ICARDA-129 En

PASTURE, FORAGE AND LIVESTOCK PROGRAM

Annual Report for 1987

PASTURE, FORAGE AND LIVESTOCK PROGRAM

ANNUAL REPORT 1987

The International Center for Agricultural
Research in the Dry Areas

Aleppo, Syria

Table of Contents

INTRODUCTION

In 1987 our research is reported in nine Chapters. Chapter 1 is a strategic overview of the Program in which we discuss the rationale of our research, its future direction, and how it is complemented by training and international co-operation. Chapter 2 reflects, more than any other, our philosophy of developing new technologies on farmers' fields. It includes reports on our on-farm research at Breda, Tah and El Bab (all sites in north Syria) which aim to study problems of adopting pasture and forages in sheep based farming systems. The Chapter also includes on-station research on the management of pastures and utilization of crop residues. Chapter 3 looks specifically at the problem of seed production in pasture plants, both in annual and native pastures, while Chapter 4 is devoted to genetic improvement of pastures and forages. Chapter 5 discusses biological nitrogen fixation, Chapter 6 yield decline in cereals, Chapter 7 the ecology and agronomy of pastures, and Chapter 8 the incidence of parasites in Awassi sheep. Chapter 9 briefly describes our training program. International co-operation is presented where appropriate in most Chapters. Throughout the Report we attempt to highlight our team approach and our commitment to farming systems research.

In reading Chapter 2 it is worth considering the point that our work on farmers' fields is a sensible blend of both 'upstream' and 'downstream' research. For example the work on medic pastures includes an element of 'on farm' research which is designed to test and modify an experimental farming system and to develop a methodology to extend to other NARS. Without the help of farmers, scientists would not receive feed-back which is essential for the continuation of their work. In the case of forages, the feedback has resulted in new plant breeding programs (for chickling) and the development of new breeding objectives.

Much of the work in other Chapters could be classified as 'upstream'. For example, Chapter 3 discusses important aspects of the physiology of pasture legumes, some of which will lead to even more basic research, hopefully conducted in collaboration with advanced institutions. The work in Chapter 6 (as is part of Chapters 3, 4 and 7) is a report of work conducted by a post-graduate student: such students are increasingly making an important contribution to the Program's basic research. The same comment applies to trainees who were involved in some of our more applied work.

Not all PFLP's activities are reported here. In particular the work on selecting new medic cultivars has been omitted. This is because the first stage of selection will end in 1987/88: a comprehensive discussion will therefore be included in next years Report. Another omission is the international nursery experiments with medics: this project got off to a good start, and results will begin to appear next year.

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.

Climatic conditions in north Syria during 1986/87

The following comments were supplied by Mr Wolfgang Goebel of FRMP.

The season was above average at wetter sites (e.g. Tel Hadya) and below average at drier sites (Breda, Boueidar), resulting in a steeper than normal rainfall gradient. For example Jindiress received 127% of its long-term average, Tel Hadya 108%, Breda 88% and an estimated 80% at Boueidar. The 300mm isohyet appeared to mark the boundary between areas of above and below rainfall. There was also a parallel temperature gradient, reflected in the number of frost days which rose from 20 at Jindiress (average 30) to 39 at Tel Hadya (average 37), 47 at Breda (average 43), and 53 at Boueidar. With the exception of February, the season was somewhat cooler than average with minimum temperatures being milder at the wetter than at the drier sites.

The season started early with rains falling during the first week of November at most sites. However, a prolonged spell of dry and cold weather followed which lasted until 18 December. The long dry spell following rain in November is most unusual at Aleppo and virtually stopped crop growth soon after emergence. Milder, rainy weather prevailed from mid December until the third week of February, broken only by another dry and cold spell during the second half of January. March was cold and wet with temperatures dropping below -5^{o}C at Boueidar on 21 and 22 March. Rainfall stopped at all sites during the second week of April, somewhat earlier than usual, but due to continuing cool weather and an adequate supply of soil moisture, crop yields were not adversely affected at Tel Hadya, in contrast to the drier sites where yields were low.

Another weather extreme of 1987 deserves recording. On August 7 the temperature at Tel Hadya reached an all-time high of 47.6^{o}C.

According to records 44 ^{o}C had not been exceeded since weather stations were first established 50 years ago. This event probably influenced the higher than expected rate of breakdown of hardseeds in medics reported in Chapter 3.

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), and hairy vetch (V. villosa subsp. villosa).

chickling - various species of Lathyrus 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. rugosa) have widely accepted common names. M. polymorpha, although often called bur medic, is referred to by its scientific name. At present we do not use a common name for M. rigidula or M. rotata.

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

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

accession - 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 - a group of similar genotypes, or an ecotype used in commercial agriculture, which has received official approval.

forage - this term 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.

herbage - plant material.

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^{o}C.

ley farming - in Mediterranean regions the farming system in which self-regenerating pastures are grown in rotation with cereals.

marginal land - land receiving 200 - 600 mm of rain which is too rocky, too steep, or where the soil is too shallow for cultivation.

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 - 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 200 mm of rainfall.

strain - is a general term to cover accession, selection, variety and cultivar. It is also used 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 - metabolizable energy

OM - organic matter

NDF - neutral detergent fibre

VFI - voluntary feed intake

Other abbreviations are as follows:

ACSAD - Arab Centre 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 Resource 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

I would like to thank the staff of PFLP, especially the senior scientists and students who contributed to this Report. Once again I must thank Zeina Ablo, Aida Battika and Zukka Musattat who prepared the typescript. Finally I express appreciation to JICA, who generously supported much of the research on animal health, the Government of Italy and the University of Perugia, who continue to support our work on marginal land, and UNDP, a major contributor to our training and workshop activities. - **P.S. Cocks**

RESEARCH HIGHLIGHTS

The response of native pasture to superphosphate has increased in each of three successive years. In 1986/87 it was reflected in liveweights, lamb growth rates, and in the amount of supplementary feeding. The proportion of legume in the pasture has also increased, especially at high rates of phosphorus.

