbage in May and of seeds in June. The quantity declined during the summer as material was removed by grazing.

Fig. 5.1 gives the impression that pasture was wasted (not eaten). However, the figure shows only the quantities AFTER grazing, and the following data on intake show that the large build-up of biomass would have been impossible to avoid.

Concurrent with the sampling of pastures, areas were protected from grazing to determine pasture growth rate. By comparing the results with the changes in biomass it is possible to obtain an estimate of the quantity consumed by sheep. The results are subject to error, but give a useful indication of the amount of pasture grazed (probably an over-estimate).

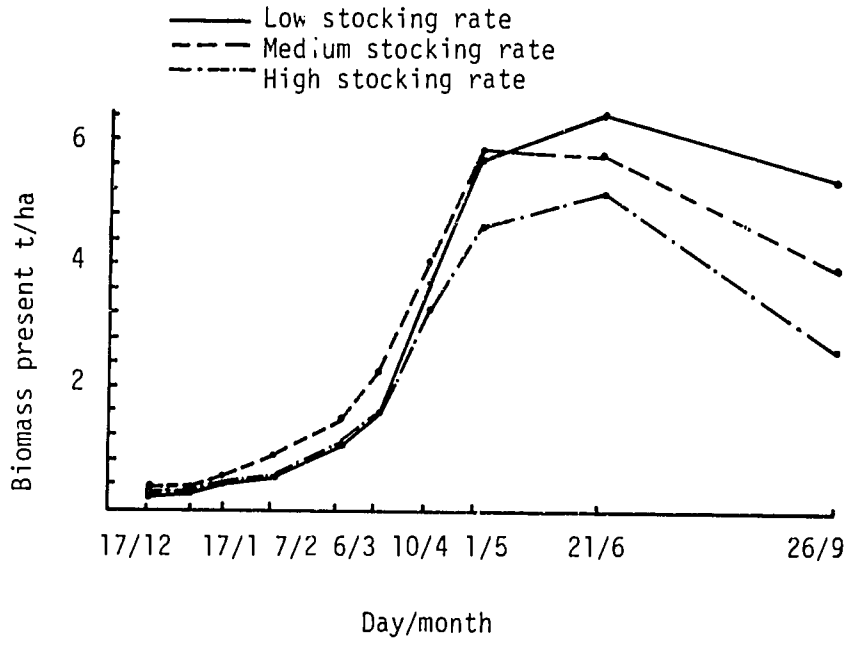


Fig.5.1. Quantity of biomass (t/ha) in medic pasture in 1988 grazed at low, medium and high stocking rates.

Table 5.2 shows the quantities of herbage eaten by each ewe and lamb for each day of grazing at the three stocking rates. The dates were determined by the timing of a complex system of measurements of protected and unprotected areas of pasture. Figs 5.2, 5.3, and 5.4 illustrate how the quantity of pasture eaten by each ewe and lamb, calculated from Table 5.2, relates to grazing at the three stocking rates. At the low SR, daily intake increased during the spring as the quantity of available pasture increased, and the appetite of the ewe responded to its increasing requirements during lactation. In summer the decline in intake of medic is explained by the grazing of wheat stubble which was grazed for half of each day.

At the medium and high stocking rates intake was much less than at low SR, a normal effect of stocking rate: the quantity

Table 5.2. Estimated amount of grazing by each ewe-lamb unit at low, medium, and high stocking rates (kg/head/day).

		Stocking Rate		
From	To	Low	Medium	High
Dec 17	Jan 4	1.4	0.9	0.3
Jan 4	Jan 17	1.6	0.7	0.4
Jan 17	Feb 7	3.4	1.3	0.8
Feb 7	March 6	5.3	2.7	1.0
March 6	March 21	5.3	2.5	1.6
March 21	April 10	8.1	2.8	2.6
April 10	May 5	10.9	3.3	2.6
May 5	June 21	8.6	2.3	1.9
June 21	Sept 9	3.5	1.8	1.4

which an animal eats is affected by the quantity present and available to be eaten. The process of grazing has a cost in terms of effort and energy devoted to selecting and removing the most attractive herbage in competition with other members of the flock. Thus it is easier for an individual sheep to eat a large quantity of pasture at the low SR than at higher SR. Despite there being fewer animals, more herbage was grazed at the low SR, but at all stocking rates the curves of the amount grazed followed the quantity present, and seasonal changes in plant growth.

The quantity of seed produced is important as a source of feed during summer, and to increase the seed-bank for regeneration in future years. Fig. 5.5 shows that grazing at medium and high stocking rates reduced the quantity of seed

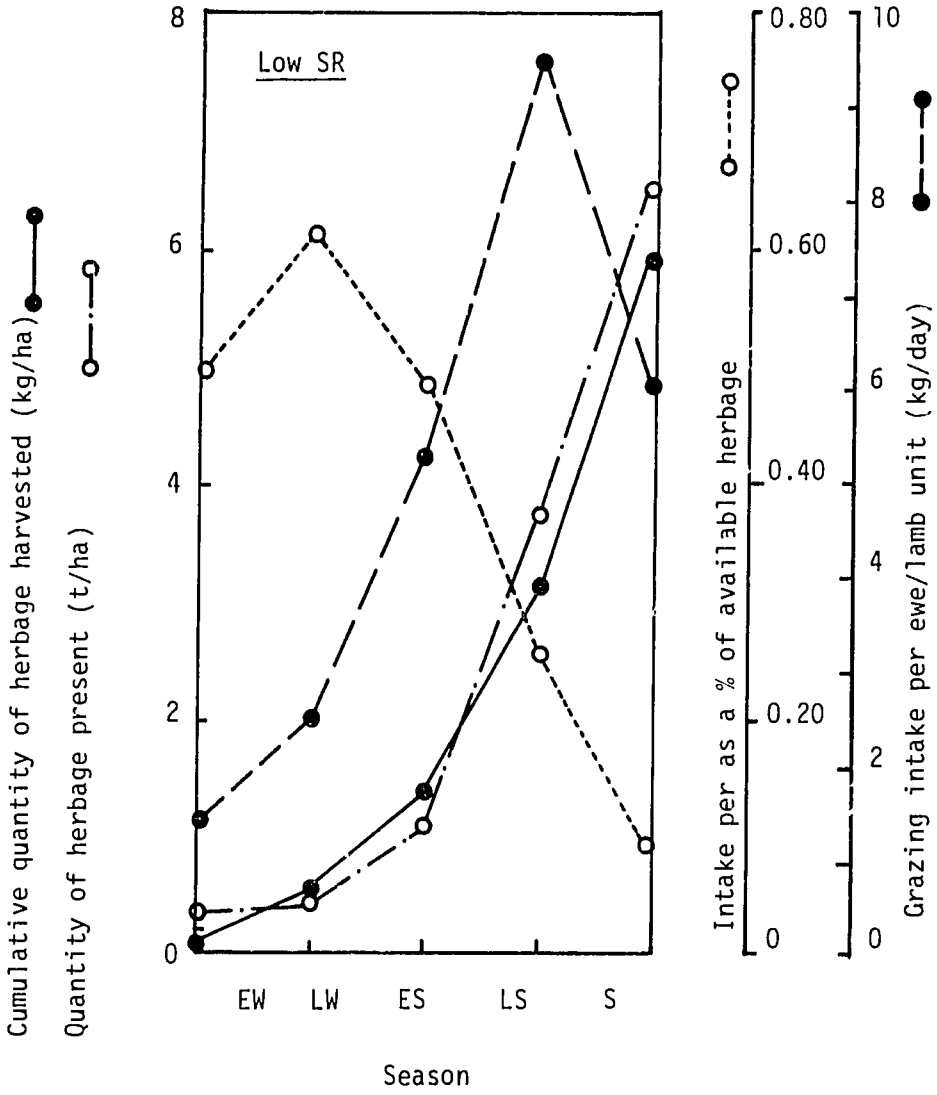


Fig.5.2. Seasonal changes in the intake of ewes (and lambs) of medic pasture (kg/day), intake as a percentage of available pasture, available pasture (t/ha), and the cumulative amount of pasture grazed (t/ha) by all sheep. Results are for the low stocking rate (4 ewes/ha). Codes for seasons are early winter (EW), late winter (LW), early spring (ES), late spring (LS), and summer (S).

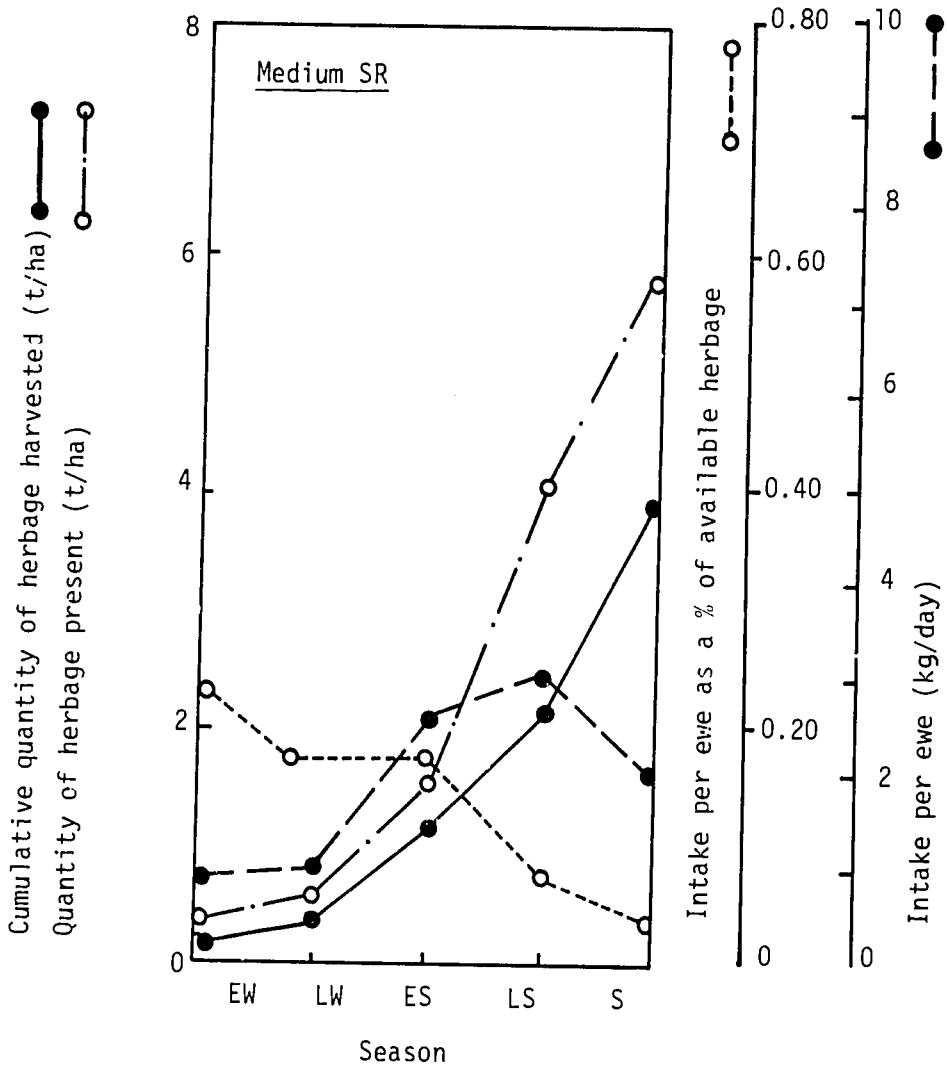


Fig.5.3. Seasonal changes in the intake of ewes (and lambs) of medic pasture (kg/day), intake as a percentage of available herbage, available pasture (t/ha), and the cumulative amount of pasture grazed (t/ha) by all sheep. Results are for the medium stocking rate (7 ewes/ha). Codes for seasons are early winter (EW), late winter (LW), early spring (ES), late spring (LS), and summer (S).

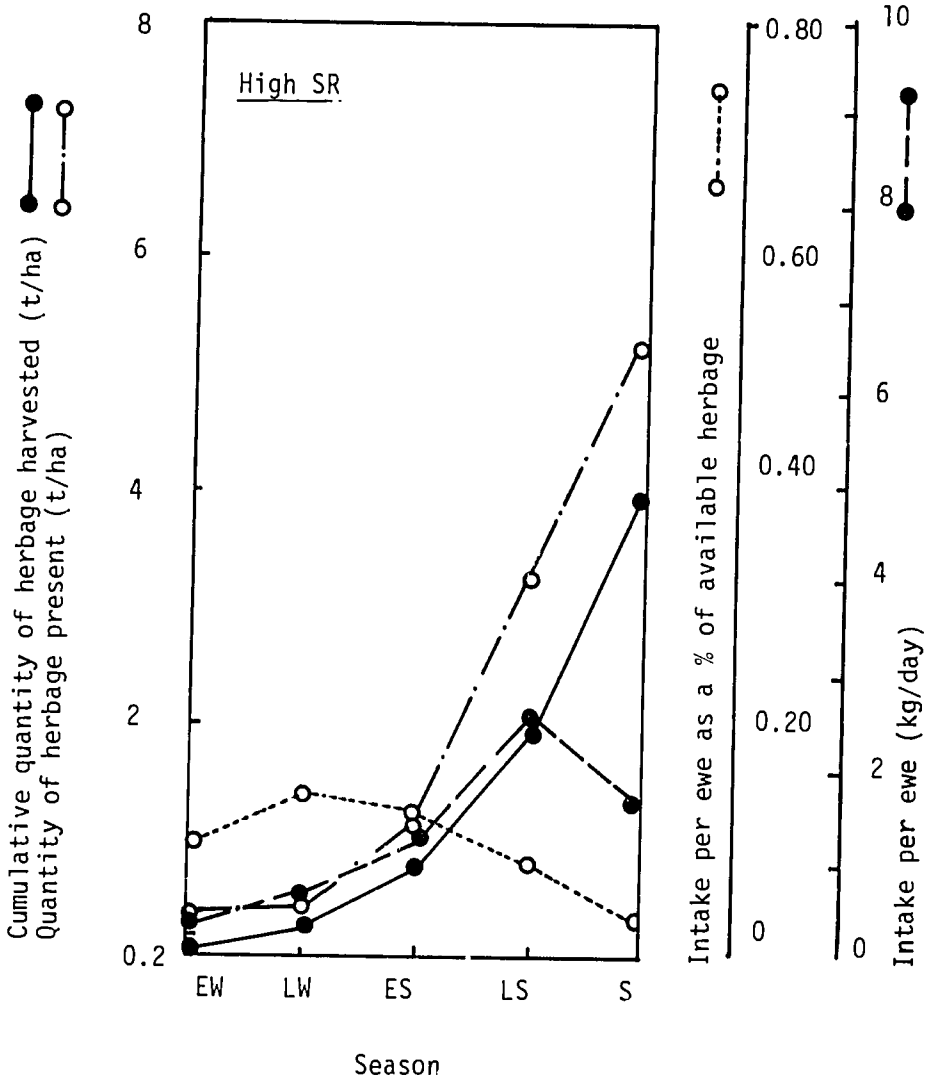


Fig.5.4. Seasonal changes in the intake of ewes (and lambs) of medic pasture (kg/day), intake as a percentage of available herbage, available pasture (t/ha), and the cumulative amount of pasture grazed (t/ha) by all sheep. Results are for the high stocking rate (10 ewes/ha). Codes for seasons are early winter (EW), late winter (LW), early spring (ES), late spring (LS), and summer (S).

produced compared with low SR. These differences persisted: the low SR rate was better able to provide summer feed, and grazing continued longer, until October. The amount of seed present at medium and high stocking rates in October is not shown in Fig. 5.5 because grazing of these treatments ended in September.

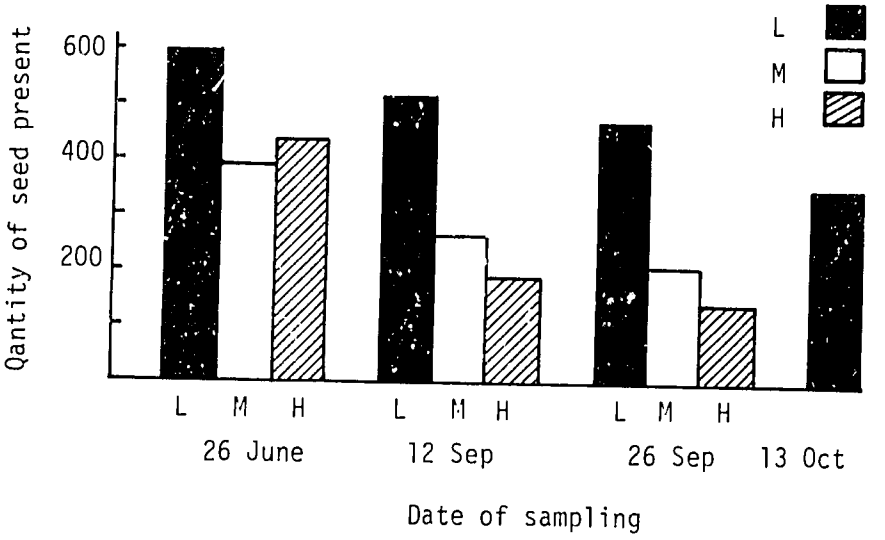


Fig.5.5. Changes in the quantity of medic seed (kg/ha) in dry pasture during summer grazing at low (L), medium (M), and high (H) stocking rates.

Animal management: Ideally pasture should provide all of the nutritional requirements of grazing animals, such that there is no need for supplementary feeding. In practice this rarely happens because of an imbalance between the seasonal growth of pasture and the nutritional requirements of animals. In the case of Awassi sheep at Tel Hadya the seasonal pattern of pasture availability is dictated by climate, the availability of stubble by the farming system, and the sheep's requirements by the date of mating which fixes the dates of lambing and lactation. With reproductive animals, stress must be avoided as much as possible because profitability depends on growth rates of lambs, amount of milk produced, and mortality of ewes.

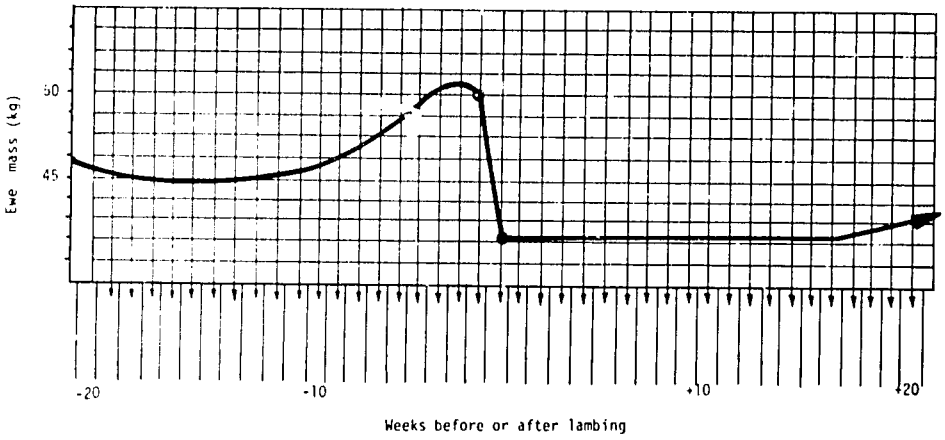


Fig.5.6. Graph used for planning the quantity of supplementary feed to be given to ewes. The line indicates the minimum body mass which can be accepted at various parts of the breeding cycle, below which the animal is at risk of nutritional stress.

Fig. 5.6 illustrates the time course of minimum body mass for the most critical parts of the breeding cycle if stress is to be avoided. We use Fig 5.6 to control feeding of the ewes and it is based on events recorded in the previous year. Body mass was recorded each week and a record made of the date of mating, the results of pregnancy tests, and the predicted date of lambing. The body mass of each ewe was maintained on control charts (eg Fig. 5.6) and the ewes fed when the body mass fell below the target.

Animal feeding therefore involved two decisions:

(1) to give sufficient feed to maintain animal health, using the control graph; and

(2) to use the minimum of supplement by utilising the pasture and cereal stubble to their limit.

One consequence of our practice is that the body mass of ewes can increase during the summer and autumn and decrease at other times of the year without a need for feeding.

Table 5.3 shows the days on which the sheep flocks were grazing with and without supplementary feeding, or being fed exclusively on purchased grain and straw. For most of the year the sheep were grazing, only 16% of the time at low SR (60 days) were they being fed on concentrates only. This percentage increased with stocking rate to 33% for the high SR flock. One effect of stocking rate therefore, is to vary the extent to which the system fails to meet self-sufficiency in feeding the sheep. This is illustrated in Table 5.4, which shows the increase with

Table 5.3. Period of time during which sheep were grazing or being fed partially or exclusively on purchased feed consisting mainly of barley grain and straw. Values given in days for each of three stocking rates.

	Low	Medium	High
Grazing green medic pasture	129	129	81
Grazing green pasture with supplement	33	15	67
Grazing dry medic pasture residues plus wheat stubble	133	145	87
Grazing wheat stubble plus supplement	10	5	8
Supplement only	60	71	122
Total	365	365	365

Table 5.4. Total quantity of additional feed (kg/ewe of supplementary feed) consumed by sheep during the year, during which most of their time was spent grazing at the three stocking rates.

	Low	Medium	High
Wheat straw	93	65	58
Barley grain	56	54	84
Cotton-seed	10	12	14
Total of above as metabolisable energy (MJ)	1202	1247	2499

stocking rate of additional feed required, so that the quantity of additional metabolisable energy needed at high SR was double that at low SR.

Animal productivity: Table 5.5 gives the rates of growth of lambs at the three stocking rates. There was little influence of SR until the lambs were grazing pods and stubble when lambs grazing the highest SR appeared to be at a disadvantage. Previously the lambs were wholly or partly dependent on their mothers' milk the production of which was apparently not affected by stocking rate. At weaning, because the lambs were in very good condition, the males were marketed and the females removed to another experiment, the objective being to discover whether they could be mated at this early age. If so, there is the opportunity of reducing the age of lambing from one and a half years to nine months, a result which would greatly increase the efficiency of livestock production.

Table 5.5. Growth rate of lambs (g/day) at three stages in their development from birth to maturity (when they were ready for marketing) at the three stocking rates.

	Low	Medium	High
Suckling stage	238	279	237
Partially weaned stage	289	244	266
Fully weaned (grazing dry pasture and stubble)	81	81	65

Table 5.6 shows the yields of animal products at the three stocking rates. Because of the greater number of animals the high SR produced the greatest value of products (Table 5.7), and was the most profitable (Table 5.8).

This simple economic appraisal should be taken with caution until a complete biological and economic analysis has been conducted. For example account has not been taken of depreciation in value of the ewes themselves, nor is it possible as yet to see the effect of changing prices.

Table 5.6. Output of animal products (kg/ha) for sheep grazing at the three stocking rates.

	Low	Medium	High
Meat	192	263	373
Milk	192	349	402
Wool	9	15	22

Table 5.7. Value of the products obtained from sheep flocks for the three stocking rates (Syrian pounds/ha).

	Low	Medium	High
Meat	12480	15780	22380
Milk	1538	2795	3216
Wool	360	600	880
Total	14378	19173	26476

Table 5.8. Profitability of sheep at the three stocking rates. Financial input, output and revenue (Syrian pounds/ha).

	Low	Medium	High
Output	14378	19173	26476
Input	1645	2967	6123
Revenue	12733	16206	20353

One technical aspect of running the experiment has been solved. A formula has been derived, and a computer program written, for the calculation of meat production from a flock of sheep. The program takes into account that the composition of the flock is not constant as older or unhealthy ewes are replaced by younger ewes. The change involves the gain or loss of a quantity of "body mass" which could be wrongly interpreted as a gain or loss in production. The formula overcomes all the complexity, and gives a rapid and accurate result.

Pending publication, the formula and program are being made available to other scientists on request.

Crop productivity: Values were obtained for the yields of lentil, vetch and watermelon during the current season. These crops are grown in rotation with wheat, and the resulting rotations are being compared with the pasture wheat rotation.

Table 5.9 gives the yields for each crop, while biomass of the crops is compared with pasture in Table 5.10. This is a useful way of comparing crop production systems, the crop which produces most biomass being regarded as having utilised the available moisture, solar radiation, and other inputs to the greatest advantage. All of the crops may be utilised completely for direct human food, or for feeding to animals, while the pasture is, of course, only utilised by animals. The relative value of the two components differs according to crop and season. It will be seen from Table 5.10 that pasture exceeds the other forms of land use in biomass productivity, and therefore has a very large potential for food production.

Table 5.11 gives the wheat yields in the various rotations.

Table 5.9. Yield of crops (kg/ha) grown in rotation with wheat, for comparison with the pasture wheat rotation.

	Seed/fruit	Straw	Residue	Total
Water melon	1258*	-	162	1420
Lentil	2117	4299	-	6416
Common vetch	1575	3329	-	4904

* 6240 kg/ha fresh melons.

Table 5.10. Total dry matter yields (kg/ha) of crops compared with grazed medic pasture. Values are for the material removed by harvesting or grazing, plus any residues remaining.

Medic pasture at	
- Low stocking rate	11278
- Medium stocking	8012
- High stocking	6620
Water melon	1420
Lentil	6416
Common vetch	4904

Table 5.11. Yield of wheat (kg/ha) in 1988 following alternative types of land use in the previous year. Values are quoted relative to the results for fallow (=100%), with and without the use of fertilizer nitrogen. The absolute values for fallow are quoted in brackets at the bottom of the Table.

	Grain		Straw	
Medic pasture	+N	-N	+N	-N
- Low SR	65	67	64	55
- Medium SR	61	61	64	53
- High SR	72	73	75	59
Water melon	104	117	105	115
Lentil	72	62	65	49
Common vetch	73	85	74	77
Fallow	100	100	100	100
	(4276)	(2781)	(7154)	(4559)

Wheat after fallow or after watermelons was substantially more productive than after any of the legumes. However this result must be kept in perspective: the site at Tel Hadya is only one of 23 in Syria where we have made this comparison and is exceptional in showing yield depression after legumes. Wheat yields are discussed further in Chapter 9.

Other research on grazing management is reported in Chapter 10 where it is used as an example of PFLP's approach to training.

- A. Smith, N. Nersoyan, F. Bahhady

CHAPTER 6: SELECTION OF WIDELY ADAPTED LEGUME CROPS TO REPLACE FALLOWS IN DRY AREAS

One of ICARDA's most important objectives is the replacement of fallows with legumes. There are three classes of legumes - the pasture legumes discussed in Chapters 1-5, the food legumes discussed in the FLIP Report, and forage legumes, the subject of Chapters 6 and 7.

It is easy to distinguish between pasture and forage legumes. Pasture legumes are self-regenerating, while forage legumes are re-sown annually. Pasture legumes are grazed, while forage legumes are cut for hay, or harvested for straw and grain. Pasture legumes are usually small seeded, while forage legumes have large seeds. Pasture legumes are selected for attributes which resemble those of weeds: seed dormancy, ability to survive intensive grazing, ability to become naturalized in a field. Forage legumes are selected for the same attributes as other crops: primarily grain and straw yield.

What then are the differences between forage and food legumes? The answer is in the way they are used: the grain of food legumes is used to feed people and of forage legumes to feed animals. The straw of both are used as animal feed, both can be used for grazing, and if economic conditions encourage it, both can be used for hay.

This difference in use has one important consequence. Because the eating habits of people are conservative it is difficult to persuade them to accept a new crop. Thus, even though the seed of vetch is quite palatable, people continue to prefer beans and peas. Researchers into food legumes are therefore constrained to a few accepted crops, in ICARDA's case lentils, chickpeas and faba beans. No such restriction applies

to forage legumes and PFLP therefore has the whole range of Mediterranean legumes with which to work. Nevertheless, as is seen in Chapter 7, palatability to animals can be a problem - even they have conservaticve tastes sometimes.

We have however, imposed on ourselves an additional constraint, that of looking for legume crops for dry areas - the 250-300 mm rainfall zone. For this zone there are presently no legume crops and farmers use rotations of cereal (usually barley) with fallow or continuous cereal. In view of ICARDA's overall objective of developing sustainable farming systems there is a clear need for legume crops in these dry areas. This objective is not in conflict with our aim to develop pasture legumes - both have a role to play although, in the long term, that of pasture legumes will probably be the greater.

In spite of the diversity of legumes in the Mediterranean basin, few have been used specifically as forage crops, and these have received virtually no attention by plant breeders. Therefore, our first goal is to develop improved cultivars of species currently in use, and our second is to examine some of the alternative wild species. Because there has been so little work our emphasis is on selecting from existing variation, although, as will be seen later, some hybridization is being used where it seems necessary.

Two forage genera are being evaluated intensively: vetches (Vicia spp.), and chickling (Lathyrus spp.). In vetches we are selecting or hybridyzing genotypes from Vicia villosa ssp dasycarpa (woollypod vetch), V. narbonensis (narbon vetch), V. ervilia, (bitter vetch), and V. sativa (common vetch). In chickling, Lathyrus sativus (common chickling), L. cicera (dwarf chickling) and L. ochrus (ochrus chickling), are being evaluated. Two of the most exciting species are narbon vetch and ochrus

chickling, both because of their potential in dry areas. Previously we had worked intensively with forage peas, but until problems of bird damage, lack of frost tolerance, and low palatability are resolved, our work with peas receives low priority.

The process of developing new crops from wild species involves firstly germplasm evaluation and seed multiplication in nursery rows; secondly evaluation of selected genotypes in microplots; thirdly evaluation of promising genotypes in advanced yield trials; and finally multilocation (regional) testing of promising genotypes in different ecological zones. Hybridization is used to overcome specific weaknesses: shattering seed pods, prostrate growth, susceptibility to disease. The reaction of selected genotypes to major foliar and root diseases under natural and artificial conditions takes place at all stages. Palatability and nutritive value of the herbage, seed, and straw are also monitored. The process begins and ends with on-farm experiments to determine farmers needs, and to see how well our new cultivars meet them.

In 1987/88 germplasm of seven vetches were evaluated in nursery rows. Promising genotypes of Lathyrus sativus, L. cicera, L. ochrus, V. villosa ssp. dasycarpa and V. narbonensis were evaluated in microplots. Advanced genotypes of V. narbonensis, and V. villosa ssp. dasycarpa were tested at two contrasting sites, Tel Hadya and Breda, and one set of chicklings (L. sativus and L. ochrus) were tested at the two sites for the third season. After crossing promising genotypes of common vetch with non-shattering wild ecotypes selection of adapted non-shattering genotypes continued into the F4 generation. Selection for resistance to root and leaf diseases among landraces and ecotypes of forage legumes was maintained.