The second phase of a phased-entry experiment comparing wheat/medic pasture with alternative rotations was successfully established. Ewes grazing medic residues and cereal stubbles increased weight throughout summer, the increase being inversely proportional to stocking rate. Wheat yields after first year medic were less than after fallow, a result which conflicted with a second, un-grazed experiment where wheat yields after established medic were higher than after fallow. A similar rotation experiment was successfully established in collaboration with SMAAR.

On-farm research on forage and pasture legumes continued. After six years farmers indicated that they would continue to use forages in rotation with barley, *but only if they could produce their own* seed. Barley yields after forage were equal or better than after fallow. Regenerating medic pastures produced up to 7t per ha of herbage and carried an average of nearly eight ewes per ha per year. Wheat yields after medic were better than after the farmers' chosen alternatives.

The palatability of several pea genotypes was compared with common and woolly-pod vetch. While none of the peas were as palatable as either vetch, some differences between genotypes were detected.

The nylon-bag technique was used to compare the nutritive value of nine barley straws, eight of which had been harvested in each of successive years. Straw of the variety traditionally used by farmers was the most nutritious, confirming earlier work. Straw supplemented with concentrate was successfully used as a diet for lactating ewes, the ranking of straw quality of four varieties being about the same at each level of concentrate.

The loss of large numbers of medic flowers during pod maturation was confirmed, losses, even in spaced plants, varying between 10 and 70%. Species differed significantly in their ability to retain flowers, and there was evidence of variation within species. The ability to retain flowers could be predicted by a function comprising pod mass and flower number per inflorescence. Retention was not improved by artificially tripping the flowers, and was considerably worse in high compared with low density swards. Where stress was imposed (by sowing at high density) yield was predicted by flowering time, early-flowering genotypes having highest seed yields.

Small medic and clover seeds were more likely to survive ingestion by sheep than large seeds. Trifolium campestre (seed mass of 0.5 mg) survived best, with 60% of seeds appearing in faeces. Of the medics, the small-seeded M. polymorpha survived better than large-seeded species such as M. rigidula and M. aculeata.

Studies of the seed bank in marginal land revealed that grasses germinated earlier and more completely than legumes. By mid-spring, before new seeds were formed, the population of grass seeds fell to zero whereas more than 1000 legume seeds per m^2 remained in reserve. Germination, though most rapid in autumn, continued for most of the growing season, ending in March.

Selection of forage legumes continued. Germplasm of Narbon vetch, woolly-pod vetch and three chicklings was evaluated in nursery rows and small plots. F3 plants of crosses between non-shattering and well adapted common vetches were grown, and F4 families will be distributed to interested NARS in 1988/89. Screening resulted in the identification of genotypes resistant to root-knot and cyst nematodes.

Medics were also screened for resistance to these nematodes. Most genotypes were resistant or tolerant to cyst nematode, but susceptibility to root-knot nematode was widespread. However, within both M. rigidula and M. rotata, resistance and/or tolerance were found.

Coating seeds with calcium carbonate or vermiculite and using organic adhesives improved the nodulation of medics. Compatible rhizobia were selected for some species (for example M. rigidula), and are being multiplied for experimental work. Introduced rhizobia genotypes survived in Syria from season to season. Networks, to test rhizobia strains and the need to inoculate have been established throughout the ICARDA region.

A bacteria capable of suppressing root growth of wheat seedlings was found in soils growing continuous wheat. While not yet established as one of the causal agents of cereal yield decline, the effect of the organism would explain one of the symptoms of decline: poor emergence and low seedling survival.

Establishment of first-year medic pasture was best when seeds were sown at a depth of 4-7 cm, regardless of the method used. Seeds sown shallower than this were at risk of dessication, while seeds sown deeper often failed to emerge.

Differences in the phosphate response of five legumes were observed. M. rigidula and M. rotata were more responsive than other medics and Astragalus hamosus, the latter not responding to phsophorus even in soil where available phosphorus was less than 3 mg per kg. In the medics, seed production was less responsive to phosphate than herbage production, although rankings remained similar.

The incidence of gastro-intestinal and lung parasites in Awassi sheep were observed in village flocks. Both classes of parasites were present, more than 60% of all sheep being infected with gastro-intestinal parasites, in winter and spring. Of the lungworms Cystocaulus, a difficult to control parenchyma-dwelling parasite was the most common. Hydatids were also present in slaughtered sheep, whose lungs were often characterized by these and other lesions. Monitoring of the flocks, including the regular weighing of ewes and lambs, and random slaughtering of ewes, will continue for at least two more years.

Nearly 1t of pasture and forage seed was distributed. Of the total, more than half was annual medics, especially M. rigidula selection 716. Most of the seed is being used for on-farm testing, although a significant amount was distributed to other international organizations, especially ACSAD. Rhizobia strains selected at ICARDA were also widely distributed.

CHAPTER 1: A STRATEGIC OVERVIEW OF PFLP

The principal objective of PFLP is to achieve a substantial increase in livestock production in west Asia and north Africa. This is an important target 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 (Table 1.1).

Table 1.1. Contribution of ICARDA commodities to human diets in west Asia and North Africa and the proportion of the value of total agricultural production from each commodity.

Commodity group	Protein contribution %	Calorie contribution %	Value %
Cereals[1]	58	59	25
Food Legumes	4	2	3
Livestock[2]	17	5	31
Other food commodities[3]	21	34	41

(1) includes rice
(2) includes poultry
(3) includes roots, tubers, starchy foods, vegetables, fruits, oilseeds and fish.

Source: CGIAR Priorities and Future Strategies, FAO, Roma (1987).

However, there is an increasing feed shortage. Feed is of two major types: material unusable by man (crop residues and natural vegetation) and cereal grains which are, of course, also human food.

Livestock can convert weeds, stubble, straw and other crop residues into foods rich in amino acids, vitamins, and minerals which balance human cereal-based diets. Yet there is a growing shortage of crop residues, and of plant material produced by the increasingly degraded rangeland. There is also an increasing shortage of coarse grains: to feed the 490 million small ruminants expected by the year 2000 an extra 35 million tonnes of barley will be needed, a target impossible to meet from increased yields which would have to increase from averages of 800 to 2600 kg/ha. The provision of improved pastures and more efficient production systems will therefore have a major impact on animal productivity.

This impact can be greatest in two important agroecological zones: arable land in the cereal zone where several advances, including the replacement of unproductive fallow with pasture and forage legumes, can greatly improve the output from sheep and goats; and communally owned marginal land within and adjacent to the cereal zone which is used exclusively for small ruminants and which currently has an output well below that possible with available rainfall.

The Program is committed to the development of stable farming systems. Productivity must be augmented at low cost, avoiding irrigation or the extensive use of fertilizers, employing superior rotations and methods of managing livestock, using legumes in arable and marginal land, and improving methods of animal husbandry and nutrition. To this end the work of the Program has been structured into four main areas: (1) the use of annual pastures and forages to replace fallow, (2) breeding of pasture and forage species, (3) marginal-land improvement, and (4) livestock management and nutrition. These have in common an emphasis on the use of legumes, which are seen as the key to efficient integration of livestock with cereals.

This Chapter gives a strategic overview of PFLP. It begins with a brief historical background and goes on to discuss the Program's activities since its formation in 1983, finally looking at its future strategies in research, training, and international co-operation. While taking into account the CGIAR priority review, the consultation with NARS at Viterbo, inputs by NARS and other ICARDA scientists at planning meetings, and the ideas presented in the ICARDA strategic plan, it is primarily a consensus of the ideas of PFLP senior staff.

In the text the term 'pasture' describes self-perpetuating plant populations which are grazed, while 'forage' describes annually re-sown crops which are harvested and fed as hay, grain or straw. Acronyms are defined on page 11.

Historical perspective

From its inception ICARDA realized that the key to increasing livestock production is the provision of more feed. By 1980 the predecessor of PFLP, the Pasture and Forage Improvement Program (PFIP), had evaluated some 16,500 legume and grass accessions for this purpose, with emphasis on vetches, peas, and medics. By 1983 PFIP had identified *Medicago rigidula* as a pasture legume adapted to northern Syria, although priority was being given to the selection and agronomy of forage legumes.

ICARDA was reviewed in 1983 and the EPR expressed concern at the lack of a systems approach in PFIP and recommended linking its research with that on grazing animals, allocating more resources to the rejuvenation of marginal land, closer collaboration with bilateral projects and national agricultural research systems (NARS), and the appointment of a grazing management specialist, microbiologist, pasture ecologist, and economist. It also suggested more involvement in north Africa, an examination of the potential of local Awassi sheep, screening them for external and internal parasites, and the testing of locally-developed genetically improved sheep (for details see Appendix 1).

As part of the response to these recommendations the Pasture, Forage and Livestock Program (PFLP) was formed by merging PFIP with the Livestock Unit, located, at that time, in the Farming Systems Program (now FRMP).

Activities since 1983

The EPR stimulated significant changes in the research strategy following the formation of the new Program. Syria was the obvious 'testbed' for new research, and strong links were developed with farmers and the Syrian ARS. Because crop and livestock production are integrated, a strong systems approach was used, and economists were involved in the design and interpretation of experiments. Training was integrated with research and NARS objectives to facilitate the interpretation and transfer of results to farmers. Publication of results assumed greater importance.

Priority went to replacement of fallow with pasture legumes, an ideal candidate for research. There are more than 30 million ha of fallow in WANA: a low input method of growing feed on fallow would greatly increase livestock and sustain or increase cereal production. Ley farming (replacement of fallow with self-regenerating legume pastures), originally developed in Australia, offered significant benefits if certain technical and socio-economic problems were solved.

These were: the lack of adapted pasture cultivars, lack of economic evaluation, poor nodulation, inappropriate tillage machinery, insufficient on-farm research, and lack of seed. Our work has now resolved many of these constraints such that, in Syria, there is now a demand for seed which cannot be met. Scientific publications, seminars, and ICARDA's training programs have stimulated interest in Morocco, Algeria, and other countries.

Following the 1983 EPR, resources allocated for research on annually re-sown forage crops to replace fallow were reduced and the emphasis was changed. Genetical work on cereal forages was stopped while all agronomic work was transferred to FRMP. However, breeding and selection of forage legumes continued with the focus on selection of non-shattering seed pods in common vetch, identification of resistance to Orobanche, diseases and nematodes, and selection for seed and straw in preference to hay.

PFLP's approach to the question of marginal land was to define the biological and environmental resources, develop low input methods of increasing productivity, and determine the constraints faced by farmers in adopting new practices. It was a long-term approach, justified by the huge areas of marginal land, and the need for soundly-based development. It has been successful insofar that stocking rates have doubled on experimental fields as a result of small applications of superphosphate. Thus the work prior to 1983, confined to the testing of exotic pasture species, has been widened to test grazing systems.

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 landraces of wheat and barley. In collaboration with the Cereal Program and the ODNRI it was decided to limit our work to genetic aspects of straw quality as most farmers cannot afford chemical straw improvement, and supplementation with protein cannot completely compensate for low quality. Our results so far indicate that quality does not appear to be associated with grain yield.