PFLP's forage work is supported by that of FRMP who are studying the adaptation of several species in a transect from areas which grow lentils to the edge of the steppe.

Expt 6.1: Assessment of germplasm in nursery rows (Preschedule F66)

Four-hundred accessions of seven vetches: 45 V. ervilia, 60 V. hybrida, 15 V. johanis, 30 V. lutea, 20 V. monantha, 50 V. palaestina, and 180 V. sativa, were screened in nursery rows in a cubic lattice design with two replicates. The accessions were scored on a scale of 1-5 (1 = poor, 5 = good) for establishment, seedling vigour, winter and spring growth, frost tolerance, leafiness, growth habit, plant vigour, time to flowering and maturity, and susceptibility to major diseases. Emphasis was given to leafiness and leaf retention as important criteria for improving straw quality.

Variability was wide (Table 6.1). We identified 16 genotypes of V. ervillia, 16 genotypes of V. hybrida, 16 genotypes of V. palaestina and 25 genotypes of V. sativa, for further evaluation.
- Ali Abd El Moneim

Table 6.1. Range of variability of seven attributes of Vicia sativa, V. ervilia, V. hybrida and V. palaestina.

	V. sativa		V. ervilia		V. hybrida		V. palaestina	
	Min	Max	Min	Max	Min	Max	Min	Max
Days to 1st flowering	124	154	121	144	106	142	113	137
Days to 50% flowering	129	156	127	150	113	147	119	145
Days to 100% flowering	134	160	128	156	120	152	125	153
Days to 1st podding	135	161	136	157	121	153	126	154
Days to 100% podding	151	175	151	164	147	164	146	164
Days to full maturity	170	189	162	182	163	177	126	183
Seed yield (g/plot)	99	1341	6	955	42	1243	29	119

Expt 6.2: Evaluation in microplots (Preschedules F62, F63, F64, F67 and F71)

The study of agronomic characters in microplots is of significant practical value: it helps breeders to establish a suitable breeding program with defined objectives and of itself may result in the selection of improved cultivars. Objective selection for herbage and seed yields and some aspects of nutritive value begins in microplots in the year following nursery row evaluation.

Microplots of the three chickling species, narbon vetch, and woollypod vetch were planted at Tel Hadya in 3.5 m^2 plots arranged in a triple lattice design. For all species, seed rate was 100 kg/ha and phosphate rate was 40 kg/ha. The experiments were duplicated: one set harvested at 100% flowering to measure herbage, and the other at maturity for seed and straw.

Results with common chickling: Thirty-six selections were tested at Tel Hadya (results of the top 16 are shown in Table 6.2). Herbage yield varied from 2810 to 5810 kg/ha with a mean of 4860 kg/ha. Seed yield ranged from 150 to 680 kg/ha with a mean of 330 kg/ha. Total biological yield ranged from 3550 to 7030 kg/ha, with a grand mean of 5400 kg/ha. Harvest index (HI) ranged from 3 to 10% (Table 6.2), the very low values being due to attack by Orobanche. Seed yield was negatively correlated with days to flowering ($r = -0.61$, $P<0.01$).

Common chickling was characterized by slow winter growth, rapid growth in spring, long flowering period, and late maturity. As mentioned the low harvest index was mainly due to severe attack by broomrape (Orobanche crenata). The exceptional rainfall in 1987/88 also favoured attack by powdery mildew (Erisiphe pisi) when pods were forming.

Table 6.2. Herbage (at 100% flowering) and straw yields (kg/ha), and harvest index, for the top 16 genotypes of common chickling (Lathyrus sativus), grown at Tel Hadya.

Selection Number	Herbage yield	Seed yield	Straw yield	Harvest index %
347	4450	210	4210	4
504	5430	460	6570	6
505	4530	560	5760	8
508	5120	340	4720	6
510	4810	500	4920	9
516	5090	370	5570	6
519	5450	450	5970	7
520	4830	680	6260	9
522	5800	490	5650	7
527	4970	330	4980	6
528	4750	450	5200	7
529	5190	640	5790	10
530	5301	436	5453	7
531	5110	650	5540	10
533	4620	330	5270	5
535	5630	250	5080	3
Grand mean(1)	4860	330	5070	4.85
S E.	571	282	742	3.33
L.S.D (P<0.05)	1144	565	1488	6.74

(1) Mean of all 36 entries.

To improve the seed yield of common chickling it will be necessary to select for early maturity to escape the worst effects of Orobanche. However, in the dry areas where we expect common chickling to be of value Orobanche is not widespread.

Furthermore, in on-farm experiments in these areas farmers have always preferred common chickling to the other forage legumes. Therefore we will persist with our work on this species.

Results with dwarf chickling: Sixteen selections, derived from nursery evaluation in 1986/87, were tested in microplots at Tel Hadya. Herbage yield varied from 6130 to 8460 kg/ha, with a grand mean of 7060 kg/ha. Seed yield ranged from 1050 to 2490 kg/ha, with a grand mean of 1710 kg/ha, and harvest index varied from 17 to 27%. Table 6.3 shows the 10 top selections.

Table 6.3. Herbage (at 100% flowering), seed and straw yields (kg/ha), and harvest index for the top 10 selections of dwarf chickling

Selection number	Herbage yield	Seed yield	Straw yield	Harvest index
488	7530	1610	6830	19
489	6852	2407	6550	27
491	6790	1970	6420	23
492	7880	1760	6010	22
493	8460	1660	6100	21
494	7360	1880	6380	22
495	7650	1890	6120	22
496	7140	2080	6500	24
500	7750	2010	6390	23
536	6130	1050	5030	17
Grand Mean(1)	7055	1709	6177	17
SE	715	391	412	2.5
L.S.D ($P < 0.05$)	1485	813	856	5.2

(1) Mean of all 16 entries.

Dwarf chickling produced more seed and straw than common chickling because it flowered earlier and was less affected by broomrape (Orobanche crenata).

Results with ochrus vetch: Sixteen selections of ochrus vetch, derived from nursery evaluation in 1986/87, were tested in microplots at Tel Hadya. Herbage yield varied from 2150 to 5020 kg/ha, with a grand mean of 3490 kg/ha. Seed yield varied from 3060 to 4980 kg/ha with a grand mean of 4320 kg/ha, with harvest index ranging from 26 to 41%. Table 6.4 shows the herbage, seed, and straw yields, and harvest index of ochrus chickling.

Ochrus chickling flowered three weeks earlier than dwarf and common chickling. It produced the highest seed and straw yields, due to its earliness and, as far as we could judge, had total resistance to Orobanche.

We have not yet been able to test ochrus chickling in a year of severe frosts.

Results with woollypod vetch: Thirty-six selections of woollypod vetch, from the nursery evaluation rows in 1986/87, were evaluated in microplots. Herbage yield varied from 5970 to 11210 kg/ha with a grand mean of 8410 kg/ha, seed yield ranged from 590 to 2330 kg/ha with a grand mean of 1920 kg/ha. Seed yield was negatively correlated with days to flowering and full maturity ($r = -0.54$ and -0.61 respectively, $P<0.01$) although not so herbage yield. Straw yield varied from 6770 to 10670 kg/ha with a grand mean of 10820 kg/ha, and harvest index ranged from 8 to 24%. The best fourteen genotypes (high yields of both herbage and seed) are shown in Table 6.5.

Woollypod vetch is unaffected by broomrape.

Table 6.4. Herbage (at 100% flowering), seed and straw yields (kg/ha), and harvest index for 16 selections of ochrus vetch, (Lathyrus ochrus).

Selection number	Herbage yield	Seed yield	Straw yield	Harvest index %
185	3310	3850	6990	35
537	2550	4430	6160	41
538	2940	4510	6780	39
539	2680	3400	6800	37
540	2150	4500	7490	37
541	4600	4180	7020	37
542	2240	4980	6910	41
543	2550	4810	8300	36
244	4490	3060	8660	26
545	3200	4260	7420	36
546	2730	4660	8100	36
547	4690	4460	8000	35
548	5020	4360	8040	35
549	3750	4150	8410	33
550	4770	4560	7570	37
551	4280	4310	7700	35
Grand mean	3498	4317	7522	36
SE	1135	231	604	1.57
L.S.D ($P < 0.05$)	2361	481	1257	3.26

Results with narbon vetch: Twenty-five genotypes of narbon vetch, selected from the nursery rows in 1986/87, were tested in microplots. Herbage yield varied from 2670 to 5490 kg/ha, (mean of 4304 kg/ha), seed yield from 230 to 4930 kg/ha (mean of 2990

Table 6.5. Herbage, seed, and straw yields (kg/ha), and harvest index for the top 14 genotypes of woollypod vetch.

Selection number	Herbage yield	Seed yield	Straw yield	Harvest index
683	9480	2820	9770	22
2426	8440	2100	9220	18
2431	8570	2830	8680	24
2437	8890	2350	10040	19
2438	9530	2410	9590	20
2441	9750	2460	9410	20
2442	9070	2650	10020	20
2445	11210	2040	9440	17
2446	9720	2220	9800	18
2450	8440	2340	10000	18
2451	8850	1920	9470	16
2455	9120	2090	9350	18
2456	8340	2240	9760	18
2457	8390	2620	8570	23
Grand mean(1)	8414	1917	8898	17
SE	822	159	623	1.4
L.S.D ($P < 0.05$)	1648	318	1249	2.8

(1) Grand mean of all 36 entries.

kg/ha), straw yield from 3950 to 9560 kg/ha (mean of 6270 kg/ha), and harvest index from 5 to 41%. Because narbon vetch is susceptible to Orobanche the late maturing genotypes produced low seed yields with low harvest index: the early genotypes are also susceptible but are able to set seed before the worst effects of Orobanche are felt. Seed yield was therefore strongly negatively

correlated (r = -0.51, P<0.01) with days to flowering. The results indicate the need to search for early maturing genotypes of not only narbon vetch but also common chickling (see earlier). The 14 genotypes which combined high straw and seed yields with early flowering are shown in Table 6.6.

Table 6.6. Herbage (at 100% flowering), seed and straw yields, (kg/ha), and harvest index, for 14 genotypes of narbon vetch.

Selection number	Herbage yield	Seed yield	Straw yield	Harvest index
67	5490	4930	9560	34
2461	4540	3940	7690	33
2462	4770	4010	7410	35
2464	5230	3800	7610	33
2465	5430	3850	7450	34
2466	5410	3970	7510	34
2467	5190	3720	6630	35
2469	5020	3730	6270	37
2473	4920	4140	6910	37
2474	3980	3500	6160	36
2475	4210	3460	6110	36
2476	4010	4310	6970	38
2477	4020	4400	6290	41
2478	5030	3510	7550	31
Grand mean(1)	4303	2994	6269	30
SE	689	279	670	1.66
L.S.D (P< 0.05)	1398	566	1358	3.4

(1) Grand mean of all 25 entries.

Table 6.7 is a summary of the microplots in 1987/88. Bearing in mind that forage legumes can be used for grazing, hay, straw, and grain, we can begin to see how the various species will fit into farming systems. The high seed and straw yields and early maturity of narbon vetch and ochrus chickling suggest that they will be of value in dry areas to farmers who want straw and grain. For those who require hay woolly pod vetch and perhaps dwarf chickling will be attractive. The results for common chickling are affected by its susceptibility to Orobanche but past experience suggests that, in the dry areas, it too will be used for grain and straw. - **Ali Abd El Moneim.**

Table 6.7. Variation in major attributes of five forage legumes evaluated in microplot trials in 1987/88.

Attributes	Species				
	Common chickling	Dwarf chickling	Ochrus chickling	Woollypod vetch	Narbon vetch
Days to 100% flowering	141-140	130-140	120-130	132-151	117-122
Herbage yield	2810-5800	6130-8460	2150-5020	5970-11210	2670-5470
Seed yield (kg/ha)	150-680	1040-2490	3060-4980	590-2830	230-4930
Straw yield (kg/ha)	3520-6570	5030-6830	6160-8660	6090-10670	3960-9560
Harvest index %	0-10	12-41	26-41	8-24	5-41

Expt 6.2: Narbon vetch and woollypod vetch at two sites, Tel Hadya and Breda (Preschedules F68 and F72)

Experiments were carried out to evaluate promising genotypes of narbon and woollypod vetch at Tel Hadya and Breda. Nine genotypes of each species were evaluated on the basis of their performance in microplots at Tel Hadya in 1986/87.

Narbon vetch: Herbage yields varied from 3.56 to 6.33 t/ha and from 3.07 to 5.76 t/ha at Tel Hadya and Breda respectively, and seed yield from 2.16 to 3.11 t/ha and from 1.92 to 2.88 t/ha respectively (Table 6.8). Straw yield was nearly 4 t/ha at both

Table 6.8. Herbage, seed, and straw yields (t/ha), and harvest index for nine promising genotypes of narbon vetch at Tel Hadya (TH) and Breda (B).

Selection number	Herbage		Seed		Straw	
	TH	B	TH	B	TH	B
0067	6.33	5.76	3.00	2.88	7.10	6.20
2391	4.68	3.19	2.60	1.92	4.59	3.66
2392	4.74	3.30	2.99	2.69	5.45	3.47
2387	3.56	3.07	2.95	2.58	4.56	3.41
2388	5.01	3.09	2.55	2.06	4.71	3.48
2380	3.69	3.34	3.05	2.40	4.64	3.42
2390	3.90	3.94	2.16	2.11	4.73	3.73
2393	4.60	3.82	2.55	2.42	4.86	4.23
2383	5.24	4.86	3.08	2.79	4.99	4.40
Grand mean	4.64	3.82	2.77	2.42	5.07	4.14
SE	0.43	0.44	0.18	0.28	0.36	0.46
L.S.D ($P<0.05$)	0.91	8.94	0.38	0.59	0.74	0.97

sites. The results (Fig. 6.1) indicate that there were only slight differences between the two sites, the similarity being due, of course, to the exceptionally high rainfall in 1987/88. For this reason Expt 6.2 will be repeated in 1988/89.

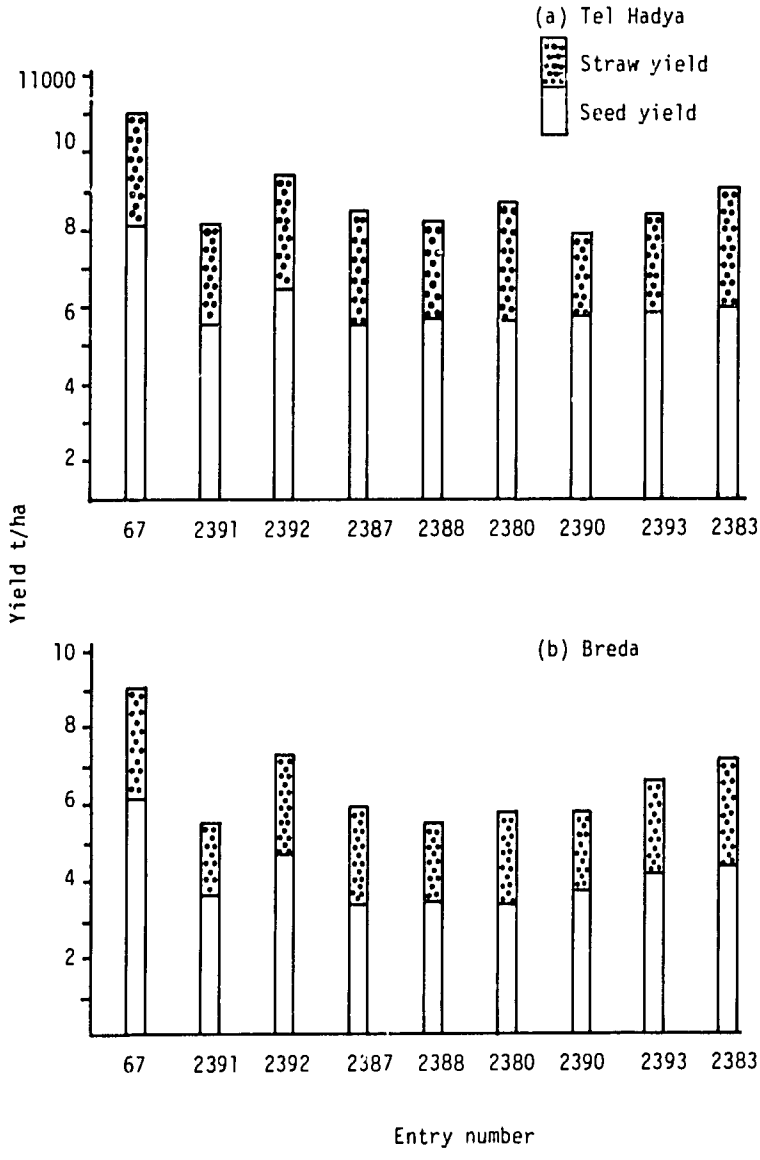


Fig.6.1. Variability among eight entries of narbon vetch in straw yield (white part of histograms) and seed yield (stippled) at (a) Tel Hadya and (b) Breda.

Woollypod vetch: In direct contrast to narbon vetch, woollypod vetch produced high herbage and low seed yields, and low harvest index. Mean herbage yields were 5.38 and 6.69 t/ha, at Tel Hadya

and Breda, respectively. Fig. 6.2 shows the variability in seed and straw yields and, by implication harvest index, among the lines of woollypod vetch. (Compare with Fig. 6.1). - **Ali Abd El Moneim**

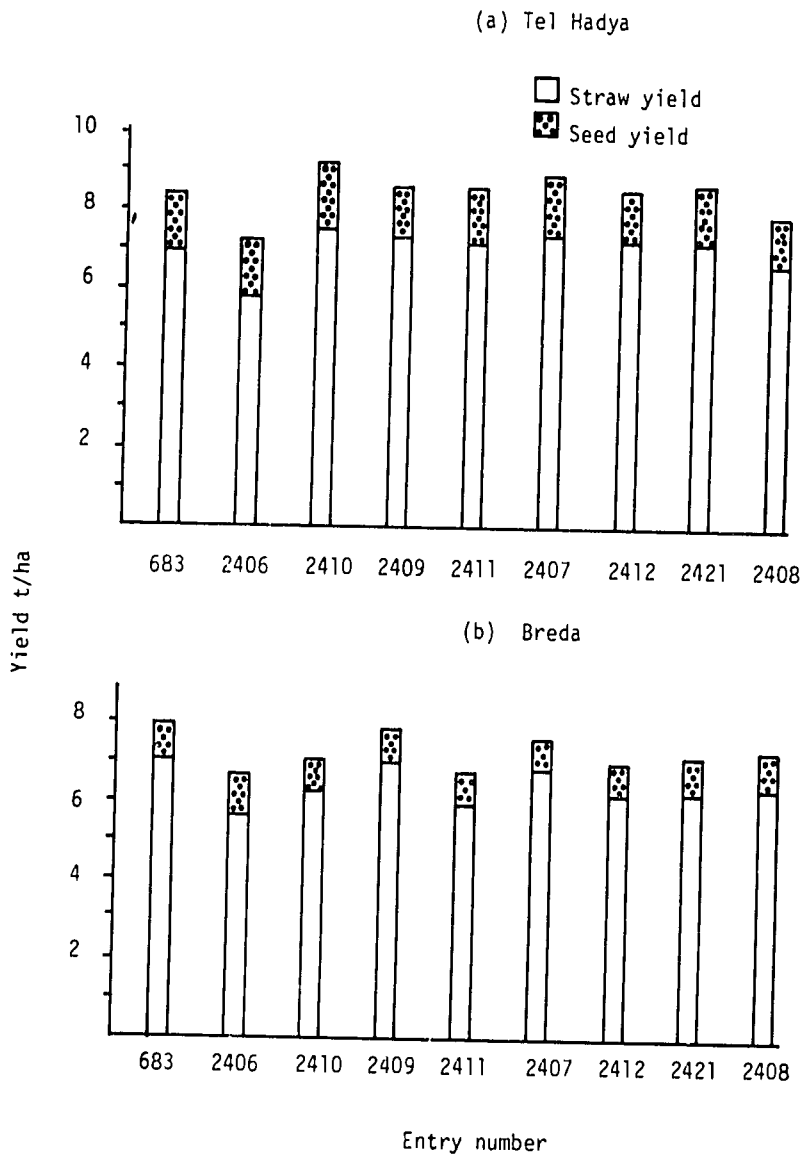


Fig.6.2. Variability among nine entries of woollypod vetch in straw and seed yield at (a) Tel Hadya and (b) Breda.

Expt 6.3: Three years results from three chickling species at two sites, Tel Hadya and Breda, (Preschedule F65)

In Expt 6.3 eleven genotypes of common chickling, four of ochrus chickling and one of dwarf chickling were compared in 1985/86, 1986/87 and 1987/88, at Tel Hadya and Breda. Rainfall for the three years were:

	1985/86	1986/87	1987/88
Breda	218	244	400
Tel Hadya	316	358	500

Herbage and seed yields were measured in each of the three years at both sites but straw yield was measured only in 1987/88.

Mean herbage yields varied from 1980 to 2810 kg/ha amd mean seed yields from 400 to 1550 kg/ha (Table 6.9). The four ochrus chicklings produced the highest seed yields, differences in herbage yield being less striking. In 1987/88 harvest index ranged from 15 to 39% for all chickling species, and for the four ochrus chicklings from 34 to 39%.

Seed yield was negatively correlated ($r = -0.85$, $P<0.01$) with herbage yield (Fig. 6.3). Mean herbage yield varied from 450 kg/ha at Breda in 1985/86 (when rainfall was 218 mm) to 4510 kg/ha at Tel Hadya in 1987/88, (when rainfall was 500 mm). Seed yield also varied from 170 kg/ha at Breda in 1985/86 to 1360 at Tel Hadya in 1986/87.

The agricultural significance of these results emerges in Fig. 6.4, where the relationships between rainfall and average herbage and seed yield are shown. After fitting curves, the data suggests that at 300 mm rainfall the seed yield of ochrus chickling is 1500 kg/ha, and even at 275 mm its yield is likely

to be about 1100 kg/ha. If the higher yielding genotypes in the microplots had been used it is possible that these yields would have been even greater.

Table 6.9. Herbage and seed yields (mean kg/ha for three years) and mean harvest index (in 1987/88 only) for 16 chickling genotypes, evaluated at Tel Hadya and Breda in 1985/86, 1986/87 and 1987/88.

Selection+ number(1)	Herbage yield	Seed yield	Harvest index
385	2302	1540	37
185	2100	1550	36
104	2103	1484	39
384	1981	1585	34
459	2806	394	17
455	2687	373	15
439	2617	558	23
347	2614	689	23
029	2578	482	19
311	2476	765	27
452	2472	456	23
453	2447	404	19
038	2434	596	21
471	2392	528	22
463	2378	483	23
476	2590	457	21
Grand mean	2431	772	25
S.E.	184	62	3.1
L.S.D ($P<0.05$)	361	122	6.3

(1) The first four genotypes are *Lathyrus ochrus*, the next eleven are *L. sativus* and the last is *L. cicera*.

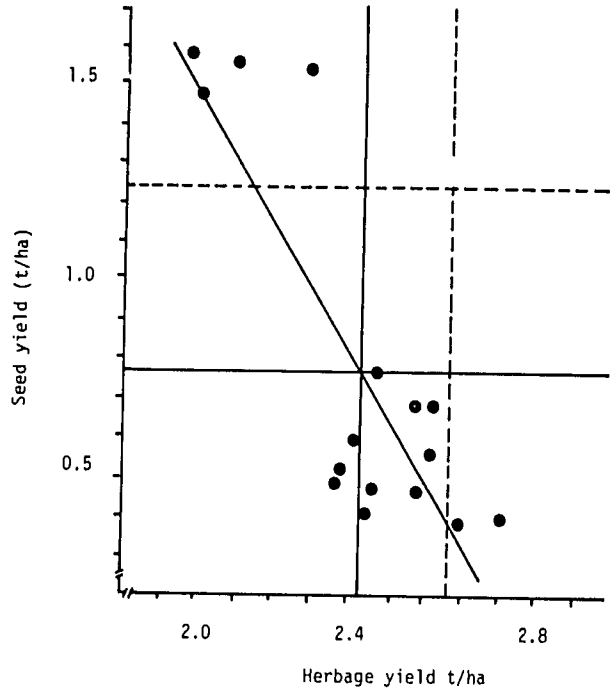


Fig.6.3. The relationship (r = -0.84***) between herbage and seed yield for 16 lines of chickling (mean of three seasons at Tel Hadya and Breda). The solid line indicates means and the broken lines standard errors of herbage yield (vertical lines) and seed yield (horizontal lines). The four accessions with high seed yield are ochrus chickling and teh remainder are common chickling.

Until now ICARDA has not tested its chickling collection for the presence of the neuro toxic agent, B - N - Oxaly 1 - L - B - diamino propionic acid (ODAP) which causes paralysis in animals and humans. We plan to do so in 1988/89. ODAP is the compound responsible for neuro-lathyrism produced by chicklings. Young animals and children are particularly susceptible, possibly due to the permeability of the blood-brain barrier in young animals (Briggs et al. 1983). Certainly there is no question of encouraging the release of any chickling species before testing for the presence of ODAP. - **Ali Abd El Moneim**

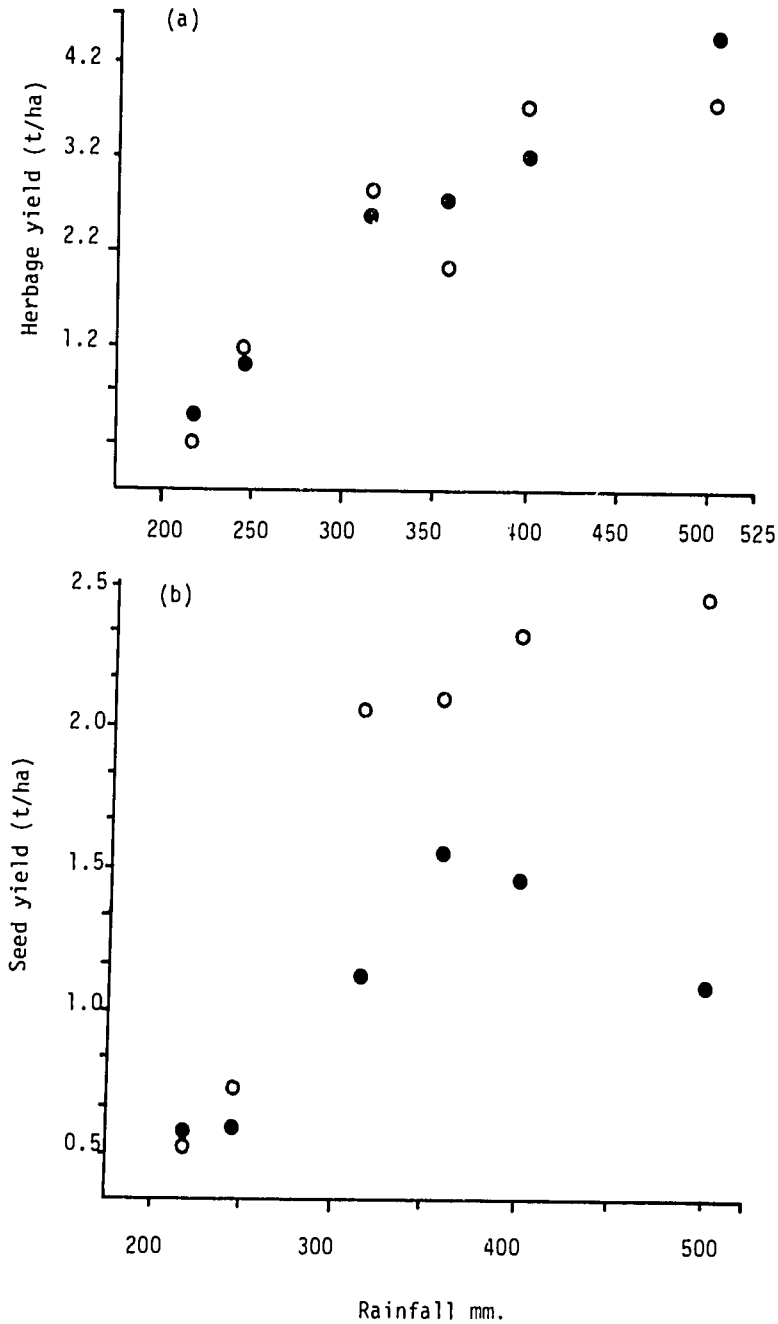


Fig.6.4. The relationship between rainfall and (a) herbage and (b) seed yields on the mean yield of common chickling (closed circles) and ochrus chickling (open cicles) at Tel Hadya and Breda in 1985/86, 1986/87, and 1987/88.

Expt 6.4: Selection for non-shattering (seed retaining) pods in six crosses of common vetch

Common vetch is the most widely used of the forage legumes in ICARDA's region. Unfortunately its use is restricted because of low seed yields caused by the shattering of seed pods. At present if a farmer wishes to harvest vetch seed he must do so before the pods are fully mature, a time when he finds it most difficult to obtain labour. If vetch pods did not shatter he could defer harvesting until after the cereal and lentil harvests and use family labour. Our objective is therefore to breed vetches the pods of which will not shatter even if the crop is left standing in the field until mid summer.

Wild non-shattering genotypes have been located. These are late flowering and therefore unsuitable in the dry areas for which our forage legumes are intended.

A breeding program for seed retention was initiated in 1984/85 and six crosses and their reciprocals were made between the late maturing non-shattering wild genotypes and a number of promising genotypes characterized by early maturity and a high proportion of pods that shatter. Gene markers such as pod, seed, and straw colours were used to eliminate pods which developed from selfing and to identify F1 hybrids. The perfonmance of F1 plants indicated that non-shattering is either completely or artially dominant over shattering.

In 1987/88 selection for non-shattering, early maturing genotypes with high herbage yield was continued and will be used to form F4 families. They will be compared in field trials with the adapted, shattering parents to measure seed yield. Selection will be in August when the intense summer heat is most conducive to pod shattering. Families with uniform growth, non-shattering

pods, and high herbage and seed yields will be selected for distribution and multilocation testing. - **Ali Abd El Moneim**

Expt. 6.5: Screening narbon and woollypod vetch for resistance to stem and leaf diseases

One of the most important selection criteria for developing productive forage legumes is resistance to major stem and leaf diseases. In 1987/88 nine promising genotypes of both narbon and woollypod vetch were tested under artificial infection.