Preliminary work was conducted on the incidence and severity of gastro-intestinal parasites in Awassi sheep. The work, supported by a consultant from JICA, has shown that lungworms may cause serious economic losses in commercial flocks.

Since 1983 there have been 42 residential, 14 long-term, 42 short-term, and six post graduate trainees. The numbers reflect a policy of maintaining high quality, with emphasis on close contact between ICARDA scientists and trainees. Indeed training is closely linked with research to facilitate the teaching of research methodologies. This has been especially important during development of the systems approach where it was necessary that research be concentrated in Syria.

For this reason training has also been the key to international co-operation. However, since 1986, more extensive co-operation, involving the testing of pasture species and the establishment of 'need-to-inoculate' networks, has resulted in expansion to six countries beyond Syria, culminating in 1987 with appointment of a pasture and forage scientist in Morocco.

Future activities

Research

It is most important that PFLP consolidates its activities on improving and utilizing feed supplies. High priority will continue to be given to replacement of fallow with pasture and forage crops and rejuvenation of marginal land. But there are compelling reasons to strengthen the research on ruminant nutrition and non-nutritional constraints to the efficient utilization of feedstuffs.

Table 1.2 shows the allocation of priorities in a matrix comprising four feeding systems and five disciplines. Particularly for the disciplines, the headings embrace many activities, an indication of which is given beneath the Table. The percentage of resources allocated to each system and discipline are also indicated in the Table.

Annual pastures will continue to receive priority over forage legumes because using pastures in rotations is a radically new approach to increasing feed supplies at low cost. NARS have little

Table 1.2. Projected priorities across feeding systems and disciplines in the Pasture, Forage, and livestock Program. Numbers in parentheses indicate approximate allocation of existing resources.

Disciplines	Feeding Systems			
	Annual pastures (35)	Marginal lands (30)	Forage crops (15)	Crop residues (20)
Plant breeding (20)[1]	B[6]	D	A	B
Plant sciences (25)[2]	A	A	C	C
Systems analysis (35)[3]	A	A	A	B
Ruminant nutrition (15)[4]	C	B	B	A
Non-nutritional constraints(5)[5]	A	B	C	B

[1] Plant breeding: includes mostly collection and selection, but also hybridization to produce adapted cultivars of pastures, forages and cereals.

[2] Plant sciences: includes ecology, agronomy, plant physiology and microbiology.

[3] Systems analysis: includes grazing management, on-farm experimentation, and computer modelling but does not include socio-economics studies which are provided by FRMP.

[4] Ruminant nutrition: includes feed analysis, palatability studies, rumen microbiology and supplementary feeding.

[5] Non nutritional constraints: includes animal health, animal breeding, and reproductive physiology.

[6] 'A' represents top priority, 'B' and 'C' intermediate priorities, and D 'low' priority.

capacity to conduct this kind of research, whereas the agronomy of forage legumes resembles that of food legumes where NARS capacity is greater. However there are important differences between forage and food legumes, especially in utilization (hay, straw, and grain), which make it important for ICARDA to continue its work in this area.

Annual pastures: the objective is, through integration of livestock and cereal production, to increase livestock productivity by introducing self-regenerating pastures of annual legumes into cereal rotations, to devise management systems for pastures and livestock, and to determine and reduce constraints to cereal production.

System-oriented research, increasingly conducted in collaboration with NARS, will be maintained, with more emphasis on drier areas and areas of higher elevation. Selection and breeding of pasture genotypes adapted to dry areas (<300 mm rainfall) will have high priority, selection criteria being based on an improved understanding of ecogeographic relationships between plants and their native habitat. In collaboration with the seed production unit, assistance will continue to be given towards the establishment of pasture and forage seed industries.

Agronomic research will focus on maximizing cereal yields in cereal/pasture rotations (in collaboration with FRMP and the Cereal Program), involving utilization by cereals of available water, weed control, tillage, the selection of cereals adapted to the new system, and the study of root diseases in these and other rotations.

Of equal importance is the stability of pasture-based systems which depends on the ability of pasture legumes to fix nitrogen and set copious amounts of dormant seeds. Rhizobium research will involve collection and selection of effective strains, production of inoculants, and development of inoculation systems. Techniques associated with biotechnology may be used later to increase the efficiency of nitrogen fixation, develop resistance to pests affecting root nodules, and introduce mycorrhorizae into farming systems. Research on the physiology of seed production and dormancy will be aimed at the development of more reliable selection criteria.

Rejuvenation of marginal land: the objective is to increase the stability and productivity of livestock production on marginal lands by pasture improvement, use of fertilizers, and improved grazing management.

Research on rejuvenation of marginal land will be increasingly directed towards the 200-250 mm rainfall zone, most subject to desertification. Special attention will be paid to the most appropriate and stable land use systems in transects from dry to wet environments. Collaboration with ACSAD will be most appropriate, especially on the genetic resources of edible shrubs and management of shrub plantations in this zone.

It is important to obtain a better understanding of the ownership and management of communal land and to develop ways of implementing pasture improvement. This work will be conducted primarily with the Syrian ARS, Syrian sites being used to train other NARS staff to develop a similar approach. Collaborative projects outside Syria will be developed later.

Annually resown forages: the objective is to breed forage legumes, especially vetches, peas, and chickling, to replace fallows in cereal rotations, with emphasis on areas receiving less than 300 mm rainfall.

Breeding will be increasingly for legumes suited to areas which are too dry for lentils. We believe that a joint FLIP/PFLP approach improving food and forage legumes for areas with less than 300 mm rainfall and developing triple-purpose legumes (for grazing, grain and straw), will be valuable. Non-shattering vetches (V. sativa) will become available shortly while a wide range of species can be domesticated later with properties varying from seed burial (V. sativa subsp. amphicarpa) to high grain yields (V. narbonensis). Factors such as low palatability to small ruminants (in peas) and human toxicity (chickling) will be removed by selection and hybridization.