Artificial epiphytotic infection with ascochyta leaf spot, stem blight and foot rot (Ascochyta pisi and Phoma medicaginis var. pinodella), powdery mildew (Erisiphe pisi E. Sp. Vicia sativa), downy mildew (Peronospora viciae), and Botrytis blight (Botrytis cinerea) were used for both species.

To determine the loss in seed yield a control was left without artificial infection, and seeds treated with 5g/kg of Galixin + Benlate 50 (1:1) for protection from seed borne diseases. At each artificial infection the control was sprayed with chlorothalonil 40% (Bravo 500), 2.5 ml/l to control Ascochyta blight, with Benlate 50 wp, 0.5 g/l to control downey mildew and Botrytis blight, and with a mixture of Cupravit 50 wp + Dithane M. 45 (1:1), 2.5 g/l to control downey mildew. A scale from 1 (resistant) to 5 (highly susceptible) was used to evaluate the lines.

Loss of seed yield (Q) was calculated as follows:

$$Q = \frac{(a - b) \times 100}{a}$$

Where a is seed yield of the protected treatment,
b is seed yield of the infected treatment,
and Q is the percentage of seed loss.

The results of scoring reveal that narbon vetch sels. 67, and to a lesser extent sel. 568, are tolerant to all three major diseases. Sels. 573 and 578 possess resistance and tolerance to Ascochyta blight and downy mildew respectively, and sels. 576 and 565 are tolerant to Ascochyta. The remainder (3 selections) are susceptible to all three diseases.

Crop losses varied from 10 to 36%, 2 to 45% and from 24 to 36% in the three diseases, respectively (Table 6.10). Narbon vetch sel. 67 is virtually resistant to two of the diseases but suffers from Botrytis blight, though less so than the other selections. In general woollypod vetch is less susceptible to the diseases than narbon vetch although it too is most susceptible to Botrytis blight (not shown). However infections of these intensities are unlikely in the dry areas.

Table 6.10. Percentage yield loss of nine genotypes of narbon vetch to artificial infections of Aschochyta blight, downy mildew, and Botrytis blight.

Selection	Aschochyta	Downy mildew	Botrytis blight
67	10	2	24
577	30	27	30
578	31	19	43
573	14	40	42
574	36	40	39
565	25	29	29
576	22	43	42
586	36	44	45
568	17	25	31

Sels. 800, 717 and 958 of woollypod vetch are moderately resistant to Ascochyta and downey mildew and tolerant of Botrytis blight. Sels. 801 and 956 are tolerant of all three diseases. - **Ali Abd El Moneim**

Expt 6.6: Screening forage germplasm for resistance to root diseases

Most of the forage legumes have been screened for resistance to root-knot (Meloidogyne artiella) and cyst (Heterodera ciceri) nematodes, and sources of resistance have been identified. The screening program is on-going as new germplasm is being developed and more seeds become available for testing.

In 1987/88, nine promising genotypes of narbon vetch and woollypod vetch were screened for resistance to both root-knot and cyst nematodes under natural condition in a field where the average number of second stage juveniles of root knot nematode was 3.550 larvae/g soil and of cysts was 340/kg. The results showed that losses in seed yield (compared with fields treated with carbofuran) varied from 47 to 76% in the case of narbon vetch and from two to 12% in the case of woollypod vetch.

Under artificial conditions in a green house, the infection rate of cyst nematode was 20,000 eggs/kg soil and of root knot nematode was 20 second stage larvae/g soil. Seeds were sown in earthen pots with six replicates of each genotype and three plants per pot.

At the flowering stage the plants were harvested, the roots washed carefully, and the density of nematodes on the roots determined. Nematodes were extracted and counted as number of nematodes/g roots.

The results revealed that all of the narbon vetch genotypes were highly susceptible to cyst nematode. To root knot nematodes six genotypes were tolerant and three lines moderately susceptible. In contrast all nine genotypes of woollypod vetch were tolerant to both of the nematodes. - **Ali Abd El Moneim**

CHAPTER 7: PRODUCTIVITY AND UTILIZATION OF FORAGE LEGUMES

In Chapter 6 we discussed the breeding and selection of forage legumes. In Chapter 7 we discuss aspects of how they are used and some problems associated with using them. In doing so we return to the farming systems approach that was outlined in Chapter 1.

Previously, on-farm experiments at Breda (280 mm rainfall) had given us valuable leads on what farmers expect from forage legumes and how they will use them. Due to lack of resources these farmers were unable to make hay and preferred to use the crops either for grazing at the green stage or harvesting when they reached maturity. The latter appeared to be easiest to manage, although it involved extra costs at harvesting. Though green stage grazing gave valuable feed for the fattening of lambs the feed became available when it could also be obtained from common land. The results of this research greatly influenced our subsequent breeding program, and this is manifest by an interest in straw yield and quality, and resistance to pod shattering.

However hay-making is practised in north Africa and so it remains necessary to measure herbage yield when a crop would be cut for hay. Many farmers are also interested in grazing, as some of our new research indicates. It is important therefore to keep our options open as to how forage legumes will be used, and to understand how the various methods of using them affect their profitability.

Chapter 7 includes three experiments, the first of which was completed in 1988/89, the second and third of which are continuing. We therefore present the results of two years data on the seasonal growth and quality of several vetch and chickling species (Expt 7.1), and present much briefer reports on further

on-farm experiments with forage legumes (Expt 7.2), and on anti-palatability factors in forage peas (Expt 7.3).

Expt 7.1: Growth and seasonal quality of forage legumes

The objective of this experiment was to analyse the growth of several forage legumes and to compare forage quality at various times during the growing season.

One of the problems we face in assessing productivity is at which time should herbage production and quality be measured. Our practice has been to measure herbage at the 100% flowering stage, because this is the time normally recommended for hay cuts, and to measure seed yield at maturity. But if farmers are more interested in grazing and straw this would seem to be unsatisfactory. Furthermore harvesting at a particular phenological age can mean big differences in chronological age and hence yield. Therefore we need to know whether growth continues after flowering at the same rate as before flowering, and the extent that forage quality changes between flowering and maturity.

Common chickling (sel. 439), ochrus chickling (sel. 104), Narbon vetch (acc. 67), woollypod vetch (acc. 683) and three genotypes of common vetch (sel. 2541, 2020 and 2037), were used in the experiment.

Identical experiments were sown in November 1986 and November 1987, at a seeding rate of 80 kg/ha, and a P_2O_5 rate of 40 kg/ha. A randomized block, with three replicates and 5 m x 5 m plots, was used. Each plot was sub-divided into several $0.5m^2$ subplots leaving adequate guard areas around the whole plot as well as between the sampling areas. At any one time, two $0.5m^2$ subplots were harvested to make up a total of $1m^2$.

There were six harvests each year, in March, April and May (Table 7.1). At each harvest, fresh material was weighed and sub-samples dried at 80-90°C for 24 hours. Further sub-samples were taken and separated into stems and leaves, and, near maturity into stems, leaves and pods, for determination of leaf/shoot/pod ratios. For the growth and development studies, the phenological stage of each entry was recorded at each harvest. Leaf area index (LAI) was measured using the electronic leaf area meter.

At each harvest, samples from each genotype, including stems and leaves, were ground and analysed for CP, IVDDM, ash, NDF, and ADF (abbreviations explained in the Introduction).

Growth and development: Based on herbage production at the first two harvests, all entries were able to survive frosts in both years. However both years were mild with less than the average number of frost days.

There were clear differences in phenology (Table 7.1). Ochrus chickling was the earliest to flower, reaching 50% flowering when the other entries were beginning to flower. In contrast two of the common vetches and the common chickling flowered more than two weeks later. Except for common chickling the entries matured by the 6th harvest, on 15 May and 24 May in 1986/87 and 1987/88 respectively. Within species maturity was approximately equal in the two seasons except for woollypod vetch which matured about 10 days later in 1987/88 than it did in 1986/87. Common chickling remained green for more than 15 days after the maturity of other entries.

Leaf Area Index (LAI): In both seasons LAI increased with time until the 4th harvest and then sharply declined (Table 7.2),

Table 7.1. Phenological stages at the different harvesting times.

Harvest Number		Plant age (days)	Woollypod vetch	Narbon vetch	Ochrus chickling	Common chickling	Common vetch sel. 2541	Common vetch sel. 2037	Common vetch sel. 2020
1	1986-87	66	V*	V	V	V	V	V	V
	1987-88	93	V	V	V	V	V	V	V
2	1986-87	87	V	V	V	V	V	V	V
	1987-88	100	V	V	V	V	V	V	V
3	1986-87	102	start F	start F	50%	V	start F	V	V
	1987-88	115	start F	start P	50%	V	start F	V	V
4	1986-87	118	100% F	50% P	50% P	100% F	50% P	50% F	50% F
	1987-88	130	30% F	50% P	50% P	100% F	start P	100% F	start F
5	1986-87	132	50% P	100% P	100% P	50% P	100% P	50% p	50% P
	1987-88	144	20% P	100% P	100% P	20% P	100% P	>50% P	30% P
6	1986-87	145	M	M	M	100% P	M	M	M
	1987-88	163	100% P	M	M	100% P	M	M	M

V = Vegetative, F = Flowering, P = Podding, M = Mature.

Table 7.2. Mean leaf area index of the different vetches and chicklings in 1986/87 and 1987/88.

Year/Harvest number		Plant age (days)	Woollypod vetch	Narbon vetch	Ochrus chickling	Common chickling	Common vetch sel. 2541	2037	2020	LSD (P<0.05)
1986-87	1	66	0.96	0.60	0.41	0.37	0.56	0.62	0.43	0.21
	2	87	3.02	1.42	0.97	1.06	1.34	1.18	1.12	0.37
	3	102	5.69	2.48	2.33	2.44	2.44	2.42	1.98	0.96
	4	118	6.98	4.09	3.95	4.49	5.04	4.63	4.07	1.27
	5	132	2.83	2.93	1.23	3.20	2.21	3.62	3.42	1.39
1987-88	1	93	2.13	1.32	0.82	0.80	1.47	1.18	0.97	0.50
	2	100	2.27	2.13	1.17	1.14	1.59	1.73	1.55	0.82
	3	115	6.78	4.28	2.32	3.00	4.00	4.06	4.33	2.28
	4	130	7.04	4.58	4.32	6.10	6.38	5.77	5.22	1.71
	5	144	4.72	3.21	4.58	6.23	2.96	6.12	4.80	1.35

narbon vetch, common vetch sel. 2037 and common chickling declining least rapidly (even increasing in 1987/88). With the exception of the 5th harvest in 1986/87, woollypod vetch maintained the highest LAI although not significantly so in the 4th harvest of 1987/88. Its peak LAI was 6.48 in 1986/87, and 7.04 in 1987/88.

The low LAI at the 5th harvest was associated with the death of old leaves. In the 1986/87 season, 58% of the leaves of ochrus chickling had died compared with only 11% in common vetch sel. 2020. In contrast only 24% of ochrus chickling leaves had died at the same stage in 1987/88, and this was the least of all the species.

Herbage yield: Fig. 7.1 shows the accumulation of herbage with time in the two years. The higher yield in 1987/88 was common to all species.

Differences in growth up to the 3rd harvest were very small, so the comparisons in Table 7.3 are of data from the 3rd harvest onwards. The entries differed in a variety of ways: in maximum herbage yield, the stage at which maximum herbage was attained, and the herbage produced at each harvest. In maximum herbage yield there were large differences (Table 7.3): in both seasons narbon vetch produced much more than the other entries, woollypod and common vetch sel. 2020 producing least.

Tables 7.1 and 7.4 show that woollypod vetch attained its maximum yield at 20 - 50% podding while ochrus chickling and common vetch sels 2020 and 2037 attained their maximum yields at maturity. Narbon vetch and common vetch sel. 2541 were intermediate, attaining maximum yields at 100% podding in 1986/87 and at maturity in 1987/88, while the yield of common chickling was greatest at 100% podding in both years.

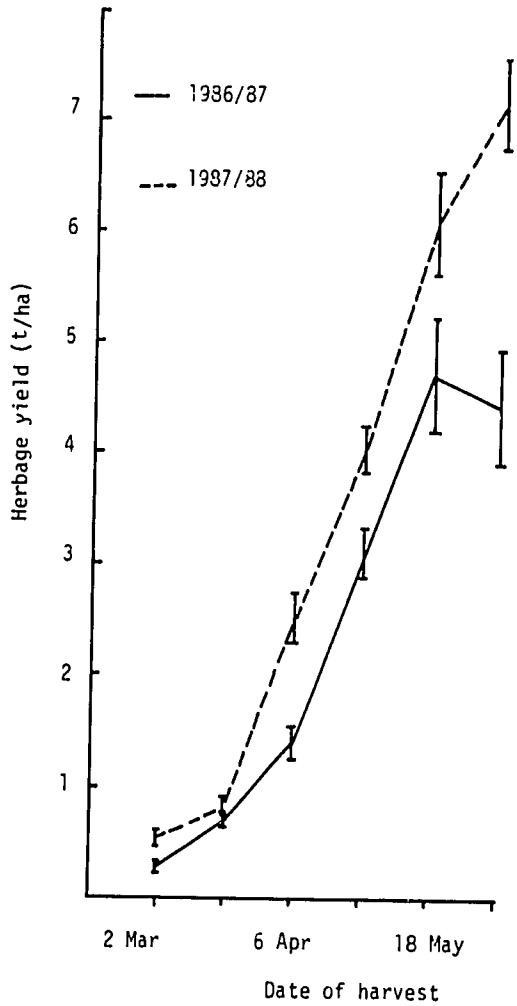


Fig.7.1. Cumulative yield of herbage (mean of all entries) of the seven forages in Expt 7.1. The bars represent standard errors.

In terms of its herbage yield woollypod vetch was best until the fourth harvest. Depending on the season, over 43% of its total yield was attained at the early flowering stage (Tables 7.1 and 7.3), and 92% and 76%, in 1986/87 and 1987/88 respectively, at 100% flowering (4th harvest). The other genotypes at similar development stages produced 50 - 71% of their maximum yield.

Table 7.3. Dry matter yield (t/ha) of the different vetches and chicklings from harvests 3 to 6 in 1986/87 and 1987/88.

Year/Harvest number		Plant age (days)	Woollypod vetch	Narbon vetch	Ochrus chickling	Common chickling	Common vetch sel. 2541	2037	2020	LSD (P<0.05)
1986-87	3	102	2.08	1.65	1.36	1.16	1.38	1.22	0.90	0.4
	4	118	4.01	3.82	2.84	2.64	3.47	2.78	2.18	0.65
	5	132	4.34	8.62	3.95	4.81	3.93	3.79	3.41	1.74
	6	145	3.69	6.05	3.98	4.49	4.74	4.33	3.61	1.68
1987-88	3	115	2.58	2.66	1.56	1.75	2.46	2.15	1.81	0.70
	4	130	4.51	4.93	3.49	4.07	4.31	3.80	3.00	0.67
	5	144	5.88	8.60	5.94	5.65	5.67	5.86	4.86	1.40
	6	163	5.68	9.83	7.70	7.12	6.54	7.69	5.30	1.25

Table 7.4. Dry matter yield (percentage of its maximum) produced by each vetch and chickling from harvests 3 to 6 in 1986/87 and 1987/88.

Year/harvest number		Plant age (days)	Woollypod vetch	Narbon vetch	Ochrus chickling	Common chickling	Common vetch sel. 2541	2037	2020
1987-88	3	102	47.9	19.1	34.2	25.8	28.9	28.2	24.9
	4	118	92.4	44.3	71.4	58.8	72.1	64.2	60.4
	5	132	100	100	99.3	87.5	100	87.5	94.5
	6	145	85.0	70.1	100	100	98.5	100	100
1987-88	3	115	43.9	27.1	20.3	24.6	37.6	28.0	34.2
	4	130	76.7	50.0	45.3	57.2	65.9	49.4	56.0
	5	144	100	87.5	77.0	79.4	86.7	76.2	92.7
	6	163	96.6	100	100	100	100	100	100

Next to woollypod vetch in the early harvests were ranked narbon vetch, ochrus chickling and common vetch sel. 2541, though differences in the 1987/88 season were less than in 1986/87. The high performance of woollypod vetch until the 4th harvest could be attributed to its early development of LAI (Table 7.2). From the 5th harvest onwards, narbon vetch outyielded all other entries.

At the 5th and 6th harvests all entries partitioned part of their biomass into pods (Table 7.5). There was considerable variation among the genotypes: in the 5th harvest, 35% and 26% of the biomass of ochrus chickling was in the pods in 1986/87 and 1987/88 respectively, common vetch sel. 2541 ranked next, and common vetch sel. 2037 was last. At the final harvest, narbon vetch and common vetch sel. 2541 allocated the greatest proportion of their biomass to pods.

Seed yield and harvest index (HI): Not surprisingly seed yield and HI followed the same pattern as proportion of pods at harvest 6. The entries could be grouped into two: a high yielding group (narbon vetch, ochrus chickling and common vetch sel. 2541) and a low yielding group. The latter was characterized by low HI.

Harvest index and seed yield are likely to determine the way in which farmers will use forage legumes. Those with high seed yield - narbon vetch and ochrus chickling - will be used as dual purpose crops for seed and straw, the animals feeding on the straw and high value seeds. Fortunately, the genotypes with high harvest index also had high biological yields the combination making these species potentially valuable as crops (Table 7.5). This is further supported by the fact that they attain maximum yield late in the season.

Table 7.5. Pod (% of biomass) in harvests 5 and 6, seed yield (t/ha) and harvest index of the vetches and chicklings.

Character		Harvest number	Woollypod vetch	Narbon vetch	Ochrus chickling	Common chickling	Common vetch sel. 2541	2037	2020	LSD (P<0.05)
Pods (% of biomass)	1986-87	5	14.77	34.63	34.63	10.73	40.7	8.70	14.93	5.80
	1987-88	5	13.22	21.26	25.85	3.97	26.25	6.18	8.99	7.46
Pods (% of biomass)	1986-87	6	39.20	54.0	49.50	29.4	61.90	33.80	44.30	8.80
	1987-88	6	38.26	35.40	49.1	29.57	45.63	25.76	29.30	8.30
Seed yield t/ha	1986-87	-	1.26	3.45	1.69	1.40	2.31	0.98	1.18	0.684
	1987-88	-	1.14	2.96	2.76	1.33	2.37	1.28	0.93	0.453
Harvest index	1986-87	-	0.26	0.36	0.30	0.24	0.33	0.18	0.25	-
	1987-88	-	0.20	0.30	0.36	0.19	0.36	0.17	0.18	0.061

Common vetch (sel. 2541) may also be a good crop species, especially if the non-shattering pod character is introduced. However it is classified as a triple purpose or even quadruple purpose legume - grazing, hay, seed, straw - being one of the most palatable (to animals) of all the legumes (Osman and Thomson 1984). It should therefore be included in the second group also, whose uses are likely to be restricted to grazing and hay making.

Forage quality: The purpose of growing forage legumes is to feed animals: quality is one of the main factors determining animal yield. Many estimates of quality have been developed by chemists, none of which accurately predicts the intake and conversion of feedstuffs. In vitro digestibility (IVDMD) is generally considered to be one of the most important (Hutton 1975).

The legumes in general, provided they are free of toxic or antipalatability factors, can be considered to be high quality feedstuffs. They are almost invariably high in protein, and this can be used to increase appetite for other lower quality feedstuffs: as was seen in Chapter 5 one of the benefits of legumes is that they encourage the utilization of cereal straw. Even the straws of legumes are far higher quality than those of most other crops.

Changes in quality parameters with time are depicted in Fig. 7.2. There were progressive reductions in percentage of crude protein (CP), and leafiness also fell as both neutral and acid detergent fibre (NDF and ADF) increased.

Very limited seasonal differences were observed (Fig. 7.2). IVDMD was almost the same in both seasons, while CP and leafiness were higher in the wetter season of 1987/88. Both NDF and ADF

were higher in 1987/88. Total amounts of digestible dry matter (DDM) and CP increased until the last (1987/88) and second last (1986/87) harvests (Fig. 7.3).

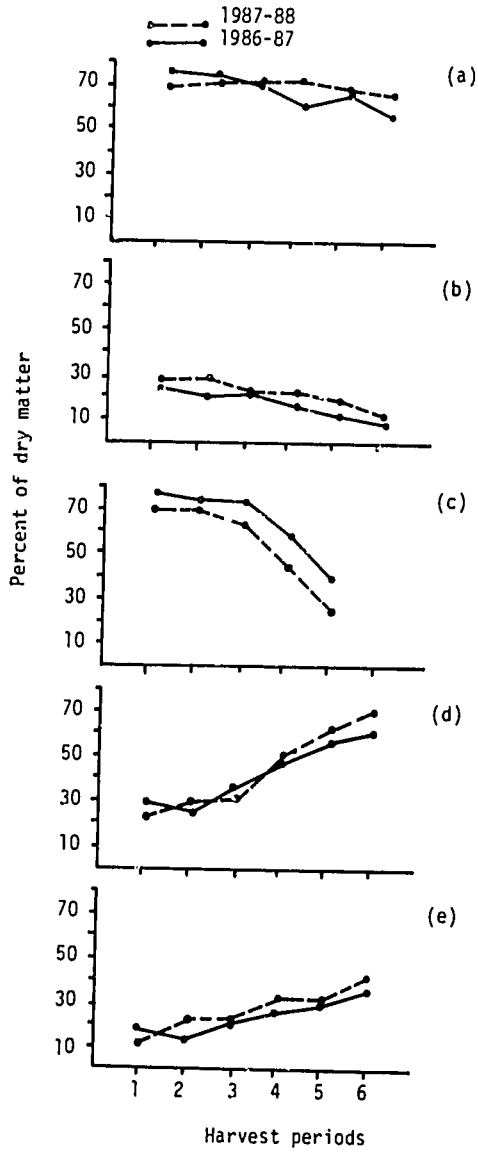


Fig.7.2. Change with time of (a) in vitro digestible dry matter, (b) crude protein, (c) leafiness, (d) neutral detergent fibre, and (e) acid detergent fibre. Data are means of all entries in 1986/87 and 1987/88.

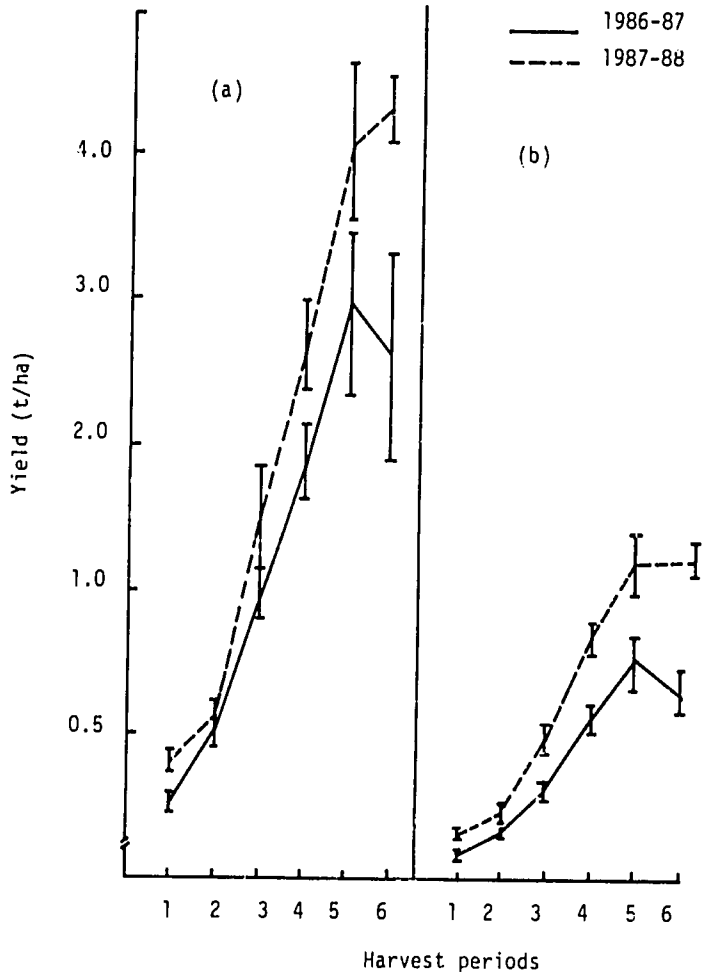


Fig.7.3. Change with time of (a) yield of in vitro digestible dry matter and (b) crude protein of the standing biomass (mean of all entries in Expt 7.1). The bars represent standard errors.

Table 7.6 shows the different quality attributes of the genotypes in the last three harvests of 1986: the data from 1987/88 are broadly similar. All seemed to attain maximum DDM yield at harvest 5, when they were at the stage of 50-100% podding, some genotypes declining by harvest 6. Narbon vetch had the highest DDM in the last three harvests, and there was little difference between the other genotypes (Table 7.6). An

Table 7.6. Seasonal changes in the nutritional parameters of the seven legumes (abbreviations are explained in the Introduction).

Character	Harvest number	Woollypod vetch	Narbon vetch	Ochrus chickling	Common chickling	Common vetch sel. 2541	2037	2020	LSD (P<0.05)
DDM (t/ha)	4	2.41	2.38	1.81	1.65	2.10	1.55	1.17	0.40
	5	3.00	4.96	2.93	2.86	2.91	2.55	2.23	1.12
	6	2.10	3.56	2.30	2.64	2.89	2.33	2.07	0.94
CP yield (t/ha)	4	0.72	0.61	0.48	0.59	0.59	0.45	0.39	0.15
	5	0.64	1.27	0.64	0.76	0.76	0.53	0.57	0.31
	6	0.50	0.89	0.54	0.67	0.73	0.54	0.53	0.24
CP (%)	4	17.8	16.0	17.0	22.5	17.00	16.1	17.7	2.31
	5	13.1	10.1	11.1	19.2	13.1	13.2	15.9	3.02
	6	8.2	5.0	6.1	9.8	4.6	7.9	9.0	3.27
IVDMD (%)	4	60.0	62.5	63.7	62.5	60.6	55.7	54.2	8.66
	5	68.7	57.6	55.2	73.1	60.5	66.8	66.1	7.02
	6	54.3	55.2	54.2	56.0	53.0	52.2	55.6	4.55
NDF (%)	4	42.54	46.94	41.90	38.04	43.46	39.29	36.87	3.82
	5	47.56	46.56	40.81	45.37	48.78	46.36	46.00	3.80
	6	52.66	54.84	47.47	48.53	57.09	47.86	45.17	4.37
ADF (%)	4	29.13	28.11	20.85	25.45	26.74	24.55	21.14	1.97
	5	28.20	29.63	24.07	27.11	25.93	26.33	23.60	2.79
	6	37.12	37.53	31.83	34.86	41.41	32.87	29.33	3.31
Leafiness	4	0.53	0.41	0.70	0.49	0.61	0.67	0.74	0.03
	5	0.28	0.23	0.28	0.30	0.43	0.54	0.54	0.11
	6	-	-	-	-	-	-	-	-

appreciable portion of the DDM yield at maturity was partitioned into the pods (Table 7.7): for example in both seasons, 50% of the DDM yield of ochrus chickling and common vetch sel. 2541 was in the pod, and, in 1986/87 narbon vetch had 57% of its DDM in pods. These differences however, are unlikely to have biological significance.

Crude protein yield also varied between genotypes and seasons (Table 7.6). Most genotypes attained maximum CP yield at harvest 5. At maturity, narbon vetch and common chickling sel. 2541 had the highest CP yields. As with DDM most of the CP yield in narbon vetch, ochrus chickling and common vetch sel. 2541 was in the pods. These differences also seem to have limited biological significance, although the low crude protein contents of narbon vetch, ochrus chickling, and common vetch (sel. 2541) may possibly affect intake.

Table 7.7. Mean digestible dry matter (mean of 1986/87 and 1987/88) and crude protein yields in the pods (% of total yield) in harvest 6 of the different forage vetches and chicklings.

	DDM	CP
Woollypod vetch	41	45
Narbon vetch	48	62
Ochrus chickling	53	54
Common chickling	32	33
Common vetch		
- sel. 2541	57	66
- sel. 2037	31	39
- sel. 2020	38	40
LSD ($P<0.05$)	12	18

Narbon vetch was the least leafy and had highest ADF and NDF in its straw. Straw quality of this species (or at least the genotype in this experiment) is lower than that of the other species. In most respects however, this lower quality may have limited biological significance and is unlikely to be a factor preventing its use as a crop for grain and straw.

Unfortunately feeding trials have suggested that intake of both narbon vetch and woollypod vetch is less than common vetch (Osman and Thomson 1984). In the past this lower intake has been attributed to higher NDF (van Soest and Robertson 1979), although Pigden (1969) believes that only when NDF exceeds 60%, exceeded by the straw of narbon vetch in 1987/88, will it affect intake. The poor leafiness of narbon vetch may also be a factor: as Minson (1975 & 1982) points out, leaves are preferred to stems even when NDF is similar. It is also possible that the lower intake of narbon vetch is associated with antipalatability factors: we will beging research on the tannins in narbon vetch in 1988/89.

The results of Expt 7.1 (and also Abd El Moneim et al 1988) support our assertion in Chapter 6 that both ochrus chickling and narbon vetch are potentially useful crops (Table 7.7). They need genetic improvement and this will require a multi-disciplinary approach involving plant breeders, chemists, and animal scientists. Selection should be for low levels of toxic compounds, grain yield, crude protein and digestible dry matter yield of straw, and palatability. Leafiness, especially leaf retention at maturity, also seems worth selecting as this appears to be closely correlated with protein content (Gupta 1968, Dangi and Paroda 1974), digestibility (Meyer and Jones 1962) and intake (Hutton 1975), - **Ali Abd El Moneim, and Mohamed Khair (Visiting scientist, ARC, Sudan)**

Expt 7.2: On-farm forage and grazing trials at El Bab (Preschedule L24)

The objectives of Expt 7.2 are (1) to measure the effect on whole-farm productivity and subsequent barley grain and straw yields of replacing the entire fallow land on farms with common vetch and chickling, (2) to introduce both forage and pasture legumes to farmers, (3) to measure yields of seed and straw harvested at the mature stage, (4) to measure the spring growth rate of lambs, and (5) to assess farmers' reactions to forage and pasture legumes and fertilizer use.

The experiments are replicated on six farms, two on deep soils of a valley bottom, two on the shallow soils of hillsides, and two on intermediate soils. Before sowing, soils were analysed for available phosphorus, and gross differences in phosphorus eliminated by applying fertilizer. Each site covers about 2ha, and is divided into two areas separated by 10m of fallow land. The two areas are split and common vetch and chickling sown in each strip. One 10 X 10m medic plot, with 10 x 10m barley plots on each side, is sown in the fallow strip. The treatments are therefore common vetch (V), chickling (C), medic (M) and fallow (F) in rotation with barley, and continuous barley (B). An adjacent 2ha piece of land is sown to barley and completes the second phase of the rotation. At some sites with deep soil 2ha medic fields were sown to allow for grazing experiments in future years.

Small areas of crops were sampled at the hay stage (50% flowering), and other areas sampled at the mature stage to estimate grain and straw yields. At three sites, including the two with deep soil, the crops were harvested for grain and straw, and on four farms, starting in early April, they were grazed by lambs.

If farmers chose the grain and straw option their yields would have been like those in Table 7.8. The biomass of all three crops (vetch, chickling and barley) was similar, but the better harvest index of barley resulted in its yield of grain being slightly higher. The feeding value of the three crops needs to be evaluated but the much higher quality of the legume straw almost certainly compensates for lower grain yields.

Table 7.8. Straw and seed yields (kg/ha) of common vetch and chickling growing on farmer's fields at El Bab.

	Common vetch	Chickling	Barley	SEM(1)	Sig(2)
Straw yield	3566	3037	2544	92	*
Seed yield	881	1062	1484	63	ns
Total	4447	4099	4028	142	ns

(1) Standard Error of Mean
(2) Significance of differences in yield

The other option offered to farmers was to use the forage for grazing. Four of the six farmers chose this option, although in discussions since harvest the farmers have indicated that they see the main value of forages in straw and seed for winter feeding. Table 7.9 shows the biomass 25 days after grazing began in protected areas - vetch clearly produces earlier feed than chickling but the latters growth rate (81 kg/ha/day) is substantially greater than the formers (57 kg/ha/day) during spring itself. Note that vetch had nearly 1 t/ha more biomass than barley, though the difference just failed to reach statistical significance. This comparison - biomass at grazing - is valid because on the shallow soils farmers use the barley mainly for grazing.

Table 7.9. Herbage yields (kg/ha) of common vetch, chickling and barley at the start of grazing and 25 days later (kg/ha).

	Vetch	Chickling	Barley	SEM[1]	Sig[2]
At the start	2379	1141	-		
After 25 days	3795	3168	2868	483	ns

(1) Standard Error of Mean
(2) Significance of differences in yields

The growth rates of lambs on the four fields used for grazing are shown in Table 7.10. From left to right in the Table the soils are shallow (two columns), intermediate, and deep: the value of grazing is therefore in soil reflected depth. The lambs also received 300 g/day of barley as a supplement to the forage: whether this is necessary is not clear, although at Tel Hadya we have been able to raise lambs on medic pasture without supplementation, and growth rates have reached 280g/day.

Table 7.10. Performance of lambs grazing vetch and chickling grown on four farms at El Bab (for description of farms see text).

	1	2	3	4
Grazing days	46	48	48	51
Stocking rate (lambs/ha)	36	35	45	39
Daily gain (g/lamb)	166	157	167	193
Mass gain (kg/ha)	278	263	361	394
Gross revenue[3]	16680	15780	21660	23640

(3) 60 SL per kg of liveweight

Gross revenue is simply the total gain in lamb biomass multiplied by its price as received by the farmers in 1987/88. Gross revenue is included chiefly as a reminder that the experiment will be subject to economic analysis.

The grain and straw yields of barley after last year's forages are shown in Tables 7.11 and 7.12. Table 7.11 shows a significant though small increase in grain yield after nitrogen

Table 7.11. Yields (kg/ha) of barley, with and without ammonium nitrate as a spring dressing.

	- N	+ N	SEM(1)	Sig(2)
Straw yield	2218	2869	49	**
Seed yield	1372	1595	40	*
Total	3590	4464	69	**

(1) Standard Error of Mean
(2) Significance * = P<0.05
** = P<0.01

Table 7.12. Yields (kg/ha) of barley after forages, fallow and barley (for crop abbreviations see text).

	V	C	B	F	M	SEM(1)	Sig(2)
Straw yield	2830	3079	2126	2685	2341	80	**
Seed yield	1599	1727	1401	1536	1601	44	ns
Total	4429	4806	3526	4221	3942	97	**

(1) Standard Error of Mean
(2) Significance ** = P<0.01, ns = not significant

application, and a slightly larger increase in straw yield (and probably straw quality). Table 7.12 shows barley yields after vetch (V), chickling (C), barley (B), fallow (F) and medic (M). The data support earlier experiments showing high barley yields after chickling. We are not clear as to why this should be so.

Comparison of forage legumes with medics is a secondary aim of Expt 7.2. Within the forage plots the yields of the smaller medic plots were approximately equal to that of vetch and chickling (Table 7.13). This was first year medic: in regenerating medic the yields will probably be substantially higher. Medic seed yields varied from 400 kg/ha (on shallow soil) to 720 kg/ha on deeper soils. Larger plots (2ha) have also been sown though the results, except for seed yields after grazing (Table 7.14), are not being monitored. The high seed yields indicate that the farmers are being cautious in the way they use the medic.

Table 7.13. Biological yield of common vetch, chickling and medic at maturity.

	Vetch	Chickling	Medic	SEM(1)	Sig(2)
Total	4447	4099	4574	208	ns

(1) Standard Error of Mean
(2) Significance

The forage legumes have created considerable interest among the farmers. Two more sites will be added this year and seed has been distributed to a further eight farmers - we will monitor how these farmers use the seed. There is also considerable interest in medics among the participating farmers.

Table 7.14. Seed yields of first year and regenerating medic after grazing on farmers fields at El Bab.

		kg/ha
First year pasture		680
Second year pasture	(above ground)	590
	(buried)	610
	Total	1200

We hope to include narbon vetch and ochrus chickling in our on-farm experiments in the near future. - **F. Bahhady and E.F. Thomson**

Will sheep eat forage peas?

A few year ago scientists at ICARDA believed that forage peas (Pisum sativum) were one of the most potentially useful crops for dry areas. They produced high grain yields and appeared to give good economic returns while maintaining barley yields (Keatinge et al 1985). Unfortunately the sheep did not agree, and body mass gains from and intake of peas were found to be substantially below that of other forage legumes (Thomson 1984). Subsequent research has shown that, while the yield potential is equal to that of vetches, chickling, and barley, intake at the hay and immature stages is less than 25% of those crops. Even as straw peas appear less palatable than either vetch or chickling though equally as palatable as barley.

The low intake of peas cannot be attributed to low digestibility because in-vivo digestibility is similar to the

readily-consumed vetches. That intake of peas remains low for long periods, and that sheep will lose weight rather than eat peas indicates that sheep do not adapt to the diet. Syrian local peas appear to possess a bitter anti-palatability factor (APF) which reduces voluntary intake.

Similar problems have been observed in Spain and Tunisia. On the other hand reports from Australia indicate that lambs grazing mature peas show no undesirable effects and their daily body mass gain is comparable to that achieved with vetch and lupins (Allden and Geytenbeek, 1984). In Canada, pea silage fed to lambs results in significantly higher voluntary intake, body mass gain, and digestibility, compared to oat and corn silage (Thorlacius and Beacom, 1981).

Both physical and chemical factors can affect intake (which we use as a synonym for palatability). Some of the physical factors are particle size, water content, and fracturing capacity, and these inter-relate with animal factors such as size of mouth, degree of hunger, and so on. The actual availability of the herbage, and whether the growing plant is prostrate or upright, also affect intake. We know that tannins (Griffiths 1981) and organoleptic compounds (Price and Fenwick 1984) occur in the testa or flour of pea seeds, although the levels appear no higher than in faba beans or soybeans. The presence or absence of heat stable anti-palatability factors, including saponins, alkaloids, flavones, isoflavones, cyanogenic glucosides and toxic animo acids is simply not known.

None of the current research explains why palatability of the plant increases with maturity and why the phenomenon does not appear to have been reported before. Perhaps the plant synthesizes a compound at budding stage for protection: if so, what is it and where is it synthesized? Perhaps there is a

chemical stored in the seeds which is translocated through the plant as it matures and is later re-stored back in the new seed. Is this problem general or are some pea genotypes free of anti-palatability factors? Could the gene causing anti-palatability be introduced into food legumes so they could be 'weeded' by animals during growth without adversely affecting the taste for human consumption? The list of questions is endless.

Expt 7.3: Order of preference of the straws of 20 peas genotypes

This experiment used straws of pea genotypes being tested at ICARDA by FLIP (their co-operation is hereby acknowledged). Its objective was to obtain preliminary data on the comparative palatability of a broad collection of pea genotypes.

The straws were chopped to lengths of 2-3 cm and fed to 110 ewes from the ICARDA flock. To make sure that they were hungry the animals had no access to feed for the previous 12 hours although water was freely available. The sheep had been randomly split into five groups of 22 animals (for the 20 pea straws and two controls). The animals were individually yoked and fed 300g of straw for 30 minutes, after which refusals were collected and the quantity eaten estimated.

Table 7.15 shows straw composition, <u>in-vitro</u> digestibility and intake/30 minutes. Highest intake was, as expected, of vetch straw: however the Table shows clearly that there were substantial differences in intake of pea genotypes from 222g to 114g/30 minutes. Chemical composition of the straws varied little and no relationship could be detected appears to exist between composition and intake. Although IVDMD does not seem to be related to intake, the short time span of the experiment may

not be enough to set in motion the digestive feedback mechanisms which would compensate for the differences. Differences of this kind are more likely to be due to differences in the animals' senses of touch, taste and smell.

Within treatments there were wide differences between individual animals, probably reflecting 'personal' likes and dislikes: some sheep ate everything offered to them while others ate little. It is noteworthy that the coefficients of variation were much larger for the less palatable straws than for the tasty straws.

Table 7.15. Mean intake of digestible dry matter (DDMI) ± standard deviation, the coefficient of variation (CV) and chemical analyses of the pea straws.

Genotype	DDMI/30 mins	CV	DM%	OM%	ASH%	CP%	ADF%	IVDMD%
Vetch	239 ± 25	10.7	87.5	89.2	10.8	6.9	37.3	45.2
Lincoln	222 ± 20	9.0	86.5	88.8	11.2	7.4	35.0	52.0
Kodiak	219 ± 48	21.9	86.8	92.6	7.4	7.3	35.3	47.5
Kelvedon Wonder	219 ± 56	25.6	87.0	90.5	9.5	5.9	40.7	38.9
Maro	217 ± 57	26.3	85.7	88.3	11.7	7.7	40.0	48.2
Prograte	215 ± 41	19.1	87.1	89.3	10.7	8.3	36.1	45.3
Early Onward	210 ± 31	16.7	86.0	90.4	9.6	7.6	37.5	47.8
Small Sieve Freezer	208 ± 45	21.6	87.3	91 6	8.4	7.9	35.5	48.7
Baf	192 ± 52	27.1	85.8	91.4	8.6	6.3	38.6	47.7
Sprite	190 ± 25	13.1	85.6	91.2	8.2	6.0	35.1	51.0
Despe	183 ± 44	24.3	85.6	91.1	8.9	6.2	41.1	45.8
Dark Skin Perfection	186 ± 101	54.3	85.4	91.1	8.9	8.3	35.6	49.6
Upton	175 ± 74	42.3	86.1	90.5	9.5	5.7	38.7	44.8
Scout	173 ± 53	30.6	85.9	91.2	9.0	7.5	41.5	48.3
Filby	169 ± 42	24.9	85.7	90.1	9.9	7.2	37.0	46.0
Frisson	167 ± 55	32.9	86.8	90.7	9.2	6.6	38.1	46.1
Onward	163 ± 103	63.2	85.4	90.5	9.5	9.3	33.3	53.0
Alaska-16A	150 ± 63	42.0	86.0	92.3	7.7	6.1	40.6	44.4
Petit Provencale	150 ± 35	23.7	86.4	91.4	8.6	7.5	36.7	50.8
Syrian Local	133 ± 90	67.7	86.7	91.2	8.3	6.7	45.9	42.6
Facima	114 ± 88	77.2	86.6	90.0	10.0	8.9	34.0	51.5

Further analysis of the best and worst straws is being carried out at the Royal Veterinary College. In this way we hope to identify the antipalatability factors present.

The results of Expt 7.3 are of great interest in that they confirm our earlier observations of the low palatability of peas in Syria: the variety 'Syrian local' was one of the least palatable straws tested. It also shows that there is considerable variation in palatability. However we must not lose sight of the fact that palatability of straw is greater than of green material, even of 'Syrian local', and it is with green material that we are most likely to find the anti-palatability factors.

Expt 7.4: Palatability of pea grain

The objective of Expt 7.4 was to compare the intake of feeds containing pea grain with feeds containing vetch grain.

Four diets were prepared and fed to four groups of four female lambs. The lambs (approximately four months old) were individually penned. The diets were as follows:

Diet A: 25% peas and 75% barley
Diet B: 50% peas and 50% barley
Diet C: 75% peas and 25% barley
Diet D: 25% vetch and 75% barley

All grains were cracked to prevent selection by the lambs. The diets were analysed for dry matter, ash, organic matter, crude protein, neutral detergent fibre, and *in vitro* digestibility.

Each group was allocated one diet and, with 2kg of good quality hay to maintain rumen function, offered 2kg twice daily. Refusals were collected daily and group intake measured for 14 days. To see if the lambs had adapted to their test diets, they were reweighed, repenned and, for the next 4 days, offered 1kg of all the diets concurrently for one hour. Intake of each diet as a proportion of total intake was calculated.

No adverse effect of inclusion of pea grain was observed: indeed intake increased as the proportion of peas included in the diet increased (Table 7.16). However, when diets A & D were

Table 7.16. The composition and intake of four pea diets (A, B, C, and D) fed to lambs for 14 days.

Diet (percentage peas)	A (25%)	B (50%)	C (75%)	D vetch control
Composition (%)				
Dry matter	88.4	88.5	88.2	88.6
Organic matter	97.0	97.0	96.3	97.6
Ash	3.0	3.0	3.7	2.4
Crude protein	15.8	19.2	23.0	15.7
NDF	8.5	7.9	10.0	6.9
IVDMD	64.4	63.7	66.4	63.8
Energy (MJ/kg)	13.1	13.2	13.3	13.2
Dry matter intake (DMI)/14 days (kg)	25.5	38.7	42.1	35.0
Body mass gain/14 days (kg)	9.9	17.9	13.1	12.9
DMI/body mass gain	2.57	2.16	3.21	2.71

compared it appears that the animals preferentially ate the vetch diet. The largest increase in weight gain occurred on diet B: 75% peas. It would appear that inclusion of vetches greatly improves palatability. However this is a preliminary experiment and the results must be treated with caution.

Table 7.17 shows the intake of the four diets by the four groups of lambs when offered a choice of diets. Group 1, previously offered diet A, showed a slight preference for diet C (the high level of peas), group 2, previously offered diet B, showed no preference, group 3, previously offered diet C, preferred diet D (the vetch diet), while lambs previously eating the vetch diet, ate only vetch or the low pea diet leaving the other diets largely untouched.

Table 7.17. Average intake of each diet as a proportion of total intake when all four diets were offered together.

Diet group	Previously offered	A	B	C	D
1	A	0.27	0.20	0.34	0.19
2	B	0.24	0.25	0.27	0.24
3	C	0.23	0.22	0.22	0.33
4	D	0.41	0.10	0.08	0.41

These results suggest that animals do acquire a taste for peas and can adapt to diets including pea grain.

In addition to Expts 7.3 and 7.4 two other experiments were conducted. These await chemical analysis but the results indicate the following:

- some genotypes of peas are even more palatable than vetch, and

- the palatability of plant parts of green peas appears to be in the following order: flowers, stems, leaves and stipules, and pods.

The experiments include measurement of the digestibility of fresh herbage, hay, and straw, and the rate of passage through the animals of chromium mordanted straw. - **E. Carter (Royal Veterinary College, University of London)**, and **E.F. Thomson**

CHAPTER 8: IMPROVING THE PRODUCTIVITY AND MANAGEMENT OF MEDITERRANEAN ANNUAL-TYPE GRASSLANDS

In this Report we have redefined the term 'marginal land'. Our old definition included two classes: non arable land within the cereal zone, and arable land adjacent to the steppe. These have proven to be confusing, and though useful in ICARDA-wide documents, have been replaced in these more detailed discussions.

The term 'marginal' implies some degree of choice. Our definition of marginal land within the cereal zone uses the phrase 'non-arable', which suggests that farmers have no choice but to use the land for grazing. This is true of steep and stony land but is not strictly true of land at the edge of the steppe where cultivation is possible but the risk of crop failure unacceptably high. We will continue to use the term 'marginal land' for the latter class of land, and use the term 'Mediterranean grasslands' for the former: the non-arable land within the cereal zone. The work we report this year is about Mediterranean grasslands.

We are not neglecting marginal lands <u>sensu strictu</u>, however. In 1988 we reached agreement with the Syrian Steppe and Range Directorate and ACSAD to conduct a large experiment on the management of marginal land in which edible shrubs have been re-established. The experiment will be on the type of land sometimes used for continuous barley or more frequently for continuous stocking of heavily degraded natural pasture. The site is typical of land under threat of desertification, one of the most serious causes of instability in agriculture within west Asia and north Africa.

Before human settlement the marginal lands were dominated by small trees, shrubs and perennial grasses. Mediterranean grasslands however, are today dominated by annual species of

grasses, legumes and herbs. They are overgrazed and the subject of severe soil erosion. Improving the productivity and management of these grasslands is therefore a high priority in the development of sustainable farming systems.

The grasslands are an important resource in the Mediterranean basin, both from the ecological and economic perspectives. They occupy a huge area, and support the grazing of sheep and goats, especially in spring. But because of low productivity, livestock also need barley grain, green barley, and other forages.

The objective of the work reported in Chapter 8 is to integrate livestock production on grasslands with that on the neighbouring arable lands, through (a) improving productivity of the pastures and (b) improving grazing management. Options for improving pasture productivity include:

- sowing improved pastures;
- applying suitable fertilizers;
- proper grazing management; and
- a combination of two or more of the above.

Expt 8.1 was designed to look at the effect of small additional amounts of phosphorus on the grazing capacity of grasslands. Expt 8.2 explores the possibility of resowing grasslands with improved pasture species, Expt 8.3 assesses the variability of grasslands and the consequences of variability on their improvement, and Expt 8.4 looks at variability in legume populations and their responsiveness to phosphorus.

Expt 8.1: The effect of applying superphosphate on the productivity of Mediterranean grasslands

The objectives of Expt 8.1 are (1) to monitor the effects of stocking rate and phosphorus application on the vegetation of

grasslands, (2) to measure the response of livestock production to phosphate application and to test whether the responses, if any, are profitable, and (3) to assess the carrying capacity of grasslands and to look for botanical indications of over grazing.

The experiment consists of three superphosphate rates (0, 25 and 60 kg P_2O_5/ha); and low (1.2 ha/sheep) and high (0.65 ha/sheep) stocking rates. Triple superphosphate is broadcast every year in November. Ninety Awassi ewes were divided into groups of five, each containing 2, 3, 4, 5 and 6 year old ewes.

Each group is permanently assigned to large (6.5 ha) or small (3 ha) plots, representing the low and high stocking rates, respectively, in each of the fertilizer treatments. The experimental design is a randomized complete block with three replications. Each year measurements are taken on soil phosphorus, botanical composition of the pasture, and herbage and seed yields. Herbage is sampled at regular intervals (every 3 to 4 weeks from December to May) to estimate yields of legume, grass and other species, and seed yield is assessed in June. Measurements of soil organic matter were taken at the beginning of the experiment and four years later in 1988. Animals graze the plots from early morning to sunset and are sheltered at night. Sheep are fed with barley grain during late pregnancy and early lactation (December to February) and in July and August each year in preparation for mating. Barley and hay is also provided whenever body mass falls below 43 kg (see Chapter 5 for a more extensive discussion of grazing management).

Table 8.1 indicates that the level of available phosphorus was less than 10 ppm when the experiment began, but has steadily increased as the result of annual applications of fertilizer. Phosphorus application, even at 25 kg/ha, has alleviated the phosphorus deficiency.

Table 8.1. Available phosphorus (ppm of Olsen P) in the soil of grassland in relation to different levels of phosphate and stocking rate.

Phosphate (kg/ha)		Year*		
		1984	1987	1988
0		7.86[a]	4.96[a]	4.61[a]
25		6.58[a]	9.07[a]	24.38[b]
60		7.17[a]	16.17[b]	54.64[c]
Stocking rate(1)	Low	7.44[a]	10.00[a]	26.76[a]
	high	6.97[a]	10.10[a]	28.98[a]

(1) Low = 1.3 ha/sheep and high =0.65 ha/sheep

* means in each column are significantly different ($P<0.01$) if followed by different letters.

Table 8.2 shows the presence of legumes in relation to other species. The legumes are increasing slightly as a result of the fertilizer and substantially with time. Annual variation in yield of legumes (Table 8.3) is partly attributed to rainfall (amount and distribution), although there is a strong suggestion that the effect of fertilizer is accumulating each year. The increase with time is attributed to the build up of plant numbers due to the continuous grazing. Plant size responded to phosphorus each year (Table 8.4). In 1987/88 the herbage yield of legumes ranged between 2.2 and 2.8 t/ha, reflecting the potential productivity of grasslands when moisture and phosphorus are not limiting factors. Fig. 8.1 (a) shows that grasses are contributing more than legumes to the total dry matter in the

Table 8.2. The percentage of annual legumes (of the whole biomass) in grassland[1] in relation to the level of phosphate and stocking rate.

Phosphate (kg/ha)		Year*		
		1984	1987	1988
0		26.4[a]	38.0[a]	48.5[a]
25		31.2[a]	46.8[b]	51.5[a]
60		29.3[a]	48.7[b]	52.0[a]
Stocking rate[2]	Low	30.5[a]	46.5[a]	52.6[a]
	high	27.1[a]	42.4[a]	48.6[a]

(1) estimated in April/May each season
(2) low = 1.3 ha/sheep and high = 0.65 ha/sheep
* means in each column are significantly different ($P<0.05$) if followed by different letters.

Table 8.3. Herbage yield (kg/ha) of legumes on grassland as affected by phosphate in different seasons[1].

Phosphate (kg/ha)	Seasons			
	1984/85	1985/86	1986/87	1987/88
Rainfall (mm)	373	316	343	499
0	17	38	143	879
25	352	117	498	2163
60	302	184	636	2831
LSD ($P<0.05$)	98.7	60.3	158.8	543.2

(1) estimated in April each year.

Table 8.4. Legume plant numbers (per m^2) and mass (mg/plant) in grassland as affected by phosphate in different seasons[1].

Phosphate	1984/85		1985/86		1986/87		1987/88	
(kg/ha)	No.	Mass	No.	Mass	No.	Mass	No.	Mass
0	301	60	70	50	228	60	757	120
25	759	50	200	60	440	110	1603	130
60	584	50	238	80	523	120	1647	170
LSD (P<0.05)		191		64		140		445

(1) plant numbers counted in April each year.

absence of phosphate fertilizer during winter. Adding phosphate (Fig. 8.1 b) results in legumes contributing more dry matter than grasses as early as January and continuing to do so until the end of the season.

The increase in plant population and productivity seem to have increased the level of organic matter in the soil, especially where phosphate was applied. The increase is also affected by stocking rate, being highest under low stocking rate (Table 8.5). Although these differences have yet to achieve statistical significance, they have profound biological and environmental significance. In the grasslands there has been a steady degradation over a long period, perhaps hundreds of years. The soil organic matter levels show that this degradation is being reversed, soil organic matter being one of the best indicators of the likelihood of soil erosion.

Of even more importance are the results in Table 8.6, and these have achieved statistical significance. Two of the

strongest indicators of degradation in Mediterranean grasslands are low numbers of seeds in the seed bank and low populations of legumes. At zero phosphorus use of improved grazing management probably accounts for the increase in seed numbers although the effect of high rainfall in 1987/88 cannot be discounted. The effect of phosphate is most striking: the numbers of legume seeds at both levels of phosphate indicate a rapidly improving level of stability.

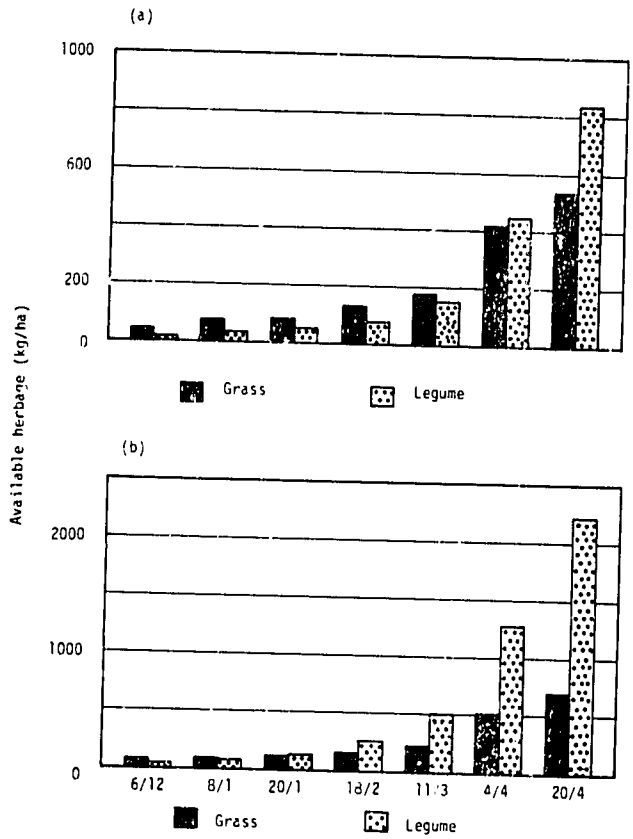


Fig.8.1. Available herbage of grasses and legumes (a) without and (b) with added phosphate (with phosphate is the mean of 25 and 60 kg/ha of P_2O_5). Note that the scales of (a) and (b) differ, the maximum yield in (b) being approximately 2.5 times that of (a). The times (day/month) of harvest were common to both charts.

Table 8.5. Organic matter (%) in soil of grasslands before (1984) and after (1988) four annual applications of phosphate at two stocking rates.

		Year*		
Phosphate		1984 (A)	1988 (B)	increase in B over A (%)
0		3.66[a]	3.98[a]	8.7
25		3.68[a]	4.37[a]	18.8
60		3.31[a]	4.06[a]	22.7
Stocking rate(1)	low	3.33[a]	4.16[a]	24.9
	high	3.76[a]	4.11[a]	9.3

(1) low = 1.3 ha/sheep and high = 0.63 ha/sheep

* means in each column are significantly different ($P<0.05$) if followed by different letters.

Table 8.6. Seed yield (g/m^2) and seed number/m^2 of legumes in grasslands as affected by phosphate in four seasons.

Phosphate	1984/85		1985/86		1986/87		1987/88	
(kg/ha)	Yield	No.	Yield	No.	Yield	No.	Yield	No.
0	2.9	2072	1.4	1596	2.1	2858	10.3	13803
25	3.7	3114	2.2	2063	6.8	8786	25.4	34598
60	4.6	3995	4.2	3379	9.9	11704	27.6	34212
LSD ($P<0.05$)	1.2	825	1.1	751	2.0	2278	12.6*	12535*

* significant at 1% level

Equally important, if this stability is to be transferred to farmers' fields, are the economic returns of applying superphosphate. Animals grazing on phosphate-fertilized plots gained weight much faster than on control plots throughout 1987/88 and the differences were significantly higher before lambing (Fig. 8.2). Similarly animals gained significantly better at low stocking rate (Fig. 8.2 b) compared with high stocking rate. Fig. 8.3 shows the supplementary feed required by sheep during pregnancy: sheep grazing on fertilized plots required less barley and hay than the contol sheep, and sheep grazing at the high stocking rate required significantly ($P<0.01$) more feed than at the low stocking rate. All these results will be part of the final economic analysis.

Considering the level of production on pasture at the end of April (Table 8.3), and assuming this represents only half of the available feed (total = grass + legume), one can get some idea about the potential for livestock production on Mediterranean grasslands. Let us assume that for proper grazing management the animals are allowed to graze half of the total feed. This means that the amount shown in Table 8.3 can be considered available for grazing till the end of the year. Assuming 800 kg dry matter is required by the ewe per year (2.1 kg/day), the total feed needed to support one sheep for 8 months (May to December) can be estimated therefore as 533 kg. This shows that the feed produced under the two fertilizer treatments (25 kg P_2O_5 and 60 kg P_2O_5) can support 4.1 sheep/ha and 5.3 sheep/ha, respectively, till the end of the season. This is exactly 2.5 times and over 3 times the potential stocking rate of the control treatment.