Research on the role of forage crops and their place in rotations will be continued.

Crop residues: the objective is to determine the role of cereal and other straws in small ruminant production systems and to improve their utilization and nutritional value.

In collaboration with ILCA and the Cereal Program, the research on factors affecting straw quality and methods of screening germplasm will be strengthened. Advanced institutions will be asked to consider using genetic engineering to generate microorganisms with enhanced ability to degrade lignified crop residues. If resources become available PFLP will start to define supplementary diets to improve the utilization of crop residues and industrial byproducts, and their interactions with pasture and forage crops. Interactions between nutrition and the sheep's breeding cycle need to be considered.

New initiatives: the remaining part of this section discusses new initiatives and how they fit into feeding systems. Implementation will depend on the provision of extra resources, in particular an increased capacity to conduct research into ruminant nutrition and its interactions with health and genetics.

PFLP intends to expand its work on sheep and goats in areas of less than 300 mm rainfall. The main existing thrust, to assemble improved feeding technologies into systems for on-farm evaluation, will be strengthened by co-operation with agronomists and economists in the other Programs.

Strong interactions between nutrition and both animal health and genetics can lead to serious constraints to feed utilization. ICARDA therefore held a workshop attended by representatives of NARS and experts from advanced institutions to discuss and set priorities. Their recommendations (Appendix 2) exceed ICARDA's capacity to respond, and show the need to widen our research. We believe that, of their recommendations, the priorities are to compare the nutritional requirements of improved with existing genotypes, and to identify selection criteria in sheep and goats through improving our understanding of the Awassi's adaptation to its environment. The effect of improved genotypes on flock productivity is neglected in on-farm research, and ICARDA should assist NARS in this area. Such work would be integrated with on-farm research in annual pastures.

An understanding of nutrition-related diseases, e.g. gastro-intestinal parasites linked with intensive grazing of annual pastures, is needed. Problems of high cost, poor availability, low efficacy, and environmental hazards of anthelmintics illustrate how techniques of disease control in developed countries can fail in developing countries. Expertise in the routine care and protection of ICARDA's flock of 600 Awassi sheep is essential, since this is not locally available.

Because of the complexity of livestock systems and the integration of livestock and crop production, the need for economic analysis, and the need to understand the various biological and sociological components of livestock production, PFLP intends to use computer models to analyse and interpret its work. This will first be confined to economic analysis using linear programming (with FRMP), expanding later to biological components of grazing systems. The latter will involve collaboration with advanced institutions and ICARDA's Computer Section.

Training

Systems-oriented research, although an effective method of improving production and efficiency, is often seen to be site specific. It is important for NARS to learn that by working on farms and, where appropriate, using a systems approach, otherwise difficult agricultural problems can be resolved. The transfer of this research and 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. A recent upsurge of interest in annual medics seems partly due to this approach.

The three-month residential training course (10-15 participants) is primarily for NARS which are starting to conduct research in pasture and animal science. Trainees are encouraged to conduct and analyse their own field studies preferably on a topic chosen by them or their home institute. The bringing together of trainees from countries with similar agro-ecologies is a useful first step in the formation of research networks, one of the main advantages of the residential course, both to ICARDA and NARS.

The Program is expanding its postgraduate degree training, which is of value in attracting new ideas to ICARDA's research and giving participants' work formal recognition. Such training also develops strong links with advanced institutions, and trains graduates in a developing-world context on topics closely related to NARS and ICARDA core research.

Apart from veterinary science, in many NARS the pasture and livestock sciences are of lower status than the crop sciences. To provide a better scientific environment PFLP will encourage the development of sub-regional networks and workshops where topics of common interest can be investigated and discussed. It will also encourage the exchange of information and the supply of materials, possibly including newsletters (cf ICARDA's crop science newsletters).

International cooperation

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. Co-operation involves leadership in networks, workshops, seminars, and nurseries' and in the design, interpretation, and joint publication of experiments.

Collaboration with NARS and some advanced institutions such as ILCA and ACSAD is often difficult because of our lack of appropriate scientific disciplines, particularly in the livestock sciences. Expertise in animal health, animal breeding, range management, and forage would assist in breaking down the barriers which exist within NARS and inhibit the development of a systems approach. Because of this problem, the diversity of its other topics, and its systems approach, it is important that PFLP focus on a few countries where impact is most likely. The countries of north Africa have highest priority after Syria, and we now have a scientist in Morocco, to cover also Algeria and Tunisia. Work with Jordan, Iraq, and Pakistan will be co-ordinated from Aleppo, and contacts are also maintained with bilateral projects.

The new international medic nursery and 'need-to-inoculate' network are examples of PFLP's approach. In spite of some early problems the nursery is being expanded to other countries (Morocco and France added in 1987/88) and more species, the data so obtained being of great value in analysing adaptation, and linking ICARDA's medic selection with that of NARS. International forage nurseries will begin in 1988/89. The 'need-to-inoculate' network has similar objectives and is of value by facilitating the collection of rhizobia and throwing light on genotype x environment interactions.

An important two-way communication between PFLP and NARS occurs at the PFLP/FLIP workshops which began in 1986. At these Workshops the concepts associated with introducing and using legume-based farming systems have been the subject of tri-partite discussions, of ICARDA, NARS, and outside experts. For example, at one workshop it became clear that NARS would experience problems in the sampling and initial evaluation of new medic varieties. ICARDA was therefore able to identify an important advisory role during which our knowledge of the distribution of medics will be greatly expanded. NARS scientists also attend Program planning meetings where their advice is of great value in determining priorities.

We hope to convey to NARS the need to accept systems and on-farm research as proper and rewarding scientific approaches. This is not necessarily so at present, especially in livestock research. ICARDA must demonstrate the concept by itself publishing its results and assisting in the design and interpretation of NARS on-farm research. This kind of co-operation is well-developed with the Syrian ARS, and we hope to extend it to north Africa in the near future.

Concluding Remarks

A consensus exists that the highest priority in livestock research is the development of improved feeding systems. This is reflected in our plans which consolidate existing research on annual pastures, forage legumes, cereal residues, and rejuvenation of marginal land. Apart from cereal residues the plans outlined under these headings can be implemented with existing resources, and we intend to maintain our agenda as described, with certain extensions. We believe, however, that there is a need to carry out more research in the livestock sciences in order to balance the plant work.

This will take the form of firstly, strengthening our systems approach by use of more rigorous analytical techniques, and secondly, determining the non-nutritional constraints to efficient utilization of feedstuffs. By redressing the existing imbalance between plant, animal, and social sciences in this way, we also expect to help in bringing together, in NARS, the various disciplines needed to increase livestock research.

CHAPTER 2: UTILIZATION OF IMPROVED FEED RESOURCES

In the ICARDA region the most complex problem faced by livestock scientists and farmers is how to utilize the various options to increase feed resources. For example, in the case of forage legumes, their agronomy is straightforward: how they should be used, whether it is profitable to use them, and how they fit into rotations are some of the questions which need answers.

This research is of a multi-disciplinary nature involving livestock scientists, pasture and range ecologists, a grazing management scientist and, increasingly, agricultural economists. Most aspects of livestock-producing systems are therefore covered.

The Chapter begins with a description of livestock productivity from native pasture, in which two rates of stocking and three levels of superphosphate are being compared. The second experiment is evaluating medics under grazing at three stocking rates, and comparing medic/wheat with other rotations. Then follows on-farm work on forages (two sites) and pastures (one site). The Chapter concludes with a description of work on the utilization of cereal and legume straws.

Experiment 2.1: livestock productivity at different phosphate and stocking rates on native pasture growing on marginal land (Preschedule ML2)

The objectives of experiment 2.1 are firstly to monitor the effects of stocking rate and phosphorus application on the natural vegetation of marginal lands, secondly to measure the response to phosphate application of livestock production and to test whether the responses, if any, are profitable, and thirdly, to assess the carrying capacity of marginal land and to look for botanical indications of over grazing.

Marginal land, often overgrazed for many years, usually has a low plant density, and is therefore of very low productivity and highly susceptible to severe soil erosion. Pasture availability is not sufficient, particularly in winter, and the sheep's diet is usually supplemented by the grazing of fallows, and by feeding of barley and legume grains and straw.

Rehabilitation of the marginal land of WANA is an important priority of ICARDA. Increasing the supply of pasture could improve livestock productivity and release land for grain and hay production with benefits to the stability of agriculture as a whole.

The strategies for improving marginal land are extensively discussed in previous Annual Reports (1984, 1985). In summary we believe that productivity of this land could be increased through:

- changing grazing management to encourage seed production;
- applying suitable fertilizer(s); and
- sowing adapted and improved pasture species.

Although easy to define we must remember that marginal land shows great variability in terms of total rainfall, soil depth, soil fertility, abundance of stones, and presence and distribution of plant species (eg Table 2.1) all of which make experimentation extremely difficult.

The experiment is being conducted at Tel Hadya on land typical of huge areas of western Syria. It will be possible to extrapolate the results by using botanical indicators of over-grazing, developing analytical methods to indicate phosphorus deficiency, and measuring the frequency and abundance of various pasture legumes. It is necessary to conduct this kind of experiment because NARS officials (and farmers) need evidence that improvement of marginal lands will give economic benefits. The experimental site is extensively used in training programs.

Table 2.1. Wild legumes found on marginal-land pasture in experiment 2.1 at Tel Hadya.

Trifolium angustifolium, L.	Astragalus asterias, Steve ex Ledel
" argutum, Sol.	" hamosus, L.
" campestre, Schreb.	" suberosus, Blanks et Sol.
" cherleri, L.	" triradiatus, Bunge
" hausskncchtii, Boiss.	Vicia peregrina, L.
" pauciflorum, d'Urv.	" sativa, L.
" pilulare, Boiss.	" villosa, Roth
" scabrum, L.	
" spumosum, L.	Lathyrus anuus, L.
" stellatum, L.	" aphaca, L.
" tomentosum, L.	" incospicuus, L.
Medicago coronata (L.) Bart.	
" minima, (L.) Bart.	Onobrychis crista-galli, L.
" orbicularis, (L.) Bart.	" kotschyana, Fenzl.
" rigidula, (L.) All.	Hippocrepis unisiliquosa, L.
" rotata, Boiss.	Hymenocarpus circinnatus, (L.) Savi
Trigonella astroites, Fish et Mey.	Pisum sativum, L.
" filipes, Boiss.	Scorpiurus muricatus, L.
" foenum-graecum, L.	Coronilla scorpioides, L. (Koch)
" mesopotamica, Hub.-Mor.	Coronilla spp.
" monantha, C.A. Mey.	Ononis spp.
" monspeliaca, L.	
" stellata, Forssk,	

Materials and Methods

There are three rates of phosphate (0, 25 and 60 kg per ha of P_2O_5) and two stocking rates (0.8 and 1.7 sheep per ha) in a factorial design with three replicates.

Superphosphate is broadcast before each growing season. The experiment began in November 1984 and sheep were first introduced in July 1985 after the completion of fencing. Ninety Awassi ewes were divided into groups of five, each containing 2, 3, 4, 5 and 6 year old ewes. Each year the oldest is sold and replaced by a two year old. The eighteen small flocks are permanently assigned to large (6.5 ha) or small (3.0 ha) plots representing the low and high stocking rates respectively in each of the fertilizer treatments.