We would like to acknowledge the Government of Italy for its support of our work on Mediterranean grasslands. - **A.E. Osman, L. Russi, M. Pagnotta, P.S. Cocks and F. Bahhady**

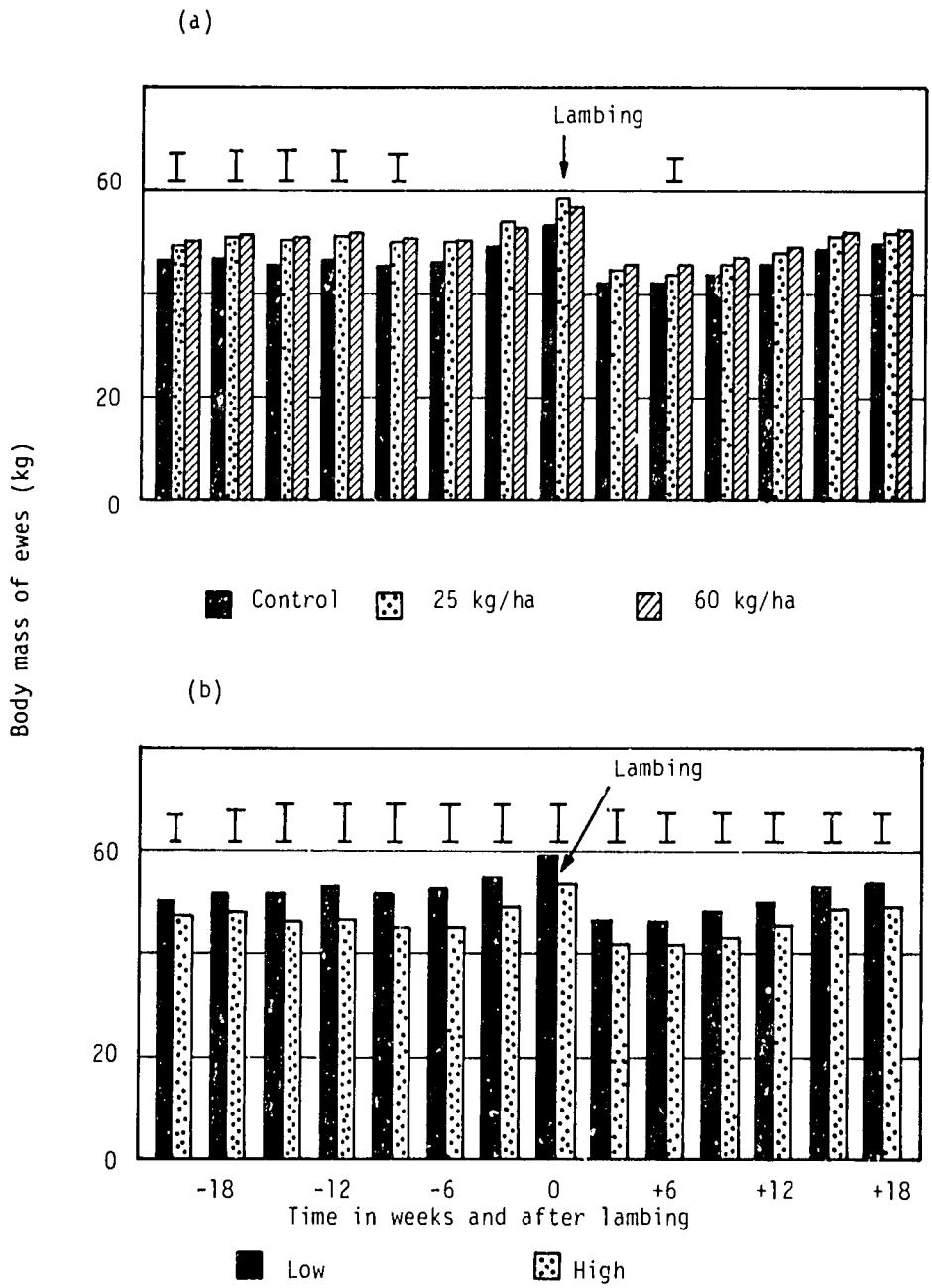


Fig.8.2. Changes in body mass of ewes in relation to lambing (time 0) as affected by (a) phosphate and (b) stocking rate. The bars represent LSD's ($P<0.05$) and the time scale (common to both charts) is the weeks before and after lambing (indicated by the arrow).

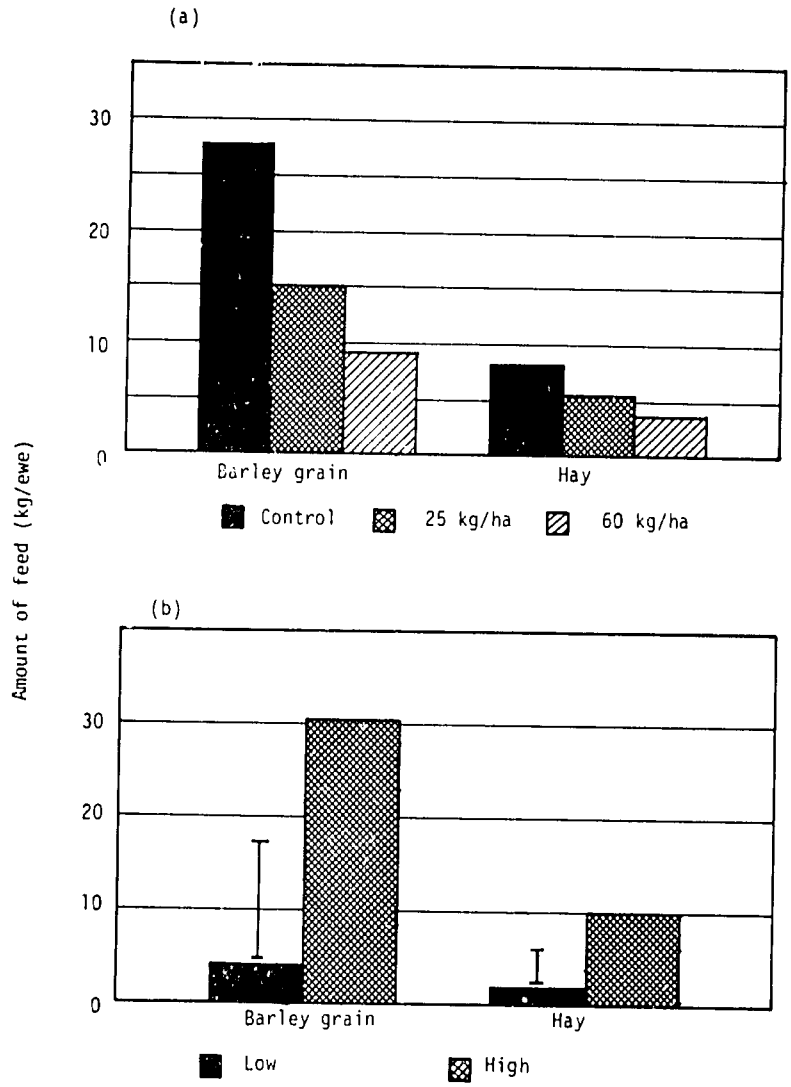


Fig.8.3. The feed consumption of ewes (kg/ewe) as affected by (a) phosphate application and (b) stocking rate. The bars in (b) represent LSD values at $P<0.05$.

Expt 8.2: The effect of time of grazing and of the sowing of pasture legumes on the productivity of Mediterranean grasslands

The objectives of Expt 8.2 were, in farmers' fields, to (1) measure the effect of sowing pasture legumes, (2) assess the

response of pastures to superphosphate, and (3) determine the effect of delaying grazing on the productivity of Mediterranean grasslands. The experiment was conducted in mountains near Terbol, Lebanon (600 mm rainfall).

The site is part of communally-owned grasslands used for grazing from December to May each year. The experiment consists of three main-plot treatments:

- natural pasture,
- sown pasture, and
- sown and fertilized pasture;

and five sub-plot treatments:

- open grazing,
- full protection from grazing,
- 3-months protection,
- 2-months protection, and
- one month protection.

The experiment was replicated four times. Four Australian cultivars of subterranean clover (T. subterraneum cvs. Mt Barker, Woogenellup, Clare and Seaton Park) and one medic ecotype (M. rigidula sel. 1919) were sown. Subterranean clover seeds were mixed at 10 kg/ha each with those of the medic at 20 kg/ha, and sown by hand in September 1985/86, 1986/87 and 1987/88. The sown and fertilized treatment received triple superphosphate equivalent to 40 kg/ha of P_2O_5 at the time of sowing.

Cages (60cm x 60cm x 30cm) were used to protect the herbage against grazing. Five cages were used in each treatment (full, 3-months, 2-months and one month protection), 20 cages for each main-plot, and a total of 240 cages for the whole experiment.

Full-protection cages were fixed in place in early December, those for the 3-months in Mid-February, the 2-months in Mid-March and the one month in late April.

Plots (60cm x 60cm) representing the open grazing treatment (five in each main-plot) were marked in December each year and maintained throughout the season. Each year measurements were taken of herbage and seed yield. Herbage was sampled at regular intervals (3 to 4 weeks from December to May) to estimate yields of legume, grass and other species. Seed yield on the pasture is assessed in June each year.

Grazing: It was not possible to keep an accurate record of grazing although observations were taken on numbers and grazing days. The record for 1984/85 shows that there were 1055 sheep and 261 goats owned by 9 people and that the animals grazed the pasture (approximately 60 ha) for 125 days from December to April. The actual time spent on the pasture each day was affected by presence of feed resources elsewhere. For example animals spent less time on the pasture whenever crop residues (vegetables) were available.

Effect of sowing pasture legumes and fertilizing with phosphorus: Table 8.7 shows that pasture productivity was slightly improved by sowing the new legumes whether alone or when combined with phosphate. The biggest differences (39% and 43%) in favor of sowing was in the spring (late April).

Effect of protection: Full protection significantly increased herbage yield (Fig. 8.4): the differences between partial protection and open grazing were not statistically significant.

Table 8.7. Total herbage yield (kg/ha) of three pastures estimated at different sampling dates during 1987/88 at Terbol, Lebanon.

Type of pasture	First sampling (1 Dec)	Days after the first sampling					
		39	60	81	106	128	149
Natural	195	372	389	555	855	1572	1594
Sown	166	325	330	604	986	1641	2224
Sown and fertilized	165	338	316	617	915	1477	2367
SE	20.4	44.2	30.7	44.7	58.8	93.8	77.8

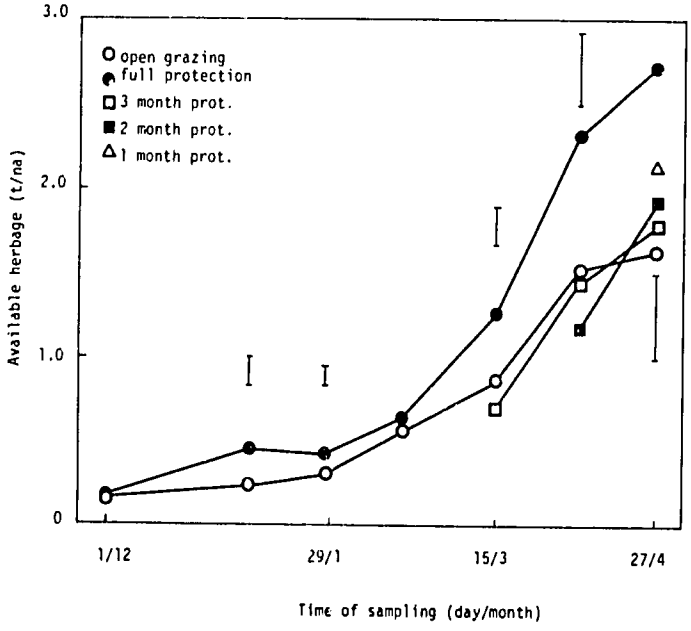


Fig.8.4. Effect of level of protection from grazing on available herbage of mountain grasslands at Terbol (Lebanon). The bars represent the LSD value ($P<0.05$) at any harvest.

The effect of partial protection however was on seed yield, especially of legumes. Fig. 8.5 shows that protecting the pasture from grazing for only one or two months more than doubled legume seeds compared with open grazing. Full protection, on the other hand, resulted in significantly less seed than partial protection, outyielding only open grazing. These results agree with those obtained in previous years.

The most likely explanation is that early grazing stimulates the production of new branches, some of which become reproductive. However if grazing continues, the pasture loses a large proportion of the branches including the reproductive ones. Partial protection saves the reproductive branches and allows them to complete their life cycle and produce seeds. A detailed study is planned this coming season to verify the above explanation (see also the trainee's experiments in Chapter 10).

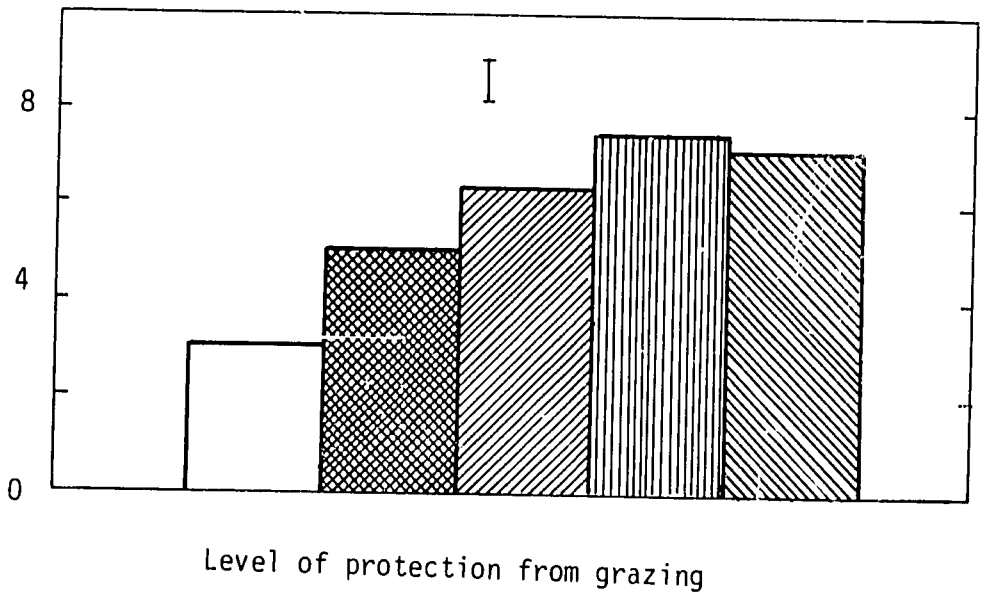


Fig.8.5. The mass of legume seeds after (from left to right) open grazing, full protection from grazing, protection for three months, protection for two months, and protection for one month. The bar represents LSD at $P<0.05$).

Grass seed showed a similar pattern to legume seed except that the differences were not statistically significant (Table 8.8). There was a suggestion that longer protection is necessary with grasses.

Table 8.8.(a) Grass seed yield (g/m^2) and (b) number/m^2 in grasslands as affected by protection from grazing in 1987/88 at Terbol, Lebanon.

(a) Yield

	open	full	3 months	2 months	1 months	mean
Natural	2.8	1.9	1.4	1.5	2.7	2.1
Sown	2.2	2.0	3.4	3.6	3.1	2.9
Sown and fertilized	3.8	3.9	4.9	3.9	3.0	3.9
Mean	2.6	2.6	3.2	3.0	2.9	

SE type of pasture (P)=1.16;level of protection (L)=0.4; P X L=0.70

(b) Number

Natural	680	1252	309	442	519	640
Sown	417	540	682	1297	535	694
Sown and fertilized	805	1920	2123	1740	892	1496
Mean	634	1237	1038	1159	648	

SE type of pasture (P)=559; level of protection (L)=203; P X L=352

In the high rainfall grasslands of Lebanon changing the grazing management to provide some protection in spring seems to achieve the same effect as applying phosphorus at Tel Hadya. However it is important to remember that in the Tel Hadya experiment a constant stocking rate is used, based on the pasture's ability to provide livestock with feed in times of shortage. This means that the natural rhythm of pasture growth - slow in winter, and more rapidly in spring - implies some 'protection' in spring, and its effect is to increase seed yields even at low phosphate. The same effect is seen in Lebanon where intensive grazing in winter is followed by actual protection in spring. It is clear that if productivity of these grasslands is to be improved grazing management must also be improved.

This argument does not imply LESS grazing, simpy a shifting of some grazing from spring to winter. Finding out how this can be achieved in land which is communally owned is part of the long-term strategy of PFLP. - **A.E. Osman**

Expt 8.3: Understanding variability in grasslands

Variability is a characteristic of grasslands in the Mediterranean basin. There are steep and gentle slopes, shallow and deep soils, rapid changes in a diverse flora, and wide extremes of climate. It tends to be greatest in the harshest conditions and where the people who manage the ecosystems are those with least resources.

Variability poses one of the more difficult methodological problems in grassland research. The land is not arable, so the scientist (and farmer also) must deal with it as it exists: it cannot be modified by cultivation. Traditional procedures, including use of analysis of variance, are clumsy in coping with

variability of this kind. Within treatment error terms almost invariably are greater than between treatment effects especially when plot size is small.

Indeed large plot size is one of the methods by which ICARDA is managing grassland variability in its research. In Expt 8.1 plot size is between 3 and 6 ha, depending on stocking rate, and much of the variability that exists on the land (but by no means all) occurs within the plots. But this kind of experiment is very expensive. The autecological work (growing wild species in controlled conditions) in Expt 8.4 is another way of managing variability: in that experiment individual plant genotypes, collected in grasslands, are studied in the deeper, less variable soils of arable land. This method, though effective, is limited in scope. The third and most powerful method is to use multivariate analysis.

The objectives of Expt 8.3 therefore are to understand variability in Mediterranean grasslands using multivariate analysis, and to develop methodologies to improve grassland management. In so doing we hope to gain further insights into the relationships between plant species and their habitats.

In Expt 8.3 we use some of the plots described in Expt 8.1, specifically plots 1, 2, 8 and 7 which are the low and high stocking rates of the 25 and zero kg/ha phosphate treatments, respectively.

Table 8.9 shows the number of legume seedlings in the four plots before the treatments were imposed (means of 3 replicates and 10 quadrats/replicate) Seedling number varied three-fold between plots and the coefficient of variation was up to 100%. Three years later there is a clear treatment effect on seedling number Table 8.10 but the coefficient of variation within plots

remains well above 50% (quadrat number/replicate had increased to 15). The question remains whether the treatment differences in 1988 are caused by the treatment itself, or reflect initial differences within the plots, or are a mixture of both.

Table 8.9. Number of legume plants/m^2 in January 1985 before stocking rates and phosphate treatments were imposed.

Plot number (phosphate, stocking rate)	Mean	SE	C.V.	Min	Max
1 (25, low)	992	656	66	206	1942
2 (25, high)	1477	1584	107	294	5091
7 (0, high)	477	402	84	29	1413
8 (0, low)	1009	511	51	441	2148

Table 8.10. Number of legume plants/m^2 in January 1988 after three years of low (plots 1 and 8) and high (plots 2 and 7) stocking rates and 25 kg/ha (plots 1 and 2) and zero (plots 7 and 8) phosphate.

Plot number (phosphate, stocking rate	Mean	SE	C.V.	Min	Max
1 (25, low)	1650	938	57	650	3530
2 (25, high)	1934	1161	60	350	3710
7 (0, high)	551	315	57	120	1320
8 (0, low)	1054	585	56	290	2240

In 1987/88 100 m long transects were laid down in plots 1, 2 7 and 8. In each transect there were 50 quadrats (1 X 0.25 m), open to grazing, fixed 2m apart. The following characteristics were observed (1) for the vegetation:

- total number of species;
- abundance of species (by scoring);
- seasonal yield of species (by scoring);
- the percentage of ground cover;
- available herbage at the end of the season;
- size of the seed bank;
- time at which flowering commenced; and
- a score of flower number

and (2) for the micro-environment:

- available phosphorus (Olsen P)
- depth of the soil
- total nitrogen
- organic matter
- volume and weight of stones
- bulk density
- slope

Turning first to the micro-environment (Table 8.11), the variability is striking. For example available P varies from 7 ppm to 97 ppm in plots receiving phosphorus and from 3 to 9 ppm in plots not receiving phosphorus. Soil depth varies from 0 to 53 cm (soils of zero depth are exposed rock surfaces) and organic matter from 2.7% to 11% (excluding exposed rocks). Clearly variation in micro-environment will explain some of the variation in plant density.

Table 8.11. Variation in nitrogen (%), organic matter (%), Olsen P (ppm) and soil depth (cm) in four plots of Expt 8.1.

Plot	Mean	SE(1)	CV(2)	Min	Max
Total nitrogen					
1	0.337	0.060	18	0.255	0.569
2	0.369	0.081	22	0.251	0.608
7	0.201	0.018	9	0.169	0.243
8	0.255	0.025	10	0.214	0.314
Organic matter					
1	5.86	1.08	18	4.21	9.00
2	6.05	1.44	24	4.26	11.00
7	3.28	0.36	11	2.65	3.89
8	4.18	0.53	13	3.04	6.69
Olsen P					
1	17.1	8.79	52	6.7	59.1
2	22.5	15.31	68	8.7	98.6
7	4.4	0.87	2o	2.9	6.7
8	5.7	1.19	21	4.1	9.3
Depth					
1	16	8.3	51	0	47
2	17	7.4	43	5	34
7	24	8.9	37	7	53
8	16	4.7	30	4	24

(1) Standard Error
(2) Coefficient of Variation

Two multi-variate techniques - K-means clustering (Engelman and Hartigan 1983) and factor analysis - have been used to describe variation both of the environment and vegetation. The following environmental parameters were included: mass of stones

(WESTON), bulk density of soil (WEXOIL), soil depth (DEPTH), phosphorus content (P_2O_5), organic matter (OM), nitrogen (N), and percentage by volume of stones in the soil (VLPRST). In K-means clustering it is possible to select the most appropriate number of clusters: after examining cluster composition a result which produced nine clusters was selected. Fig. 8.6, shows the statistical distance between clusters and their relationship with the parameters used to form the clusters.

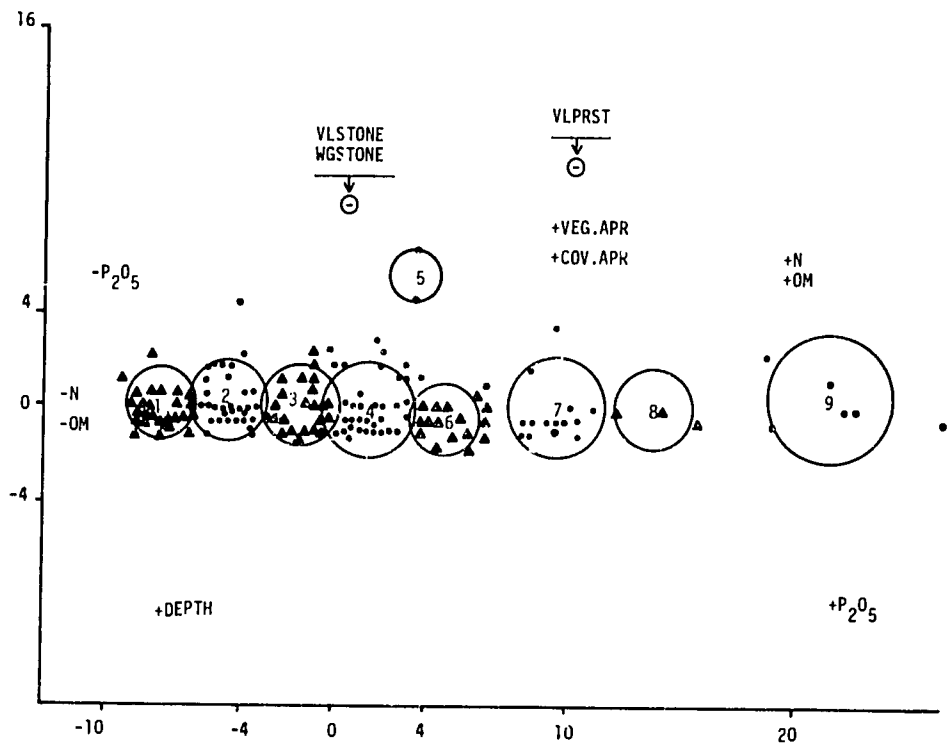


Fig.8.6. The statistical distance between nine clusters formed by K-means clustering. The symbols differ so that adjacent clusters can be clearly seen. The position of the parameters (depth, available P, and so on) relative to the clusters give an indication of which cluster has the highest value of any parameter (for example cluster 1 has the highest values for phosphate and depth of soil).

The analysis reveals some interesting relationships. For example, the correlation between the mean score of T. stellatum and the mean level of available phosphorus in each cluster is strongly significant (r = 0.80) which indicates that T. stellatum is more heavily dependent on adequate supplies of phosphorus and probably the most responsive species. Similarly the relationship between density of T. tomentosum and the quantity of stones is significant (r = 0.80): it would appear that stones create a micro-environment - possibly by reducing evaporation, protecting seedlings from the wind or from grazing - which encourages T. tomentosum.

There are two other points arising out of Fig. 8.6. Firstly quadrats falling into the same cluster are not necessarily adjacent quadrats, illustrating once again the variability of the site. Secondly more shallow soils tend to have higher organic matter content than deeper soils (if 50 cm can be called deep). This may compensate for what would otherwise be the low water-holding capacity of the soil and explain why the percentage of cover and amount of herbage in April was negatively related to depth.

The first two factors in principal factor analysis of the environmental data explain 48% and 22% respectively of total variance. Factor 1 is associated positively with organic matter, nitrogen, and phosphorus, and negatively with soil depth. Factor 2 is associated mainly with stoniness. Fig. 8.7 shows how the seven environmental variables are distributed between factors 1 and 2.

Fig. 8.8 shows the areas covered by each of the four plots in relation to factors 1 and 2. In comparing plots 1 and 2, both receiving phosphorus, it becomes evident that plot 2 (the high stocking rate) has higher soil fertility and is more stony than

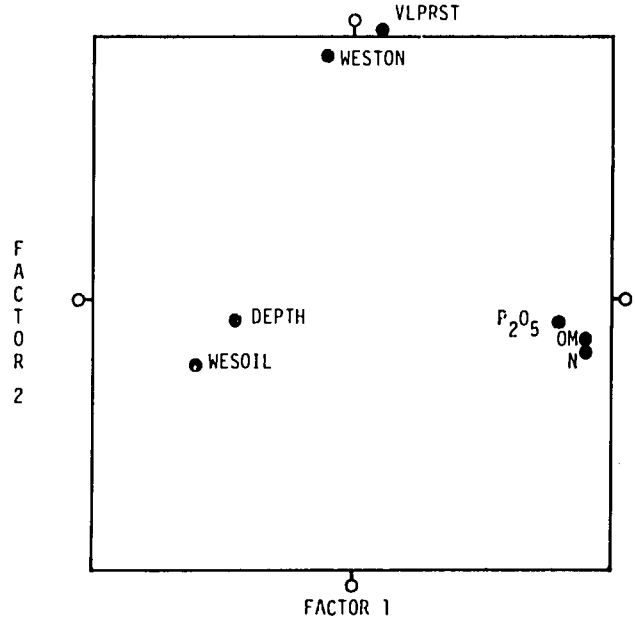


Fig.8.7. Distribution of the seven parameters used in the factor analysis of environmental variables relative to factors 1 and factors 2.

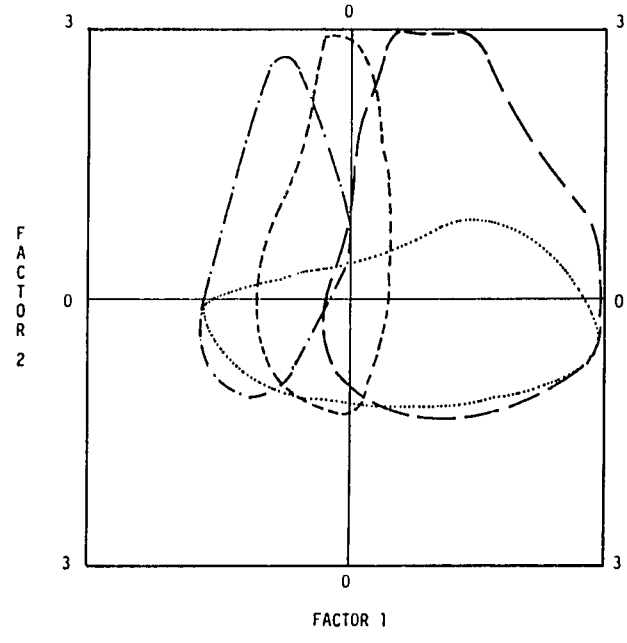


Fig.8.8. Distribution of quadrats in plot 1 (enclosed by dotted lines), plot 2 (enclosed by large dashes), plot 8 (enclosed by small dashes), and plot 7 (enclosed by altternate dots and dashes), relative to factors 1 and 2 of a factor analysis of seven environmental variables (see text).

plot 1. Plots 7 and 8 are similar, although the low stocking rate (plot 8) appears to be a little more fertile.

The research needs to be continued to take into account the interaction of soil fertility and years. Analysis in greater depth will then be possible, and the interaction between vegetation, micro-environment, season, and treatment will become clearer. But already the results show how some plant species react to their environment, and illustrate the extreme variability of these grassland ecosystems. - **M. Pagnotta, P.S. Cocks, and Dr R.W. Snaydon (University of Reading, U.K.).**

Expt 8.4: Predicting the responsiveness of grasslands to phosphorus using soil analysis

The objective of Expt 8.4 is to develop a methodology for predicting the responsiveness of grasslands to phosphorus based on the legume species present and chemical analysis of their leaves.

The data of Expt 8.1 are of great importance in increasing the productivity of grasslands. They are, however, specific to the Tel Hadya site and, while we believe Tel Hadya to be typical of large areas of grassland, we need to develop methods of extrapolating our results more widely. One of the most important questions is whether or not any particular grassland will respond to phosphorus.

The answer clearly depends on soil phosphorus, legume population, and grazing management. Although critical levels for phosphorus in arable land are well known, the evidence accumulating in Expt 8.1 suggests that grasslands have higher critical levels. If so, because of the variability discussed in

Expt 8.3, it will be difficult to predict responsiveness. Moreover the various legumes may respond in different ways to phosphorus application making prediction through soil tests extremely difficult. Remember that in grasslands we are dealing with mixtures of species (there are 45 legumes in Expt 8.1) and not monocultures as with cereals and other crops.

Several experiments have looked at the responsiveness of different pasture legumes to phosphorus. In Expt 8.4 we firstly analyse data obtained from an experiment reported in the 1987 PFLP Report (page 247) - by fitting curves to data relating P in the leaves to fertilizer applied - and then relate this data to soil and plant analyses of 53 grassland sites in north Syria.

Phosphorus in the shoots of grassland species: As reported in 1987 five annual legumes appeared to respond to different levels of phosphorus. The responses are illustrated in Fig. 8.9 which shows the increase in seed yield due to phosphorus of M. rigidula, M. rotata, M. noeana, M. polymorpha, and Astragalus hamosus (seed yields were not reported in 1987). Clearly M. noeana responded to a lower level of phosphate with a much sharper inflexion than the other species. On the other hand with A. hamosus, although the increase in absolute terms was low, the response continued to the highest level of phosphorus applied. The Mitscherlich equation,

$$y = A\ (1 - e^{-kx})$$

where y is the yield obtained, x is the amount of fertilizer added, A is the maximum yield, and k is a parameter of the curve representing the rate at which yield tends to its asymptote (Mead and Curnow 1983), was used to fit the curves.