Barley grain is used as a supplement during mating, late pregnancy and early lactation or whenever the average liveweight of the ewes falls to 46 kg. The amount fed to each flock is recorded.

Sheep are weighed weekly throughout the year and milk production daily during lactation. Measurement of milk production begins after removal of eight-week-old lambs for sale and continues until the end of lactation.

Pasture productivity is monitored by sampling the herbage during the growing season; monthly from December to February and every two weeks in March and April. At each sampling, 30 quadrats per plot (20 in the first season) are collected along a transect between opposite corners. Fifteen of these are from inside protective cages (60 x 60 x 40 cm high) and fifteen from matched sites near the same cages, the cages being re-located after each sampling. Each sample consists of four cylindrical units (10.5 cm diameter) taken to a depth of 10 cm. The number of plants and weight of grasses, legumes and weeds are determined in the laboratory.

Seed yield was first measured in 540 quadrats (50 x 50 cm) in June 1985: all vegetation in the top 1 cm of soil was collected. The same number of samples (in quadrats of 20 x 20 cm) have been collected each year thereafter: 270 in June from inside protective cages and 270 at the end of September from outside, to estimate the amount of seed left in the field after summer grazing. The seeds are hand-sorted, threshed, divided into grasses, legumes and weeds, counted and weighed.

Soil samples were collected firstly before any phosphorus was applied, and secondly at the end of each growing season. All financial inputs and outputs are being monitored for a final economic analysis.

From now on we will name the treatments receiving 0, 25 and 60 kg per ha of P_2O_5 the P0, P25, and P60 treatments and the ones with 0.8 and 1.7 sheep per ha, the low SR and high SR treatments. Year 1, Year 2 and Year 3 will represent the 1984/85, 1985/86 and 1986/87 growing seasons.

Results and Discussion

Pasture response to phosphorus: Table 2.2 shows the effect in Year 3 of phosphate application (average of two stocking rates) on available biomass of grasses and herbs. Treatment P25 resulted in by far the highest biomass of grasses until early April, but no differences were found at the final sampling two weeks later. For herbs P60 resulted in the highest biomass from early February until early April, but again no differences were detected at the end of the growing season. At this stage grasses and herbs contributed approximately 400 and 500 kg per ha respectively to total available biomass. However the contribution of legumes (Fig. 2.1) was greater at P60 (640 kg per ha) than at P25 (500 kg per ha) and P0 (140 kg per ha), while the total available biomass reached 1580, 1440, and 1050 kg per ha ($P<0.05$) at the final harvest, respectively.

Table 2.2. Dry matter yield (kg per ha) of grass and herbs in grazed marginal land pasture at Tel Hadya during Year 3 (1986/87) as affected by phosphorus application.

Species	Month	P_0	P_{25}	P_{60}	LSD[1]
GRASS	Dec 1	24	45	25	11.5
	Jan 8	33	56	31	15.0
	Feb 1	44	106	55	24.4
	Feb 22	98	160	108	43.6
	Mar 9	91	164	144	44.5
	Mar 22	145	188	139	34.5[2]
	Apr 5	207	313	248	80.5
	Apr 20	435	431	369	(n.s.)
HERBS	Dec 1	19	16	21	(n.s.)
	Jan 8	37	44	50	(n.s.)
	Feb 1	79	76	104	24.4[2]
	Feb 22	202	156	263	56.6
	Mar 9	257	239	340	71.8
	Mar 22	340	286	359	66.7[2]
	Apr 5	429	379	487	78.3[2]
	Apr 20	468	512	574	(n.s.)

(1) L.S.D.'s significant at P<0.01.
(2) L.S.D.'s significant at P<0.05.
(n.s.) F-test not significant.

It is important to point out that growth rate in spring was high, and was highest during the last two weeks of growth. The biomass at the last sampling provides food as dry residues during summer.