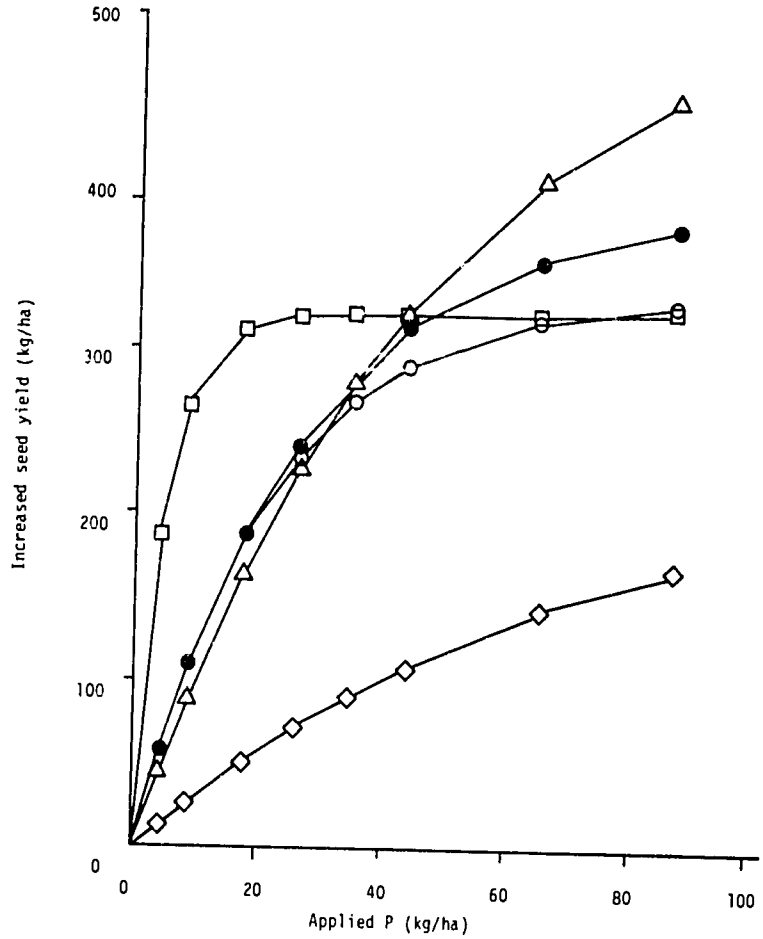


Fig.8.9. Effect of phosphorus level on the increase in seed yield after P application compared with a zero control of M. rigidula (closed circles), M. rotata (triangles), M. noeana (squares), M. polymorpha (open circles), and Astragalus hamosus (diamonds). The curves were fitted using the Mitscherlich equation (see text).

Fig. 8.10 shows curves of the responses of shoot tissue to phosphate at the winter harvest. Based on this data Table 8.12 summarises the levels of phosphate applied which are required by the five species to give 90% of the calculated maximum concentration of phosphorus in the shoot tissue.

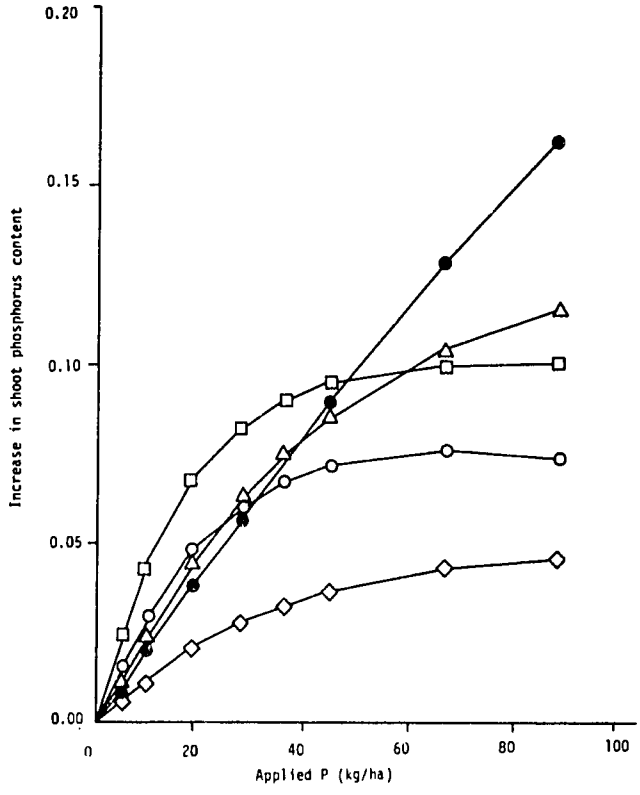


Fig.8.10. Effect of phosphorus application on the concentration of phosphorus in the shoots of M. rigidula (closed circles), M. rotata (triangles), M. noeana (squares), M. polymorpha (open cicles), and Astragalus hamosus (diamonds). The curves were fitted using the Mitscherlich equation (see text). Data are the increase in shoot P concentration compared with un-fertilized controls.

The highest k value recorded for P% in the shoot tissue was 0.03375 for M. noeana: this species has a response with the greatest curvature (Fig. 8.10), and requires the lowest amount of phosphorus (36 kg/ha) to reach the 90% maximum concentration (Table 8.12). M. rigidula has the highest calculated maximum concentration (0.453%) in the shoot tissue and needs the largest amount of P (453 kg/ha) to reach the 90% maximum concentration, reflecting its low value of k (0.00266), the curve being almost a

Table 8.12. Calculated maximum concentrations of phosphorus (%) in both shoots (S) and in the youngest open leaf, (YOL) and the levels of phosphate required in the five species to give 90% of the maximum concentration at the winter harvest at Jinderis during the growing season 1986-87.

	Maximum P% in		P (kg/ha) required for 90% of the maximum P% in	
	YOL	S	YOL	S
M. rigidula	.201	.453	77	453
M. noeana	.142	.101	124	36
M. rotata	.217	.131	57	94
M. polymorpha	.211	.078	103	41
A. hamosus	.896	.049	1673	71

straight line (Fig. 8.10). For the medics the lowest maximum concentration in the shoot tissue (0.078%) was in M. polymorpha: its k value was high (0.02965) and it needs also a small amount of phosphorus (41 kg/ha) to reach 90% maximum concentration.

The youngest open leaves were also analysed as these represent tissue of equal physiological age. However in our data phosphorus concentration of the whole shoots seemed to give more useful data.

Survey of phosphorus concentrations in the leaves of grassland legumes: To check what is happening in the grasslands themselves a study was carried out during April and May. Annual legumes were collected from 53 sites between the Syrian desert and the Mediterranean Sea. The sites were chosen as typical of the

Mediterranean grasslands of north Syria. In all, 68 species of 18 genera were collected. Eight soil samples were taken with a 15 cm auger from the top soil (0-15 cm) of each site and bulked for chemical analyses: pH and available phosphorus in the soil were determined.

Plants of each species in each site were kept separately in plastic bags and were oven-dried for about 48 hours at 70°C for determination of phosphorus levels.

The species collected included 15 medics, 21 clovers, 6 Trigonella and 7 vetches. Of the medics, four were widely distributed: M. rigidula was the most widespread, being found at 31 of the 53 sites, M. coronata at 26 sites, M. polymorpha at 25 and M. minima at 23 sites. Of the less common medics, M. intertexta, M. scutellata and M. truncatula were each found at only one site.

The most widespread species overall were Onobrychis crista-galli, Hymenocarpis circinnatus and Trifolium stellatum, which were found at 38, 37 and 35 sites, respectively. Trifolium campestre was also abundant, being found at 31 sites.

Available phosphorus in the soil was found to vary from site to site, ranging from as low as 0.9 ppm (of dry soil) to as high as 46.7 ppm. It was less than 5 ppm at 14 sites, and above 20 ppm at only four sites. Phosphorus concentration of plant tissue at individual sites varied from 0.085% to more than 0.600 %P. The highest mean value of P% for a species was 0.343%, (Trigonella asteriodes), and the lowest was 0.114% (M. intertexta). Among medics, the concentration of phosphorus in the plant was relatively high in M. rotata and M. polymorpha, being 0.268% in the former and 0.238% in the latter, while for M. rigidula it was relatively low P%. In Astragalus hamosus the mean P% recorded in the shoot tissue was 0.234%. Phosphorus

Table 8.13. Shoot phosphorus concentration of selected legumes, Olsen phosphorus in the soil, and the correlation between the two, in a survey of grasslands in north Syria.

	Mean P	Available P	Number of sites	r
Astragalus hamosus	0.234	10.7	18	0.26 NS
Hymenocarpis circinnatus	0.158	8.3	37	0.54***
Medicago coronata	0.180	9.1	26	0.57**
M. minima	0.185	7.3	23	0.35 NS
M. orbicularis	0.171	11.1	15	0.58*
M. polymorpha	0.238	10.6	25	0.13 NS
M. rigidula	0.189	8.5	31	0.59***
Trifolium campestre	0.154	9.4	31	0.39*
T. tomentosum	0.214	8.9	27	0.35 NS
Trigonella monspeliaca	0.197	9.5	27	0.63***

accumulation in plant tissue therefore depends not only on the levels of available P in the soil but also on species.

Medicago rigidula was one of the species that showed a highly significant correlation ($P<0.001$) between phosphorus concentration in the shoot tissue and available phosphorus in the soil (Table 8.13). Other species (A. hamosus, Hippocrepis unisiliquosa and Trifolium tomentosum), were among nine species (out of 19 which were collected at more than 15 sites) in which this correlation was not significant. Two medics, M. polymorpha and M. minima, also showed no significant correlation.

The data strongly suggest that phosphorus deficiency is common on grasslands: at least half of the M. rigidula samples seemed to suffer from phosphorus deficiency. The data also suggest that the legumes vary in responsiveness: M. noeana clearly needs less phosphorus than most other species. - **M. Turk, Prof. A. Willis (University of Sheffield), and P.S. Cocks**

CHAPTER 9: SOIL AND PLANT FACTORS AFFECTING THE YIELD OF WHEAT AFTER MEDIC (PRESCHEDULE M67)

Experience in Syria is showing that, in most circumstances, yields of wheat after medic are better than in traditional rotations (Chapter 1). However, Tel Hadya itself appears to be an exception and therefore merits special attention (Chapter 5). If we understand what happens at ICARDA's headquarters we can give sound advice if and when it happens elsewhere. We believe that progress made in the past year will probably be sufficient not only to solve the problem at Tel Hadya, but also to focus attention on ways of increasing cereal yields generally.

Experiments have been carried out in which wheat plants, or the soil in which they are grown, have been interchanged between land used for clean fallow or for medic pasture in the previous year. The research is still in progress, but the information obtained so far merits an early report.

Preliminary analyses of our results indicate that, under experimental conditions medic soil is capable of giving a greater yield of wheat than fallow soil even where the reverse occurs under normal management. The rare failure of the medic soil to confer its advantage in the field is attributed to an adverse influence which it can sometimes have on wheat seedlings. The nature of the adverse factor is as yet unclear but, even in the absence of a detailed explanation, there is evidence that the problem may be avoided by a change in soil management: the use of slightly deeper tillage, consistent with depths necessary for pasture regeneration.

The following is an account of the experiments which have provided this information.

Definition of the problem: The experiment described in Chapter 5 (Expt 5.1) was used in the research. The soil is a deep clay loam, overlying calcium carbonate at depths of over one metre, although occasional rock outcrops occur. It is a well structured reddish brown clay classified as a vertic luvisol, with moderate levels of phosphorus, but in which crops respond to nitrogen.

The following comparisons show that yields of bread wheat (cultivar Sham 2) grown after fallow in Expt 5.1 are comparable to other yields at Tel Hadya. Thus in 1986/87 (rainfall 358 mm) yield was 2480 kg/ha compared with 3013 kg/ha in an adjacent field (data of G.D. Ferrara). Similar comparisons are available from other years.

In contrast with wheat yields after fallow, low wheat yields were obtained after other crops, as follows:

- in 1987 after medic - 59% and 61% of the yield after fallow without and with 40 kg/ha of nitrogen respectively.
- in 1987 after lentil - 75% and 81%
- in 1987 after vetch - 70% and 77%
- in 1988 after medic without and with 90 kg/ha of nitrogen respectively - 67% and 66%
- in 1988 after lentil - 62% and 72%
- in 1988 after vetch - 85% and 73%

The problem therefore applies also to rotations with medic, lentil and to a lesser extent vetch.

The strategy of this years' research was to identify the main target areas for future research by determining when and where the mechanisms occur which cause the yield differences. There are many possible target areas. For example let us divide the

pasture cereal rotation into four periods: period 1, when sheep graze green pasture, period 2, when they graze dry pasture, period 3, the juvenile stage of cereal growth, and period 4, the stage of crop maturation. In periods 1 and 2 there may be influences from grazing animals, growing or dead pasture, growing and decaying roots in the surface soil, or chemical reactions in the subsoil. In periods 3 and 4, soil effects continue, but the effect of pasture is transmitted through its previous effects on the soil.

In period 1, subsequent cereal yields may be influenced by the amount of seed produced by weeds, by the growth or control of micro-organisms (including pathogens), and by the input of soil nitrogen by the pasture legumes. The trampling of soil in both periods 1 and 2 may affect soil structure. Rain falling in period 1 will be used by the growing pasture and not stored for later use by the cereal.

The present investigation is directed towards the surface and subsoil in periods 3 and 4 (crop growth and maturity). Experimental methods were used to separate the influence of soil on the growth of wheat, to show in which period the influence was exerted, and whether it was in the upper or lower layer of soil. It will be possible later to identify the factors in periods 1 and 2 affecting these processes.

Expt 9.1: The effect of transplanting wheat seedlings from soil after medic to soil after fallow and vice-versa

The objective of Expt 9.1 was to determine whether the deleterious effects of pastures on wheat occur at the seedling stage (period 3) or later (period 4).

Wheat seedlings were transplanted from their normal situation in medic soil, growing as part of the pasture-cereal rotation, and relocated within rows of wheat growing in fallow soil as part of the fallow-cereal rotation. In view of the retardation of growth which inevitably attends transplanting, appropriate control treatments were set-up involving transplanting within medic soil, and within fallow soil. Incoming or "visitor" plants, were thus surrounded by the existing or "resident" plants.

The experiment was set up as a randomised block with three replicates, and a large number of resident and visitor plants were studied in rectangular plots. The treatments are illustrated in Fig. 9.1. Four types of plot are shown, which for the "visitor" plants consistute four treatments: transferred from

medic soil to fallow soil,
fallow to fallow,
fallow to medic, and
medic to medic.

In a sense, there were also four treatments for the resident plants according to the type of visitor plant which was growing nearby. At the time of starting the experiment the concept of four resident treatments was mainly theoretical, as it was anticipated that there would be little difference among the residents apart from the effect of reduced competition from visitors, and the possible transfer of pathogens. The residents were nevertheless subjected to the same labelling and recording system as the visitors. Transplanting took place during the first week of March when the wheat was at the early vegetative tillering stage. The choice of transplanting day depended simply on the presence of good conditions - neither too wet nor too dry

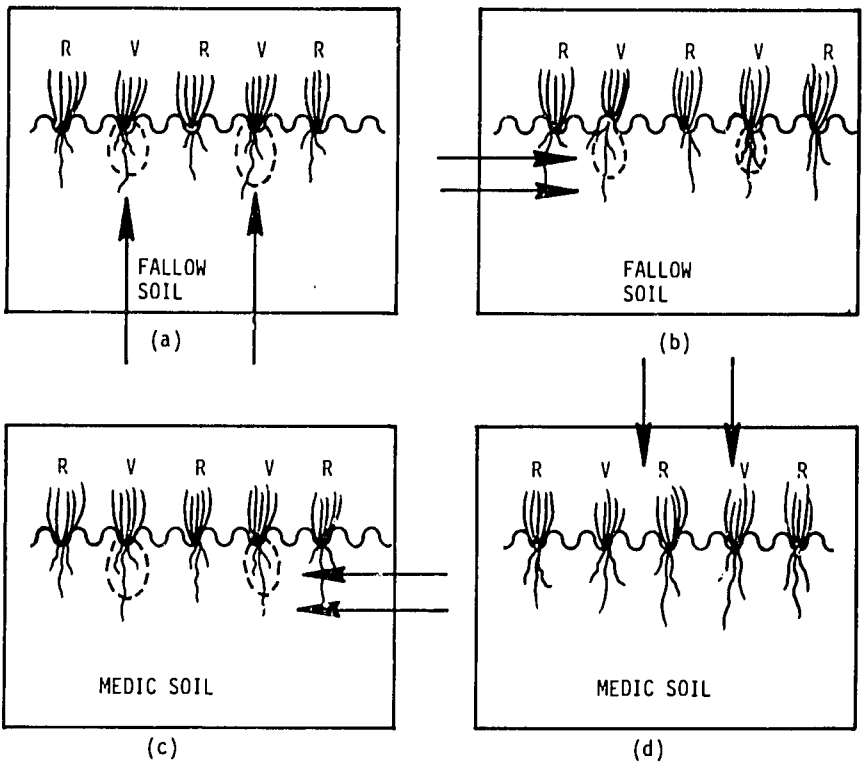


Fig.9.1. Design of an experiment in which (a) wheat was transplanted from medic soil to fallow soil ("visitors",V) and grown among the undisturbed wheat plants on the fallow soil("residents",R) for the measurement of grain yield.

A control for the influence of the disturbance associated with transplanting alone, without a change of soil, was obtained by transplanting from fallow (a) to fallow (b), the disturbed plants again being termed "visitors". Similar transfers were made of wheat plants from fallow to medic (d) with appropriate controls (b,c).

to cause damage. All transplanted plants were labelled, and were assessed as being in "good" or "poor" condition.

At harvest, the position of each culm was recorded, allocated a unique identification number, and the following measurements were taken: number of nodes, stem length, number of seeds, and

total mass of all grain from the head. The last two parameters were used as an indication of productivity, and were closely correlated ($R = 0.96^{**}$), showing that there was little variation in seed size. The stem parameters were used as an indication of the overall vigour of the plants. In the results data are given for individual culms and whether they come from uniculm and multiculm plants. The initial analysis has been for all culms, irrespective of the number per plant.

Grain yield varied significantly among treatments. The yield from residents was more than double that of visitors, due to the retardation of growth caused by transplanting. Plants from medic soil produced less grain (0.27 g/head) when grown as visitors to fallow soil than the fallow to fallow visitors (0.40 g/head) indicating that the period of time spent in the medic soil (before transplanting) had imparted a disadvantage to the plant not ameliorated by the change to fallow soil. Seedlings from medic soil replanted in medic soil yielded the same (0.29 g/head) as those replanted to fallow soil. The results suggest that the adverse factor occurs early in the life cycle (before a critical stage), in this case before the seedlings were transplanted.

For comparison, the seedlings which were transferred from the fallow soil and placed as visitors in the medic soil had a yield of 0.61 g/head, compared with 0.40 g/head for fallow to fallow visitors. Thus not only did the medic soil fail to confer a disadvantage beyond the critical stage, but it was found to be superior to fallow after the critical stage, since the yield of fallow to medic visitors was 50% greater than that of fallow to fallow visitors.

We conclude from these results that the soil in the year after medic pasture has two properties compared with fallow soil: the first being good and the second bad. The bad property

operates before a critical stage in the growth of the wheat, and the good property operates later.

Soil disturbance: A further point of interest in the results (Fig. 9.2) is that the wheat plants grown without disturbance in the medic soil (residents in medic) had higher yields relative to

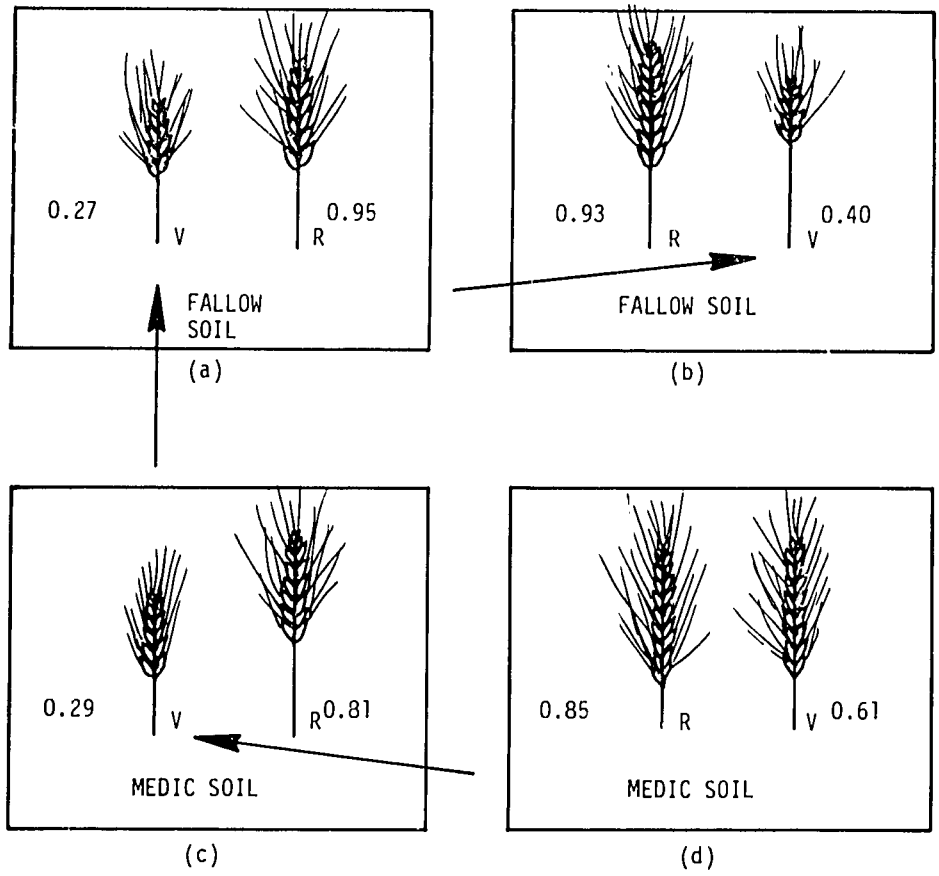


Fig.9.2. Wheat yield on fallow soil (a) for plants transferred from medic soil ("visitors", V) or growing permanently in fallow soil ("residents", R) compared with (b) visitors from fallow to fallow (V) and their associated residents (R). Results for a similar set of comparisons for medic soil are given in (c) and (d). Values in g/head of grain.

wheat in fallow soils (residents in fallow) than was experienced in the field generally. The mean yield in medic soil was 0.83 g/head), which was 88% of that for wheat in fallow soil (0.94 g/head) compared with only 66% in the field as a whole. The presence of a weaker neighbour was a feature both of medic and fallow soil and could not explain the relative improvement of wheat on the medic soil.

The principal difference in the conditions of growth, between the experiment and the field generally, is that the soil was dug out at intervals along the row and visitor plants were inserted, whereas there was no such disturbance in the field as a whole. The the fact that the soil was disturbed could have been the important factor, reducing the effect of the deleterious factor. Further evidence supporting this explanation is given in the following section. - **A. Smith and N. Nersoyan**

Expt 9.2: The effect of interchanging 'medic' and 'fallow' soil

The objective of expt 9.2 was to determine whether the deleterious factors to wheat in medic soil occur in the surface layer (0 - 20 cm) or the sub-soil (below 20 cm).

The upper layer of soil was transferred from land which had been used for medic pasture in the previous year to land which had been used for fallow, and vice-versa. Wheat was then sown and its growth and yield related to treatment. As in Expt 9.1 it was necessary to set up appropriate controls to measure the effect of soil disturbance *per se*, irrespective of interchange between rotations. Fig. 9.3 illustrates the four soil treatments.

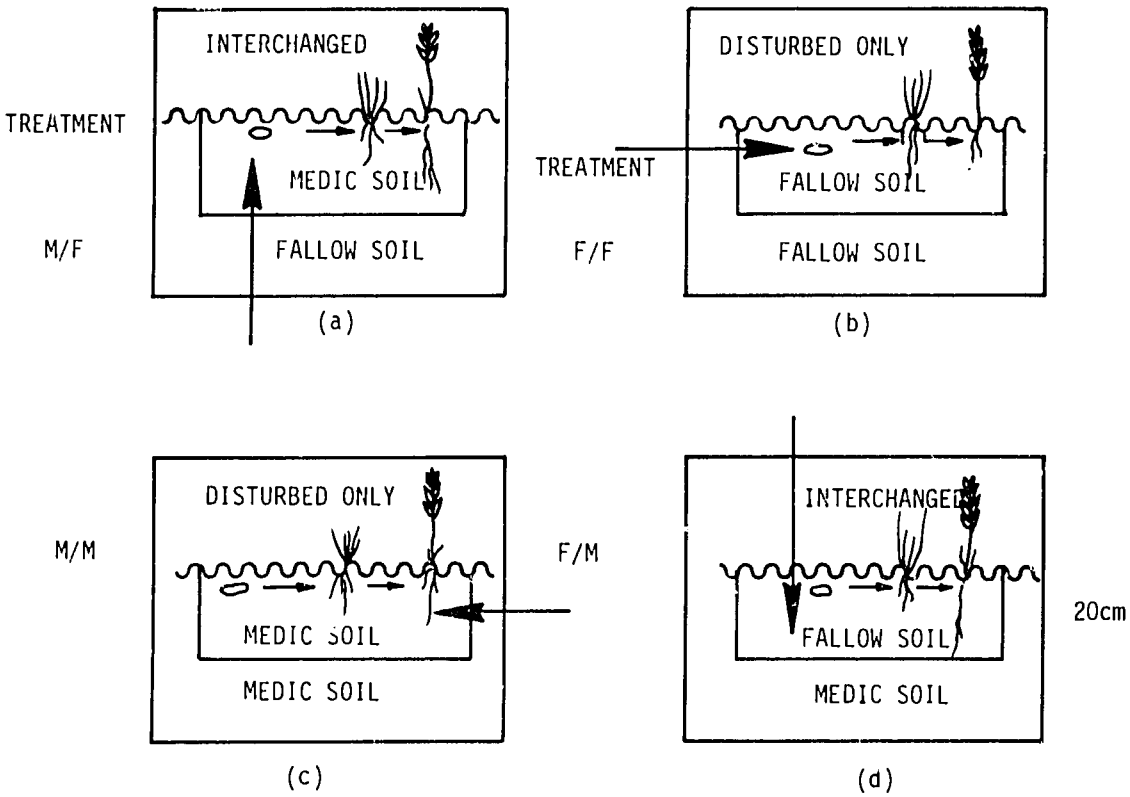


Fig.9.3. Design of an experiment in which the surface 20 cm of soil was transferred from a medic/wheat rotation to a fallow/wheat rotation (a) prior to sowing the wheat, the yield of which was then compared with that for all three other possible soil interchanges (b,c and d).

Soil transfer took place in November 1987, and wheat was sown in December. The material harvested from the plots was subjected to detailed recording to facilitate a study of the plants as a population of individuals. The latter was considered necessary in view of the results which were emerging from Expt 9.3 (the next section) on distributions of plant yield among plant populations.

Analysis of the results from Expt 9.2 are not yet complete. However there is already evidence to support the hypothesis that

soil disturbance will overcome the problem in medic soil. Wheat growing on medic soil which had been disturbed (treatment M/M) gave a mean of 30 grains/head, which was 11% greater than the 27 grains/head from disturbed fallow soil (treatment F/F). - **A. Smith and N. Nersoyan**

Expt 9.3: Distribution of individual plant yield within wheat populations

The objective of Exp 9.3 was to determine whether differences in wheat productivity between the various soils were due to a small change in ALL plants, as could occur with an overall change in soil fertility, or to large changes in a few plants, as would be the case of a pest or disease.

A large number of culms were examined individually within Expt 9.1, records being made for some 500 visitors and 800 residents per treatment. The decision to make such a detailed study was based on the general observation that there was wide heterogeneity in plant size, and the presence of small or dwarf plants, having short culms and small seed heads, in certain treatments.

Fig. 9.4 gives the frequency distribution of seed yield among 1824 heads of wheat growing on fallow soil (the resident plants of Expt 9.1) showing a high number of unproductive culms. A normal distribution is expected in healthy populations, and a skewed distribution in populations undergoing intense competition for nutrients, water or light, or subject to disease or other biotic stress.

In Fig 9.4, the distribution is skewed, with 7% of the culms having no grains, and a further 28% having less than 30

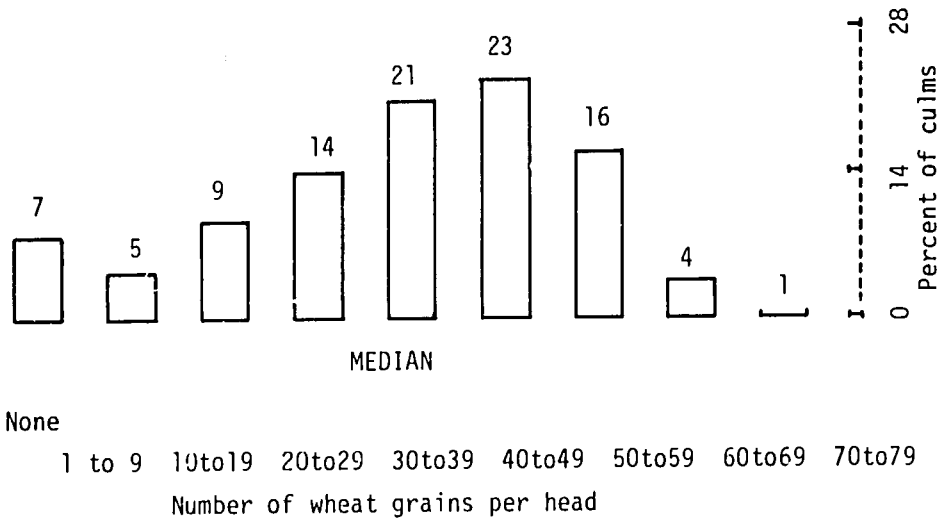


Fig.9.4. Frequency distribution of grain yield among culms from plants growing in fallow soil at Tel Hadya. Values are for the number of seeds/culm.

grains/head. The median value for the whole population was 39 grains/head, the 54% of the culms having this value or less yielding approximately one third of the total yield. Most of the production came from 46% of the culms, which together were responsible for two thirds of the yield of grain (4276 kg/ha).

Fig 9.5 gives the frequency distribution of grain yield/culm among 466 culms which had grown in medic soil before being transplanted into fallow soil. For comparison, the figure includes the distribution of 547 culms of plants transferred from fallow to fallow. The two distributions illustrate the effect of soil type during early growth on grain yield distribution among plants in the two wheat crops. The medic soil accentuates the skewness which already exists with the crop grown after fallow.

The changes in distributions suggest that depression of growth is not uniform but that there is a much greater chance of an individual plant being damaged in medic soil than in fallow

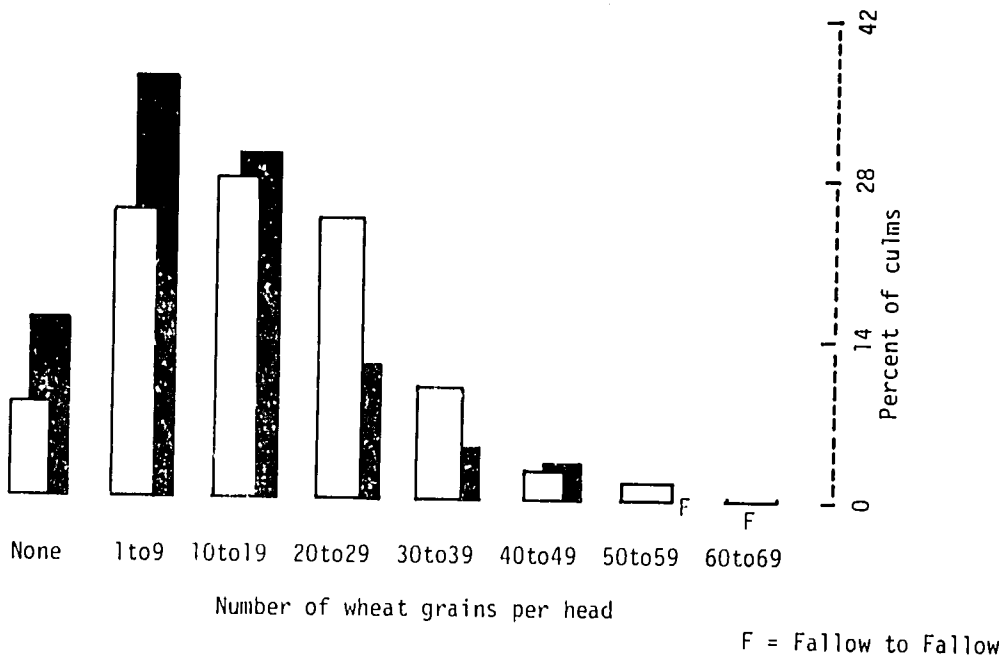


Fig.9.5. Frequency distribution of grain yield per culm for wheat plants transferred in early March from medic soil to fallow soil (shaded) compared with that for plants transfered from fallow soil to fallow soil.

soil. The data suggest the presence of a random factor, such as a pest or disease, or possibly allelopathy induced from medic residues.

Fig. 9.6 gives the frequency distribution of grain yield of 516 culms of plants sown in fallow soil and transplanted to medic soil, compared with the distribution of 461 culms of plants grown in medic soil and transplanted to medic soil. The interpretation is essentially the same as for Fig. 9.5: plants germinating in medic soil yielded less than plants germinating in fallow soil. It should be noted however, that the fallow to medic plants were 50% better than those which were transplanted from fallow to fallow. - A. Smith

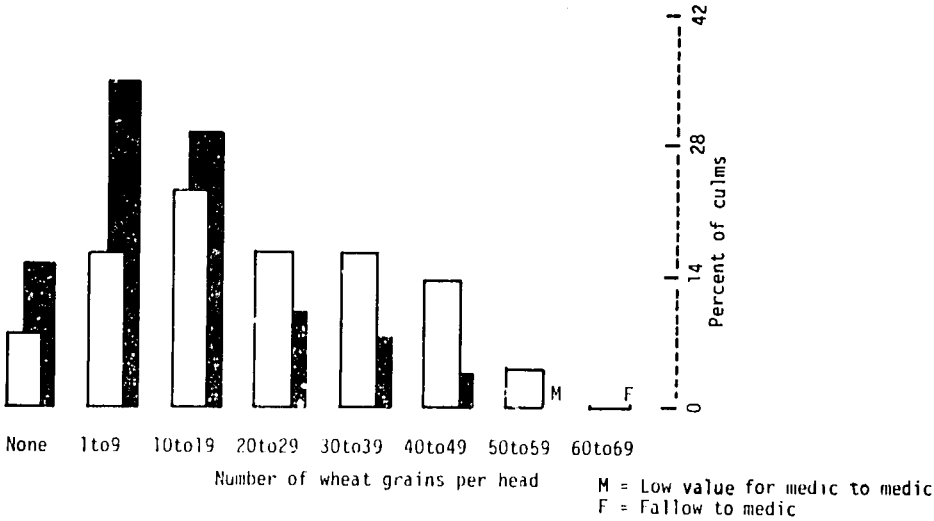


Fig.9.6. Frequency distribution of grain yield per culm for plants of wheat transferred from medic soil to medic soil in early March, (shaded) compared with that for plants transfered from fallow soil to medic soil.

Expt 9.4: Comparison of biomass yields of wheat seedling transferred in groups from medic to fallow soil and vice-versa

The objective of Expt 9.4 was to minimize the effect of transplanting and so confirm that the deleterious factor in medic soil operates early in the crop's life cycle.

In Expt 9.4, groups of plants were interchanged between medic soil and fallow soil in an analogous manner to individual plants in Expt 9.1. The advantage of using groups, effectively sections of drill rows, was that there would be less disruption to growth, and less competition from more vigorous resident neighbours. While setting up the experiment, the samples of rows were stratified into "good" and "poor" sections. The plants were grown to maturity, and total biomass and seed yield were measured.

The classification into good and poor plants took place in early March. The results at maturity are in Table 9.1. It can be seen that the plants classified as poor ultimately yielded only about 60% of the good plants, both in the medic and fallow soils, indicating that the ultimate performance of the plants had been committed before March.

Table 9.1. Biomass (kg/ha) of wheat plants resident in medic and fallow soils, and biomass of visitors, the latter classified as 'good' or 'poor' when transplanted.

	Biomass
(a) in medic soil	
Residents	7350
Visitors from fallow-good	9320
-poor	5410
Visitors from medic-good	6690
-poor	4230
(b) in fallow soil	
Residents	9300
Visitors from fallow-good	8410
-poor	5510
Visitors from medic-good	7560
-poor	4100

Of the plants which started their growth in fallow soil, only the good ones were capable of responding to the opportunity of extra growth when transferred to medic soil, while the poor plants had no such response. A similar analysis will be made of the results for the individual plant experiment.

When residents and visitors are compared, the plants which grew exclusively in fallow soil give a good indication of the disturbance effects: a reduction of only 25% in biomass, compared to a 57% reduction in Expt 9.1. The transplanting of groups of plants is therefore a useful method for the continued study of this phenomenon. - **A. Smith, L. Ayalew (Ethiopian trainee)**

Conclusions: The results of all four experiments indicate that the problem of low wheat yield after medic at Tel Hadya may be attributed to an event occurring between germination and tillering: a soil pest or disease, alleiopathy from medic residues and some aspect of soil structure are all possibilities. It is unlikely to be due to the depletion of stored soil moisture during the pasture phase. A simple solution is predicted to be the use of an additional tillage before the cereal is sown, which, it is hoped will restore the wheat yield to that of the fallow rotation, or even higher. It has further been observed that there was a high proportion of low-yielding culms within a seemingly normal crop of wheat. Thus there may be a general phenomenon adversely affecting the growth of wheat, and the expression of this varies according to the conditions, the problem encountered in medic soil at Tel Hadya simply being an extreme case.

CHAPTER 10: THE QUALITY OF BARLEY STRAW

Cereal straw and grazed stubble are such important components of animal feed in WANA that straw often approaches grain in economic value and an estimated 50 million tonnes are produced, mostly from wheat and barley. In collaboration with the Cereal Program and the ODNRI we decided to limit our work to genetic aspects of straw quality as most farmers cannot afford chemical straw improvement. Our results so far indicate that quality does not appear to be associated with grain yield.

The initial research identified differences between genotypes in digestibility and voluntary feed intake (VFI). These differences were due to variations in the proportion of leaf, which, in mature plants, is related to plant height. Our attention has now turned to investigating the fundamental reasons for genetic variation within the stem and leaf fractions. The use of the in sacco (nylon-bag) technique has made it possible to study the rate and extent of digestion, two important parameters determining VFI. This well known technique was introduced to ICARDA by Frances Herbert whose research for her PhD was nearly complete at the time of her untimely death.

Two experiments were completed in 1988. Expt 10.1 investigated the response in intake of sheep offered straw from nine barley genotypes supplemented with protein. Expt 10.2 studied the effect of plant height on digestibility VFI (in sacco) and the extent of disappearance (digestion) of leaf and stem fractions from four barley straws.

Expt 10.1: Digestibility and voluntary feed intake of nine barley straws (Preschedule L27)

The objectives of Expt 10.1 were (1) to compare the voluntary

feed intake and digestibility of nine barley straws and, (2) using the nylon bag technique, measure their rumen degradability.

The experiment used the same nine straws that were used in a 1987 study (PFLP Annual Report 1987, pages 89-95) where unsupplemented straws were offered to sheep: eight of these straws were also used in the 1984 research of Capper, Thomson and Rihawi, (1988). Details of the straws are in Table 10.1 (reproduced from the 1987 Report). The same experimental design (3 x 3 lattice) and sheep were used as in the 1987 study, but the sheep were 50.1kg ± 3.26 (SEM) at the start of Expt 10.1 compared with 43.8kg ± 2.12 at the start of the 1987 experiment. Four week feeding periods were used and sheep received 200 g soyabean meal (SBM) daily, a mineral supplement, and ad libitum straw. The digestibility of the straw was estimated assuming a degradability of SBM taken from feeding tables. Statistical analysis of the 1988 data was not complete at the time of writing.

Table 10.1. Morphological attributes of barley genotypes harvested in 1984 and 1985 (data based on hand-pulled plants).

	Badia	ER/ Apam	Beecher	Arabi Abiad	Arabi Aswad	C63	Rihane	Arar	Antares
Stem height (cm)									
1984 harvest	69.0	39.2	69.6	-	-	61.2	49.3	48.0	43.4
1985 harvest	45.5	33.1	53.1	29.6	44.4	54.3	41.5	32.0	37.1
Leaf proportion									
1984 harvest	0.56	0.63	0.56	-	-	0.63	0.62	0.63	0.67
1985 harvest	0.61	0.61	0.56	0.70	0.64	0.55	0.60	0.61	0.71
Days to maturity									
1984 harvest	147	143	146	-	-	151	144	142	156
1985 harvest	173	165	171	166	164	174	171	174	181

The digestibility and VFI of the unsupplemented (1987 experiment) and supplemented straw are shown in Table 10.2. Supplementing with SBM increased the mean digestibility of the organic matter (DOM) and VFI across the nine straws by nearly 3 percentage units, and 89 OM/MBM (metabolic body mass, using the 0.75 power), respectively. Antares, Arar and Rihane had the highest and ER/Apam the lowest DOM whether or not SBM was offered. Although unsupplemented, Antares had by far the highest VFI, and its VFI responded less to supplementation than all other genotypes except Beecher: eight out of the nine genotypes therefore had VFIs differing by only 4.5g OM/MBM. Beecher straw had the lowest VFI.

The effects of supplementation on DOM and VFI become clearer when the 1987 and 1988 results are compared using regression analysis (Fig. 10.1). The results of Capper et al. (1989) are also shown in Fig. 10.1 although they are not included in the statistical analysis.

Supplementation increased the DOM of all straws except C63, which agrees with the findings of Capper et al (1989) (Fig. 10.1a). The change in DOM after supplementation was, except for C63 and ER/Apam, similar for all genotypes.

Supplementation of the straw genotypes had a greater effect on OMI than it did on DOM (Fig. 10.1b). In particular poor quality straws responded more to protein than did good quality straws. Indeed, the data suggests that if an unsupplemented straw had an OMI of about 50g OM/MBM, there would be no further response in OMI to protein. Capper et al (1989) found that this threshold was about 60g OM/MBM, indicating that the nutritive value of straw varies considerably between years. Part of the difference in the two sets of results could be because Capper and his colleagues used different amounts of a different protein

Table 10.2. Digestibilities and voluntary feed intakes of straw from nine genotypes of barley offered ad-libitum to sheep, with (1988 experiment) and without (1987 experiment) protein supplementation*, and the protein content of the straws.

	Arabi Aswad	ER/ Aram	Rihane	Badia	Beecher	C63	Arabi Abiad	Arar	Antares	Mean (SD)
Digestibilities of organic matter (%)										
Without supplement	49.2	44.1	49.9	45.1	46.3	49.5	45.3	50.0	51.8	47.3 (2.73)
With supplement	51.5	44.5	54.7	49.2	49.7	48.8	48.8	56.4	53.3	50.7 (6.05)
Intake of straw organic matter (g)										
Without supplement (g)	709	511	702	630	562	656	600	647	826	649 (120.9)
With supplement (g)	1034	898	980	936	754	925	935	911	957	925 (132.6)
Without supplement (g/MBM)	41.9	33.2	41.6	34.9	36.3	41.1	37.8	40.5	48.3	39.5 (4.54)
With supplement (g/MBM)	51.0	46.5	50.7	48.3	39.0	48.6	47.0	48.2	49.0	47.6 (3.55)
Protein content of straw** (%)										
1987 experiment	4.0	3.1	3.8	3.4	2.8	3.9	3.6	4.0	4.6	3.7 (0.62)
1988 experiment	4.1	2.9	3.9	3.7	2.8	4.1	3.4	3.8	4.7	3.7 (0.68)

* Soyabean meal, containing 52.3 percent crude protein.

** Straw used in both experiments came from same crop harvested in 1985.

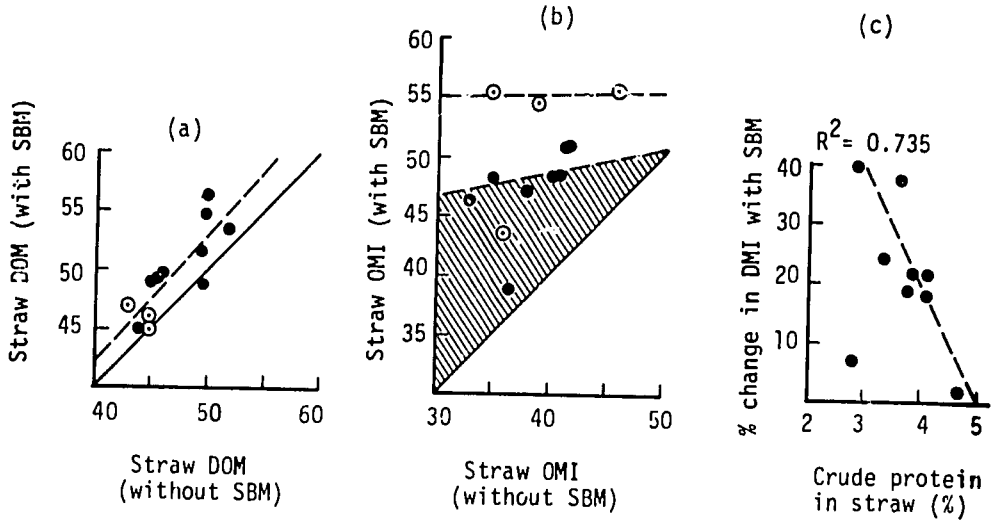


Fig.10.1. Effects of protein supplementation (with SBM[1]) on the change in (a) digestibility of straw organic matter (DOM), (b) intake/kg metabolic body mass (OMI), and (c) the effect of protein content in the straw on the change of OMI as a result of adding SBM.

The results are based on nine barley genotypes used in the 1987 (without SBM) and 1988 (with SBM) experiments. In (b) and (c) Beecher (B) was excluded from the regressions. Open cicles are the results of Capper et al (1988) and C is a result from C63. Each point is a mean of four observations, the solid line in (b) a regression of one passing through the origin, and broken lines are fitted regressions. The hatched area in (b) is the response to added protein.

[1] Soya bean meal.

(cottonseed meal) with a different rumen degradability than SBM. Our results, from in vivo experiments, agree with the findings of in vitro experiments that poor straws respond more to ammoniation than good straws.

The 1987 study shows that straw protein is closely correlated with intake (r^2 = 0.85), and that the decrease in OMI response to protein supplementation as straw quality increases is related to the protein content of the straw (Fig. 10.1c).

Expt 10.2: Comparison of in sacco digestibility of barley straws with phenotypically different stem heights

The objectives of Expt 10.2 were (1) to compare digestibility of genetically uniform straws with contrasting stem heights induced by different amounts of irrigation and (2) to compare the nutritive value of stem and leaf fractions at different stem heights.

Previous studies have shown that the proportion of leaf in mature cereals increases as plants get shorter but the extent to which the nutritive value of the leaf and stem fractions change is not known. To study this question mature (senescent) barley plants were sampled in June 1987 from the Cereal Program's line-source sprinkler (LSS) experiment at Breda. In this experiment several genotypes were sown in a replicated randomized block design at varying distances on either side of an irrigation pipe. This allowed, in the dry season of 1986/87, a gradient of moisture to be applied, the amount of moisture decreasing as the distance from the sprinklers increased. The result was that plants close to the sprinklers were tall while plants further away were short. All other factors such as soil, location, agronomic practices and time of sowing and harvesting were the same, thus removing these otherwise confounding factors from the measurements. Because only small quantities of straw were available, the in sacco technique was used .

To keep the size of the experiment manageable, only four of the genotypes were sampled, and the irrigation comparison was limited to the plots closest (tall stems) and furthest (short stem) from the sprinklers, with one intermediate plot (medium stems). The plants were separated into leaf and stem fractions, and the fractions milled through a 2 mm sieve before 2 g samples were placed in nylon-bags. Twelve bags (four genotypes and three

stem heights) of one fraction were placed in each of three rumen fistulated Awassi castrates offered 800 g daily of good quality hay and minerals. Bags containing leaf were removed after 6, 12, 24, 48 and 72 h incubation, and bags containing stem after 24, 48, 72 and 96 h.

The percentage disappearance of dry matter from the bags was fitted to the equation:

$$P = a + b\ (1-e^{-ct})$$

Where P is the percentage disappearance at time t, and a, b and c are constants (Orskov and MacDonald, 1979). The constant a is an indicator of the proportion of soluble material, the constant b expresses the amount of potentially fermentable cell-wall material, and the constant c the rate of disappearance (fermentation). The sum of a and b, the asymptote, shows the extent of fermentation, that is the amount of material that would disappear if straw particles remained in the rumeno-reticulum long enough to remove all fermentable material. This is not usually the case since particles, once they have been reduced to about 1 mm in diameter, have a high probability of leaving the rumeno-reticulum. The asymptote is therefore somewhat empirical, and the 48 h disappearance a better indicator of the amount fermented in the reticulo-rumen.

The proportion of leaf in the mature barley plants decreased substantially as stem height increased (Fig. 10.2), with Beecher having the tallest stems and lowest leaf proportion. Stem height appeared to be a more important factor affecting 48 and 72 h disappearance of leaves than genotype ($P<0.001$), ($P>0.05$) (Table 10.3), with leaves from short stems being more fermentable than leaves from tall stems. The percentage of soluble material in the leaves (constant a) differed between genotypes ($P<0.01$) and

Table 10.3. *In sacco* disappearance of leaves after 48 and 72 h incubation, and the content of soluble material (a), the content of potentially fermentable cell-wall material (b), and the rate of digestion (c), of mature leaves from four barley genotypes with contrasting stem height.

	Stem height	Leaf proportion	Disappearance (%)		Constants[1]			
			48 h (n=3)	72 h (n=3)	a (n=3)	b (n=3)	c (n=3)	a+b (n=3)
Genotype								
Arabi Aswad	46.3 (8.11)[2]	0.49 (0.049)[2]	72.0	72.2	0.016	0.711	0.068	0.727
Beecher	70.3 (14.15)	0.38 (0.072)	71.9	73.2	0.065	0.693	0.057	0.758
ER-Apam	44.3 (7.17)	0.45 (0.046)	74.3	78.4	-0.048	0.844	0.061	0.796
Rihane	61.7 (12.99)	0.43 (0.074)	73.1	76.4	0.002	0.774	0.056	0.776
Stem height								
Short	36.3 (3.47)	0.55 (0.019)	79.6	80.6	0.017	0.811	0.067	0.828
Medium	61.0 (7.78)	0.41 (0.027)	72.5	75.5	-0.024	0.789	0.060	0.766
Tall	69.8 (9.27)	0.36 (0.035)	65.8	68.3	0.034	0.666	0.055	0.700
S.E.D. (overall)	5.72	0.029	2.44	4.07	0.0449	0.0559	0.0092	0.0354
significance								
Genotype (G)	-	-	ns	ns	**	***	ns	*
Height (H)	-	-	***	***	*	***	ns	***
G X H	-	-	ns	ns	**	ns	*	*

[1] Derived from the equation $P = a+b\ (1-e^{-ct})$, where P is the dry matter disappearance at time t (Orskov and McDonald, 1979)

[2] S.E.M. in parenthesis.

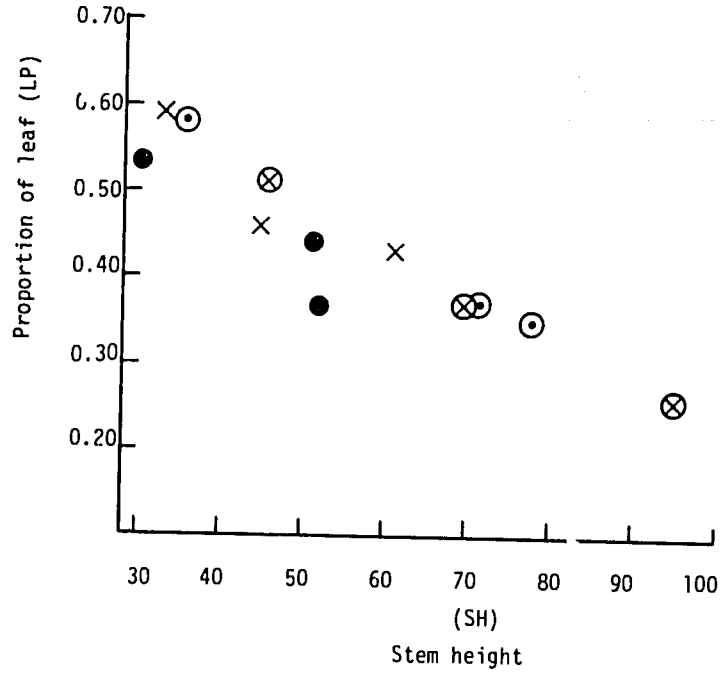


Fig.10.2. The effect of stem height on the proportion of leaf in the straw of four barley genotypes, Arabi Aswad (cross), Beecher (cross within circles), ER/Apam (closed cicles) and Rihane (open cicles).

stem heights (P<0.05) but these values are difficult to interpret as none differed significantly from zero (Student's t test).

The percentage of potentially fermentable material in the leaves (constant b) differed between genotypes (P<0.001) and stem heights (P<0.001), with ER/Apam having the highest value and Beecher the lowest. The value of b decreased with increasing stem height. The rate of disappearance of leaves (constant c) was similar across genotypes (P>0.05) and stem heights (P>0.05) although a decreasing trend in c can be seen as stem height increases. The extent of fermentation of leaves (a+b) differed between genotypes (P<0.05), with ER/Apam and Arabi Aswad being the highest and lowest, respectively: it too decreased significantly (P<0.001) as stem height increased.

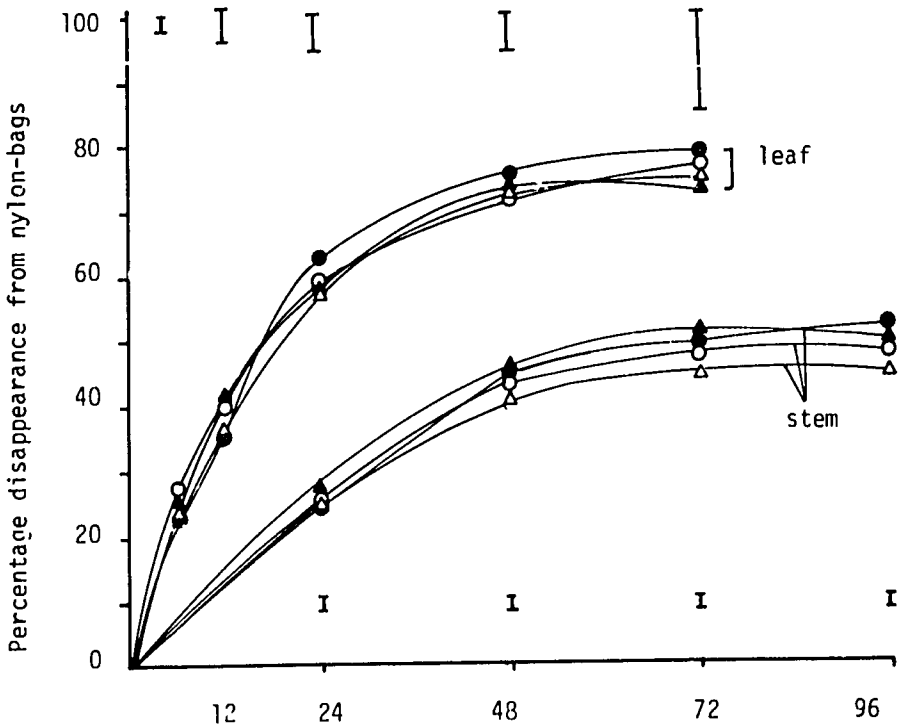


Fig.10.3. Percentage disappearance of leaf (upper curves) and stem (lower curves) fractions from the straw of four barley varieties incubated in nylon-bags for different times. Vertical bars show SEM (ns is P>0.05), * is P<0.05, ** is P<0.01 - applies only to comparisons between stem fractions; see Table 10.1 for significance levels between leaf fractions). Symbols for varieties are shown in Figure 10.2. Curves were fitted by eye. Constants of equation showing leaf disappearance are shown in Table 10.1.

The disappearance of stem and leaf material is shown in Fig. 10.3. The slower rate and lower extent of fermentation of stem compared with leaf is apparent. As there were non-significant effects (P>0.05) of stem height on the rate and extent of fermentation, these have been combined and the statistical analysis only compares the effects due to genotypes. Anomalous results were obtained when the exponential equation was fitted to

the stem data, largely because of large variations in the results and because data from only four incubation times are available. However, significant differences in disappearance at 72 ($P<0.05$) and 96 ($P<0.01$) hours were apparent, with Beecher stems giving lower values than Arabi Abiad and ER/Apam. (Because of the greater mechanical resistance of stem to rumination and the slower rate of fermentation of stem compared with leaf, it is reasonable to assume that stem particles take longer than leaf particles to reach a size small enough to pass from the rumen. Therefore the 72 h disappearance of stem approximates the extent of fermentation in the reticulo-rumen although this value is close to the asymptote).

Expt 10.2 makes important progress in showing that leaves from short barley plants are more digestible than leaves from tall plants and that stem height (per se) may be a more important factor affecting nutritive value than genotype (per se). Thus different genotypes with the same stem height and leaf proportion are likely to have similar nutritive value.

It is now clear that protein content of straw, even though it only ranges from 2 to 4 percent, has a marked affect on VFI even though 4 percent is still about 3 percent below the level at which ewes could maintain liveweight. The results indicate that screening barley for straw protein should be considered.

The trade-off between protein content in the grain and that in the straw could then assume importance. For example instead of increasing the protein content in grain from 10 to 14 percent by selection, it would be better, if the grain is used to feed animals (as it is), to increase the protein content in the straw from 4 to 7 percent. In this case the gain in nutritive value of the straw would be far more important (to livestock nutrition) than the loss in nutritive value of the grain.

It is now abundantly clear that Beecher is a genotype with extremely poor quality straw: it is fortuitous that it was with Beecher that our research began. If Beecher is ignored, the differences between the other genotypes in our experiments are relatively small, especially after differences in protein content are removed. -The late Frances Herbert (Wye College, University of London), E.F. Thomson, and R.C. Campling (Wye College, University of London). Dr E. Acevedo (Cereal Program) kindly provided the LSS samples for Expt 10.2.

CHPATER 11: TRAINING AND INTERNATIONAL CO-OPERATION

Systems-oriented research, although an effective method of improving production, is often seen to have the disadvantage of being site specific. For ICARDA to be successful it must produce results which are useful in many environments. It is therefore important for its collaborating NARS to learn that by working on farms and, where appropriate, using a systems approach, they are widening the scope of the research and making it easier to resolve difficult agricultural problems. The transfer of this research and its resulting methodologies to NARS, where ICARDA and the NARS jointly deem it to be appropriate, is the main objective of PFLP's plans in training and international co-operation.

PFLP encourages problem-oriented training, designed to complement its research. For example if NARS and ICARDA believe that a new result is of potential value, we design training courses to facilitate its adaptation and subsequent adoption, firstly by NARS, and later by farmers. The recent upsurge of interest in annual medics seems partly due to this approach. We give an example in grazing management later in this Chapter.

The key words for PFLP in international cooperation are 'focus' and 'collaboration': focus on countries with Mediterranean environments and a capacity to conduct livestock research, and collaboration with NARS scientists and other ICARDA programs. Collaboration involves leadership in networks, workshops, seminars, and nurseries, and in the design, interpretation, and joint publication of experiments. Our nurseries are discussed in Chapter 3, results from our rhizobia network are presented in Chapter 4, and, later in this Chapter we present a brief description and summary of the recommendations of one of our Workshops. The first year of our work in north Africa is also briefly described.

An overview of training in 1988

Training is important in our activities. Its objectives are to improve the technical skills of NARS scientists and technicians in pasture, forage and livestock science. Our training also seeks to achieve a network of researchers in the region, and is therefore part of our out-reach activites.

As for as possible we attempt to link training to our other work, especially individual training where we associate trainees with projects of relevance to their own countries. Good examples are the training we offer in on-farm research and medic seed production. Even in our residential course we attempt to assign projects to trainees which are, on the one hand, part of our main-stream research, while on the other, complete within themselves. In doing so the trainee becomes involved in the whole research process - planning and implementing the field work, analysing the results, and writing the technical report.

The residential training course: The overall objectives of the course are (1) to improve the capabilities of junior scientists and (2), assist in establishing links with national programs.

From 1 March until 20 June 10 trainees from 8 countries (Oman, Syria, China, Turkey, Saudi Arabia, Ethiopia, Algeria, and Tunisia) participated in the course at Tel Hadya. The syllabus included field and laboratory techniques for annual forage breeding, agronomy and utilization of pastures and forages, the ley farming system, biological nitrogen fixation, livestock nutrition, grassland improvement, and grazing management. Every trainee was closely associated with a senior scientist who assumed responsibility for his/her project. Details are given in Table 11.1.

Table 11.1. Participants in the residential training course and the titles of their projects.

Name	Country	Title of project	Supervisor
Abd El Hamid Elghssani	Oman	Sheep nutrition	Faik Bahhady
Hannan Talgeh	Syria	Selection criteria of forage legumes	Ali Abd El Moneim
Chen Li-Bo	China	Germplasm evaluation of forage legumes	Ali Abd El Moneim
Ayhian Aydin	Turkey	Microplot evaluation of chickling	Ali Abd El Moneim
Hamdan El Hassan	Saudi-Arabia	Grazing management of medic pasture	Alan Smith
Liyeuseu Alchu	Ethiopia	Grazing management and cereal growth	Alan Smith
Numan Kalicalp	Turkey	Sheep nutrition	Faik Bahhady
Khaldi Ashour	Algeria	Grassland improvement	Ahmed Osman
Ali Hamami	Tunisia	Medic seed production	Ali Abd El Moneim
Abd El Khader Bedda	Algeria	Medic seed production	Ali Abd El Moneim

At the end of the course most participants selected germplasm which they felt might be suitable for their own countries, and seeds were supplied to them for testing. Continued contact with the trainees will be maintained through visits and correspondence.

Short term training: Short term training provides concise, problem-oriented training on specific aspects of our work. It comprises field and laboratory work, lectures, and discussions over a period not exceeding four weeks. In 1988 a Jordanian spent three-weeks studying biological nitrogen fixation and the production of rhizobia, and a Moroccan spent four weeks studying inoculum isolation and production.

Long term training: In 1988 there were five courses: medic seed production, on-farm research, livestock nutrition, grazing management, and grassland improvement.

Lack of experience in seed production of medics is restricting their use in the region. From February to August two trainees, one from Algeria and one from Morocco, were trained on practical aspects of medic seed production, including use of herbicides, the effect of grazing, and use of the suction harvester. From January to October, one trainee (from Syria) studied the methodologies being developed at El Bab (Chapter 7), another (also from Syria), who studied sheep nutrition, measured the feeding value of barley straw. A trainee (from Iran) studied the productivity of medics in a two course rotation using different stocking rates (Chapter 5), and, recently, another from Iran has commenced a similar study. For two months in spring a Syrian trainee studied the carrying capacity of native pasture and conducted a survey of native legumes.

Visiting scientists: PFLP offers opportunities to experienced scientists from NARS to conduct research on topics of mutual interest. In 1987/88 there were three visiting scientists:

- Dr Mohamed Khair from Sudan completed experiments on the seasonal changes in quantity and quality of vetch and chickling herbage (Chapter 7). He is co-authoring two scientific papers on his work.

- Dr George Maalouf from Lebanon conducted research on the selection criteria of forage legumes.

- Dr Mohsen Adam from Egypt identified forage legumes with drought tolerance.

Training of trainers: Previously, little attention has been given to improving the quality of training conducted by the national programs themselves. Through the UNDP project on biological nitrogen fixation PFLP selected a Syrian who was trained in training for two years. The training focused on subjects related to strengthening needs assessment, curriculum development, teaching methods, instructional materials, evaluation, and management of training programs.

Graduate degree training: PFLP works jointly with Universities to select and supervise graduate students. This cooperation establishes links between our scientists and those at the Universities and at the same time helps to advance graduate studies. PFLP has provided four places for graduate degree training in the last two years. -- **Ali M. Abd El Moneim**

Training in grazing management

We thought it would be useful to include details of a training program, particularly one with emphasis on field studies. The following is a description of the course on grazing management conducted by Dr Alan Smith as part of our residential course. We include it because of its relevance to two of our themes - sustainability and pasture improvement.

As discussed in Chapter 5 grazing management is concerned with harvesting and maintaining pastures for the well-being of livestock. However, since grazing interferes with plant growth and reproduction, it is essential for trainees to realise that decisions about grazing management have serious consequences on the sustainability of livestock-based farming systems.

The course language is English. However each group consists of persons of several nationalities, and there is a complex pattern of common languages and language differences such that no one language ever seems to be entirely successful. English is best, but it has to be spoken carefully and slowly because, of the participants who declare that English is their second language, about half have difficulties with it. Since many countries of north Africa use French in addition to Arabic, it is best to repeat every statement in these languages.

The above cocktail is used for every exposition: for concepts, proposals for action, corrections of misunderstandings, planning what is to happen in the next hour, forward planning of the work, preparation of reports, and so on.

A second training manual has been prepared for the grazing management course (Technical Manual 16) to reinforce the practical application of concepts put forward in the original manual (Technical Manual 15). Figures from the second manual have been reproduced here to give readers an idea of the kind of material we use.

Expt 11.1: Experiment conducted by trainees with simulated grazing

The objective of Expt 11.1 was to teach concepts of grazing management using simulated grazing.

Medic pasture was 'grazed' by simulated grazing: plant material was removed by hand to imitate the actions of grazing sheep. In this way herbage removed can be weighed, and a rapid indication obtained of the influence of grazing on plant growth. The terms 'harvesting' and 'cutting' are used, the term 'grazing' being avoided because of possible confusion with real grazing.

A pasture of regenerating M. rigidula was used. Ten trainees worked as five pairs, each pair choosing a uniform area on which to establish one replicate ($2m^2$) of 6 treatments:

- HL: hard cutting of leaves only,
- HB: hard cutting of whole branches (shoots),
- ML: mild cutting of leaves,
- MB: mild cutting of branches,
- I: initial, where all biomass was removed at the start of the experiment, and
- O: final, allowed to grow until the end of the experiment when all biomass was removed.

The treatments were first imposed on 10 March and thereafter at weekly intervals until 4 May. On 4 May the plots were split, one half being cut to determine herbage and pod mass and pod number, and the other half being allowed to regrow until 31 May.

Pasture production: The material removed by the cutting of branches or leaves only is shown in Fig. 11.1. The influence of these treatments was reflected in the biomass present on 4 May, illustrated in Fig. 11.2. All types of harvesting caused a reduction in the quantity of pasture compared with what would have happened without cutting. The productivity for each treatment, calculated as the total of that harvested and the quantity remaining on 4 May, is given in Fig. 11.3, with, for comparison, the quantity of pasture present at the start of the experiment. Hard cutting of branches was the least productive, compared with the other treatments or the uncut control. Hard cutting of leaves (HL) was highly productive, almost equal to the best treatment, no cutting.

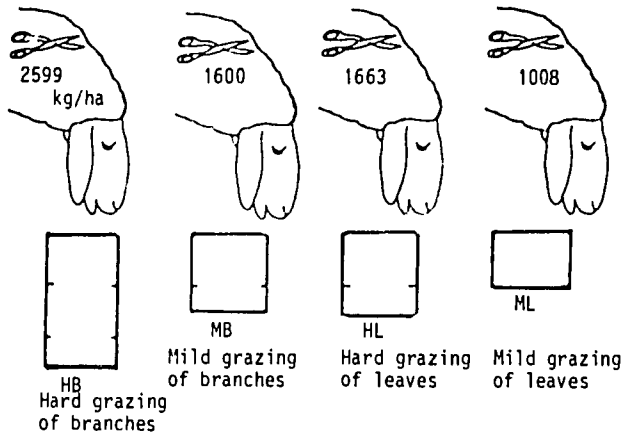


Fig.11.1. Quantity of medic pasture (kg/ha) removed by cutting to simulate four grazing (cutting) treatments
HB Hard grazing of branches
MB Mild grazing of branches
HL Hard grazing of leaves only
ML Mild grazing of leaves only.

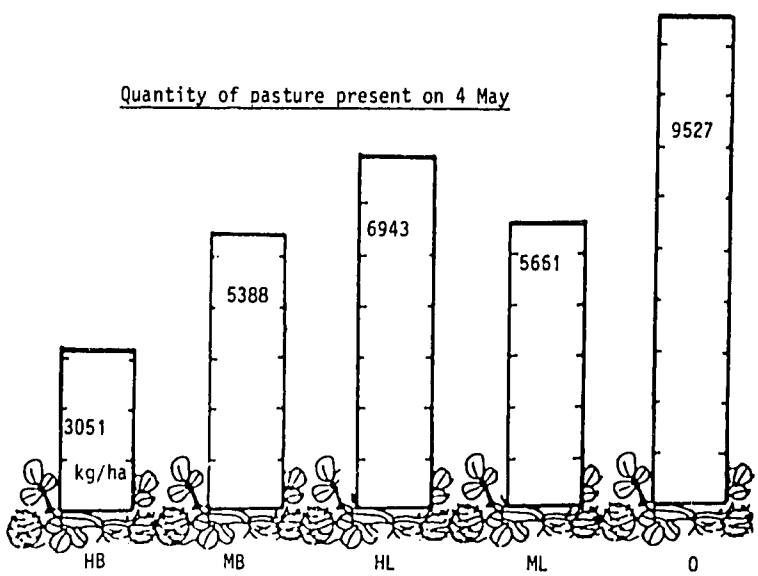


Fig.11.2. Quantity of medic pasture produced by regrowth under the influence of the four cutting treatments described in Figure 11.1, and present as standing aerial biomass (kg/ha) on 4 May when it was at a maximum. For comparison, the quantity resulting from continuous growth (without harvesting) is also given (Treatment 0).

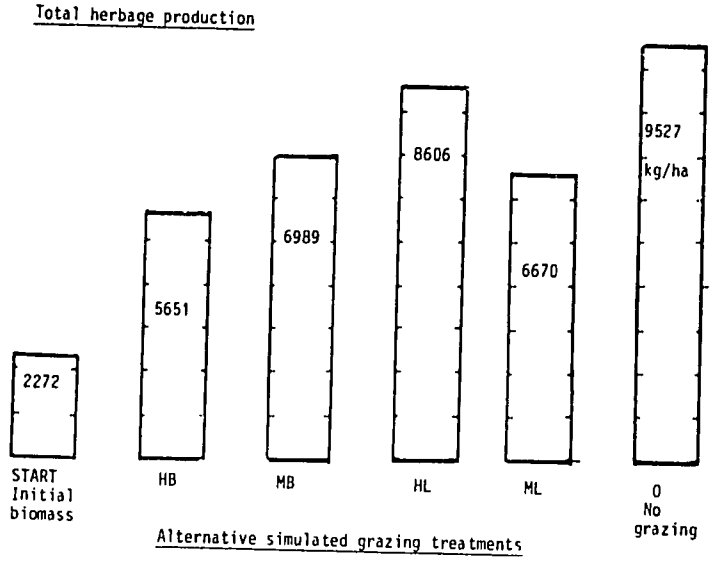


Fig.11.3. Productivity of medic pasture (kg/ha) as a total of the quantity harvested by cutting to simulate four types of grazing by sheep (see Fig.11.1) and the biomass remaining to be harvested. For comparison, the initial quantity of pasture present ("START") is shown to illustrate the low yield which would result from overgrazing. The productivity arising from uninterrupted growth, in the absence of cutting, is also given (Treatment 0).

The trainees had difficulty in coping with the amount of field work in this period. When absolutely necessary it is possible to help them to complete the work by using technicians and some unskilled labour. We expect our trainees to participate fully in the field work, even when receiving assistance.

Pod production: Pod mass on 4 May was low, but pod mass increased rapidly during May (Fig. 11.4). There was a similar change in pod number, low numbers in HB, MB and ML showing the greatest increase (Fig. 11.5). Pods were largest in the most severe treatments (HB, MB and HL), compared with ML and 0 where little or no herbage had been removed (Fig. 11.6).

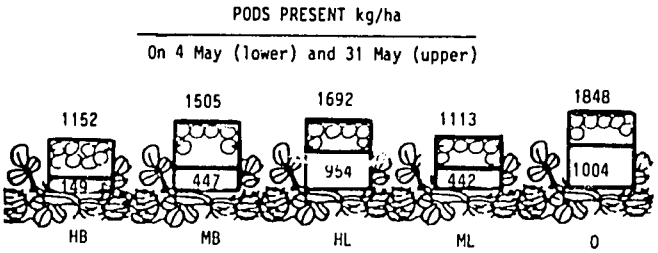


Fig.11.4. Quantity of pods present in medic pasture at two dates in May for contrasting cutting treatments described in Figure 11.1.

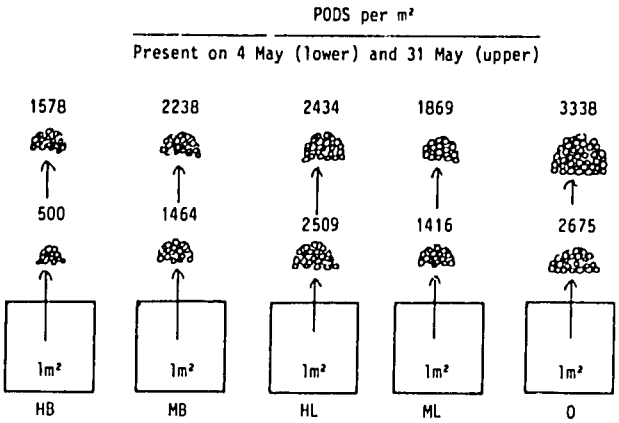


Fig.11.5. Number of medic pods present (per m^2) at two dates in May for contrasting cutting treatments described in Figure 11.1.

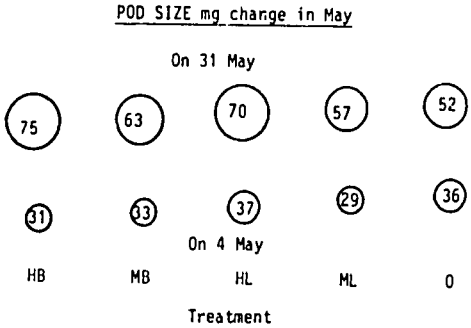


Fig.11.6. Influence of five cutting treatments, described in Figure 11.1 and 11.2, on the size of pods produced by a medic pasture (mg/pod). The large increase in size during May is also illustrated.

Pasture recovery during May: Fig. 11.7 shows the values for the quantity of pasture present on 4 May (when the treatments ended) and expresses them as a percentage of the ungrazed pasture (O). Simulated grazing treatments vary from 32% to 73% of the uncut treatment, the mean being 55%. The dotted areas show the changes between 4 and 31 May, and a new set of percentages are given relative to the new value of 100% for the uncut treatment on that date. The extremes for simulated grazing are now closer together, 52 and 78%, the mean being 68% for the 4 treatments. Differences among treatments were highly significant (F = 17.5 ***) on 4 May, but were not significant on 31 May (F = 2.6, 0.10> P>0.05, NS).

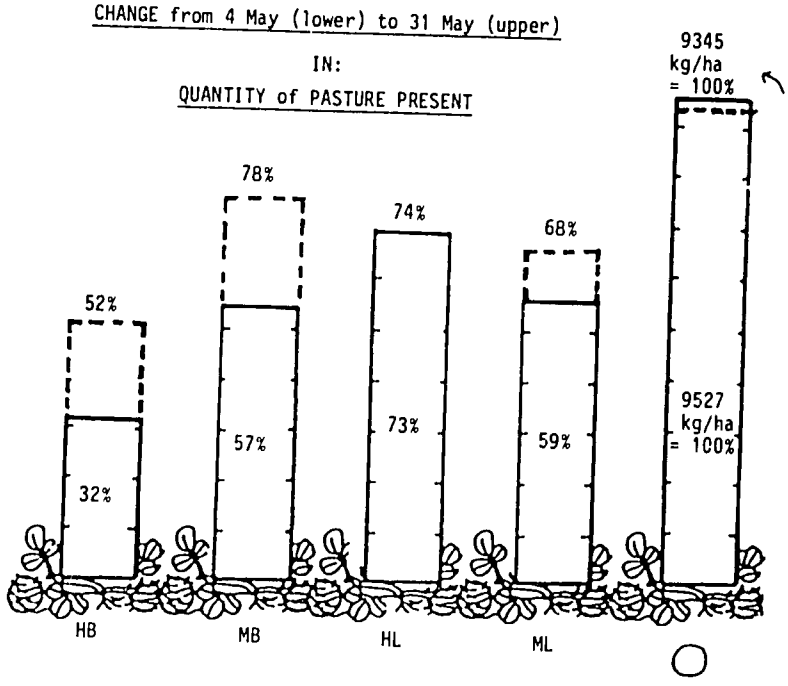


Fig.11.7. Herbage (kg/ha) present on 4 May following five cutting treatments (described in Figure 11.1), also expressed as a percentage of the value for treatment 0. The increase due to further growth during May is shown as a dotted line, together with the final quanities present as a percentage relative to treatment 0.

This part of the work was used to teach computing skills and to introduce new analytical techniques. Where further calculations are made, after the course has finished and the trainees have returned home, it is intended to keep them informed via additional technical manuals.

Correlation tests: To help the trainees interpret their results, and to stimulate their thinking about statistics, it is worth analysing the results in a different way: to ignore the classification of plots into treatments, and to take each plot separately.

If the quantity of herbage removed (as a percentage of that present at the end of cutting) is considered a measure of 'grazing' pressure, then the following correlations indicate the effect of the cutting of branches (HB and MB) on eight yield parameters:

- biomass on 4 May, r = -0.84 ***;
- total herbage production by 4 May, r = -0.66 **;
- mass of pods on 4 May, r = -0.80 ***;
- number of pods on 4 May, r = -0.88 ***;
- biomass present on 31 May, r = -0.57 *;
- total production by 31 May, r = -0.60 **;
- mass of pods present on 31 May, r = -0.32 NS; and
- number of pods present on 31 May r = -0.49 *.

The same analysis conducted on the effect of removing leaves (HL and ML) showed that there were no significant correlations, the value of the highest correlation coefficient being -0.40 for total production on 31 May.

This exercise, useful in itself, encouraged the trainees to broaden their use of statistical techniques, and to consider the use of different experimental designs.

Review of results on simulated grazing of medic pasture: The philosophy of the course is one of exploration and hope. The intention is to persuade the participant that progress can be made in solving vital food-production problems for their own country if they, as individuals, can think afresh. With motivation and enthusiasm, the individual can accept the challenge to consider new ideas, and the satisfaction of testing them at any level (small or large) dictated by the difficulties he encounters in his own country.

The results of previous trainees added to those in 1988 present a coherent investigation spanning three years. Mahdi and Asgar (in 1986) made the firsts steps and their findings were confirmed by Regmi (in 1987) who was able to control accurately the quantity of material harvested. Finally, the concepts were confirmed and expanded by the work (reported above) conducted by Ghassany, Aydin, Kilicalp, Abdel Kader, Libo, Hassan, Ali, Achour, Ayalew and Miss Thalgeh in 1988. Their experiments have shown that medic grows best without removal of plant parts, and that the greatest yield of herbage and pod is obtained from ungrazed pasture.

Of course the trainees realize that although hand harvesting and storing might result in maximum yield, such a procedure is costly and could not be recommended. The results they obtained however, make it easier to explain how the pastures react to grazing and how we can devise better methods of grazing management. - **A. Smith**

Co-operation with north African countries

Dr Philip Beale was posted to Rabat, Morocco at the end of December 1987. During his first months he focused on Morocco where he has built up an extensive network of people interested in pasture and forage science. Some of his activities were as follows:

- an ecogeographic survey of wild legumes (details later)

- selection of cultivars of M. aculeata, M. truncatula, M. orbicularis, and M. polymorpha, based on local germplasm (with Mr M. Bounejmate, Head of Forage Research, INRA)

- On-farm evaluation of balansa clover (T. balansae) to improve weedy fallows (with Mr Azdine Lahlou, INRA and Mr El Houcine El Mzouri, INRA, Settat)

- development of the rhizobia laboratory (with Ms Imane Thami Alami, INRA)

- selection of forage legumes utilizing germplasm supplied by ICARDA (with Mr Chaouki Al Faiz, INRA)

- development of experiments to measure sheep production from weedy fallows improved by medics (with Mr Bouchaib Boulanour, INRA, Settat and Dr Scott Christiansen, MIAC, Settat)

- links have been established in Algeria and Tunisia

Expt 11.2: Ecogeographic survey of wild legumes in Morocco (Preschedule M39)

In line with ICARDA's philosophy on selecting pasture legumes (Chapter 3) 161 sites were sampled during the summer of 1988 in the Oudja region (24 sites), Marrakesh region (37 sites), Beni Mallal region (28 sites), Settat region (28 sites), Tangiers region (29 sites) and the mountain region (15 sites). At each location all legume pods were collected in five 0.2 m^2 quadrats spread randomly across the collection site, while the total diversity of the site was sampled by an intensive search of the whole area. Thus for each site the yield of wild legume seed could be calculated and the diversity of genera and species could be described.

A total of 1194 accessions were collected belonging to 18 genera and at least 50 species (Table 11.2). It is possible that each accession is a mixture of genotypes and a number of new (to Morocco) species will probably be recognised when the accessions are grown out.

Where a species was found its seed yield ranged from zero within the quadrats up to 340 kg/ha of Scorpiurus sulcata, 310 kg/ha of a mixture of Trifolium angustifolium (264), T. glomeratum (31), and other Trifolium species (17), and 160 kg/ha of a mixture of Medicago aculeata (93), M. orbicularis (14), M. polymorpha (21) and M. truncatula (31).

Soil samples were taken from each site and climatic data has been collected. Each site will be described in terms of climatic and edaphic conditions and the rhizobia populations described. - **M. Bounejmate (INRA), P.E. Beale, and L.A. Materon**

Table 11.2. Number of accessions collected in an ecogeographic survey of wild legumes in Morocco.

Genus	Species	No of accessions	Genus	Species	No.of assessions
Anthyllis	sp.	29	Scorpiurus	sulcata	121
				vermiculata	20
				sp	10
Astragalus	bacticus	3	Trigonella	sp.	26
	epiglottis	11	Trifolium	angustifolium	40
	hamosus	53		arvense	3
	spp	14		bocconei	2
Coronilla	sp.	0		bullatum	31
Hippocrepis	sp.	34		campestre	46
Lotus	sp.	37		cherleri	26
Medicago	aculeata	50		glomeratum	42
	intertexta	3		isthmocarpum	22
	laciniata	55		lappaceum	26
	littoralis	22		plebium	12
	minima	32		resupinatum	12
	murex	3		scabrum	54
	orbicularis	46		stellatum	19
	polymorpha	98		subterraneum	6
	scutellata	3		tomentosum	13
	tornata	6		spp.	9
	truncatula	69			
Onobrychis	sp.	19			
Ornithopus	sp.	23			

Workshop on the role of legumes in the farming systems of Mediterranean areas

Workshops play an important consultative role in the Program's activities: during workshops we are able to get expert opinion of our research, particularly on new initiatives, and,

perhaps more importantly, to consult with NARS on the relevance and application of our work. We have been fortunate to obtain UNDP funding for a series of workshops on food and forage legumes, the third of which was held in Tunis in June. Continued funding is now guaranteed by the Government of Italy, as part of our pasture improvement project.

Because of the nature of the funding, both FLIP and PFLP have been heavily involved in the workshops, a great advantage in strengthening and broadening the discussions. This was especially true of the 1988 workshop which discussed the role of legumes in Mediterranean areas.

The objective of the workshop was to discuss legumes in relation to human and animal nutrition, sustainability of production systems, crop sequences, and socio-economic aspects of agriculture. There were 41 participants from Algeria, Australia, Cyprus, Egypt, France, Greece, India, Iraq, Italy, Jordan, Morocco, Portugal, Syria, Tunisia, Turkey, the United Kingdom, the United States, and, of course, ICARDA.

Recommendations of the workshop were wide-ranging and are summarized below:

- grain legume (food and forage legume) research should be strengthened through greater co-operation between countries of the Mediterranean basin, and be broadened to include the drier areas (<300 mm rainfall);

- quality of grain legumes should be monitored closely, and innovative methods of cooking food legumes should be encouraged;

- while the value of legume straw was recognized emphasis

on quality research in feed legumes should be on grain quality, especially for non-ruminants;

- where livestock are involved research should have a farming systems perspective, especially so in developing and evaluating the ley farming system, and increasing the stability and productivity of grasslands;

- particular attention is needed on the role of legumes in crop sequences, including interactions with weed control, other agronomic practices, nitrogen dynamics, and the effect of legumes on subsequent cereal yields;

- on-farm research was encouraged, particularly where it leads to a better understanding of rural socio-economic environments, and offers opportunities to involve extension workers;

- an urgent need to evaluate the genetic resources of pasture legumes and their rhizobia in the Mediterranean basin was recognized; and

- facilities to produce seed of all legumes, especially pasture legumes, should be improved.

The 1988 workshop has greatly encouraged, and provided the means, for both FLIP and PFLP to broaden their research linkages throughout the region. The 1989 workshop will build on that of 1988 by focusing on the problems of the ley farming system in the Mediterranean basin and, in consultation with NARS and outside experts, develop plans for its implementation in selected countries. - **A. Osman and H. Ibrahim (Workshop organizers)**

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Appendix 1: Publications

Refereed journals

Abd El Moneim, A.M., Cocks, P.S., and Swedan, Y. (1988). Yield stability of selected forage vetches (Vicia spp) under rainfed conditions in west Asia. Journal of Agricultural Science, Cambridge, 111, 295-301.

Brockwell, J., Daoud, D.M., and Materon, L.A. (1988). Symbiotic characteristics of a Rhizobium specific annual medic, Medicago rigidula (L.) All. Soil Biology and Biochemistry 20 (6): (December).

Capper, B.S., Thomson, E.F., and Rihawi, S. (1988). Genetic variation in the feeding value of straw. Animal Feed Science and Technology, in press.

Cocks, P.S. (1988). Seed production and seed survival under grazing of annual medics (Medicago spp) in north Syria. Journal of Agricultural Science, Cambridge, 110, 455-463.

Lorenzetti, S., Pagnotta, M., and Falcinelli, M. (1988). Genetic variability in Medicago rigidula L. Allioni evaluated at a low phosphorus level. Agricoltura Mediterraneana, 118, 199-203.

Muller, S., Glatzle, A., and Cocks, P.S. (1989) Performance and yield of self regenerating medic (Medicago spp) in short rotation with cereals in northern Syria. Herba, in press.

Thomson, E.F., Orita, G. (1988). Seasonal prevalence of protostrongylid and Dictyocaulus species of lungworms in Awassi sheep in north-west Syria. Tropical Animal Health and Production, 20, 187-189.

Thomson, E.F., Bahhady, F.A. (1988). A note on the effect of live weight at mating on fertility of Awassi ewes in semi-arid north-west Syria. Animal Production, 47, 505-508.

Books

Beck, D.P., and Materon, L.A. (1988). Nitrogen fixation by legumes in Mediterranean agriculture. Martinus Nijhoff Dordrecht.

Thomson, E.F., and Thomson, F.S. (1988). Increasing small ruminant production in semi-arid areas. Kluwer Academic Publishers, Dordrecht.

Other publications

Bellar, M. (1988). Screening forage vetches, peas, and chicklings for foliar diseases. Third Arab Congress of Plant Protection, El Ain (in Arabic).

Cocks, P.S. (1988). The sustainability of small farms in west Asia and north Africa. Paper presented to an IFAD consultation on the sustainability of small farms, Rome.

Cocks, P.S. (1988). Introducing pasture legumes to farming systems in north Syria - a case study. Paper presented to a University of Cukurova/FRMP Seminar on Farming Systems Research, Adana.

Cocks, P.S. (1988). Strategies for improving feed resources in west Asia and north Africa and their potential impact, in 'Tropical Weiden und Futterresourcen' ed. J. Alkamper, Universitat Giessen, pages 23-34.

Cocks, P.S. (1988). Constraints to developing ley farming systems in west Asia and north Africa. Paper presented at the International Conference on Dryland Farming, Amarillo, Texas.

Erskine, W., Cocks, P.S., Pala, M., Nordblom, T. and Thomson, E.F. (1988). Use of on-farm research as a method of

extending legume production in Mediterranean farming systems. Paper presented at the Workshop on the Role of Legumes in the Farming Systems of Mediterranean Areas, Tunis.

Glatzle, A., Cocks, P.S., Muller, S., and Beeker, K. (1988). Ertrag und Leistung selbstregenerierender Medicagoweiden im gentreide-ley farming in Nord Syrien, in 'Tropische Weiden und Futterresourcen' ed. J. Alkamper, Universitat Giessen, pages 141-150.

Ketata, H., Ibrahim, M.H., and Osman, A.E. (1988). Challenges facing agricultural research in the Arab region with emphasis on GCC countries. Proceedings of a Workshop on Agricultural Networks for the Countries of the Gulf Co-operative Council, Kuwait.

Materon, L.A., and Cocks, P.S. (1988). Constraints to biological nitrogen fixation in ley farming systems designed for west Asia, in: Microbiology in Action (Murrell, W.G., and Kennedy, 1.R., eds), John Wiley and Sons, New York.

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barley grain or cottonseed cake. Paper presented at The Science Week, held in Damascus, November 1988 (in Arabic)

Russi,L., Pagnotta, M., Osman. A.E., and Bahhady, F. (1988). Use of Syrian marginal land for fat-tailed sheep production. Paper presented at a Workshop on Small Ruminant Research and Development in the Near East, Cairo.

Smith, Alan (1988). Grazing managment for food production Technical Manual 15 En, ICARDA, Aleppo.

Thomson, E.F., Bahaddy, F.A. and Martin, A. (1988). Sheep husbandry at the cultivated margin of the north-west Syrian steppe. ICARDA. (In press).

Touma, M. (1988). Grazing management of a medic system. Paper presented at The Science Week, held in Damascus, November 1988 (in Arabic).

Thesis

Rink, Anette (1988). Sheep husbandry in Syria, the Awassi: productivity, parasitic infestation and phenotype. Diplomarbeit, Justus-Liebig-Universitat Giessen.

Turk, M.A. (1988). The growth of annual legume species in marginal rangelands in Syria with special reference to response to phosphorus. Awarded the Degree of Doctor of Philosophy at the University of Sheffield.

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Pasture Ecologist: A.E. Osman

Microbiologist: L.A. Materon

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Grazing Management Scientist: A. Smith

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H. Sawmy
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