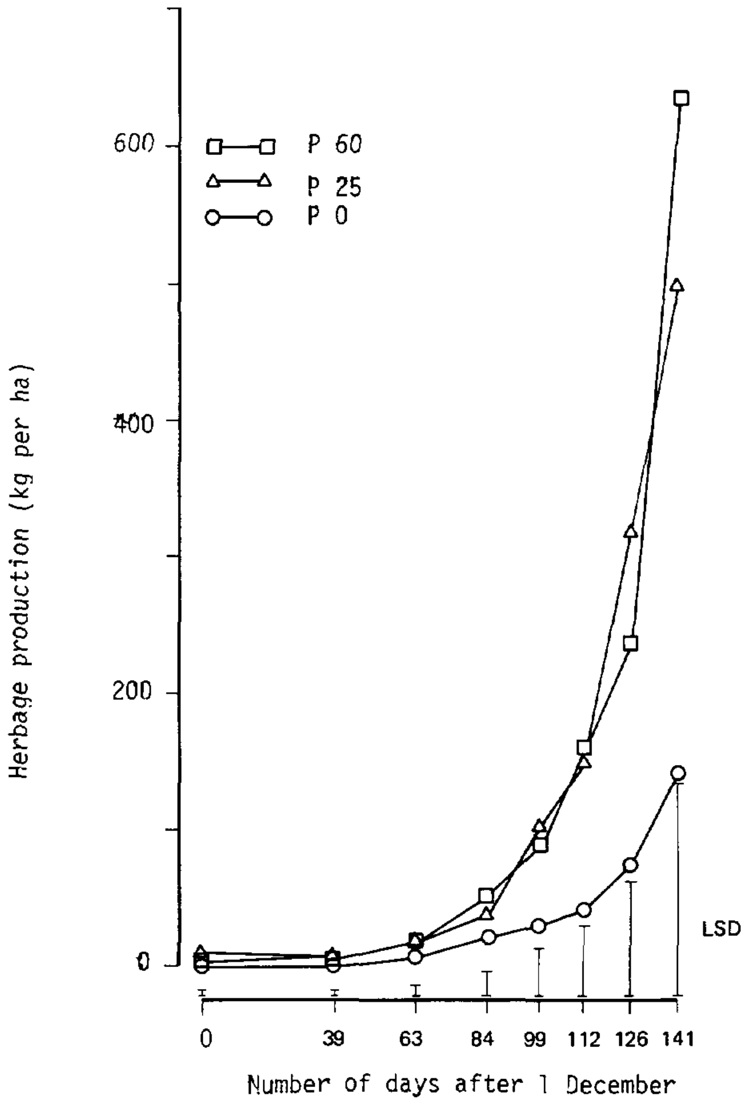


Fig. 2.1: Available legume herbage (kg per ha) in grazed native pasture on marginal land at Tel Hadya at three rates of phosphorus application, 0 (circles), 25 (triangles), and 60 (squares) kg of P_2O_5 per ha (mean of two stocking rates). Bars represent L.S.D. at $P<0.01$.

Legume response to phosphate fertilizer started in Year 1 and has continued in Years 2 and 3, the largest response being in Year 3 (Fig. 2.1 shows Year 3 only). A similar response occurred for seed yield (Table 2.3), the response in seed numbers in Year 2 being reflected in Year 3 by better plant density throughout the season (Table 2.4). Seed numbers at the end of Year 3 suggest that in Year 4 differences in density and hence biomass will be even greater. Further analysis reveals that the response in legumes is not only due to improved density but also to higher mass per plant (Fig. 2.2). Significant differences were found mainly from late February ($P<0.01$).

Table 2.3. Effect of superphosphate on seed yield (kg per ha) and seed number (number per m^2) for legume species on marginal land.

Fertilizer treatment	Year 1		year 2		Year 3	
	Seed yield	Seed number	Seed yield	Seed number	Seed yield	Seed number
0	28.6	2072	14.2	1596	21.0	2858
25	36.6	3114	22.2	2063	68.3	8786
60	46.1	3995	41.6	3379	99.0	11704
L.S.D. ($P<0.05$)	11.7	825	10.5	751	22.0	2278

Table 2.4. The population density of legumes (number of plants per m^2) in grazed marginal land pasture at Tel Hadya during Year 3 as affected by phosphorus application.

MONTH	P_0	P_{25}	P_{60}	L.S.D.(1)
Dec 01	145	379	256	125
Jan 08	122	289	247	110
Feb 01	154	361	313	122
Feb 22	285	478	450	164
Mar 09	252	645	504	180
Mar 22	284	605	565	164
Apr 05	223	670	407	145
Apr 20	228	440	523	140

(1) L.S.D.'s significant at $P<0.01$.

The results strongly indicate that applying phosphate will benefit pasture availability both during and at the end of the growing season, mainly due to the increased contribution of legumes. The benefit will therefore be not only in a higher yield of dry matter but also in better quality forage, with a higher protein content, results that could otherwise be obtained only by the use of expensive nitrogen fertilizer.

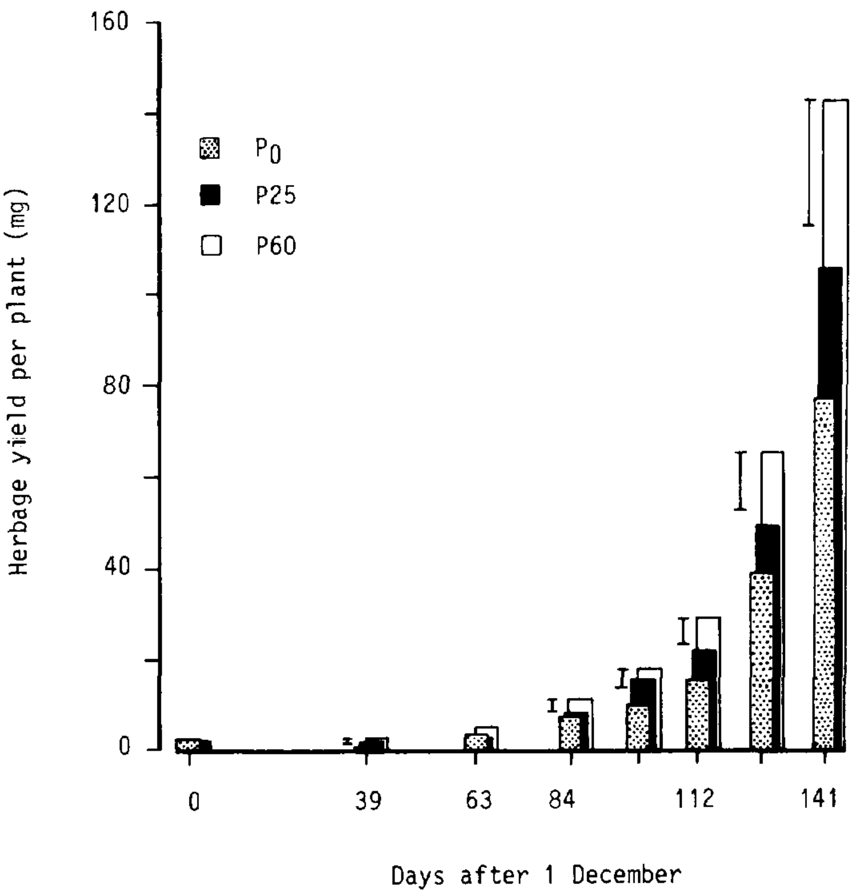


Fig. 2.2: Mean mass of legume plants (mg per plant) in grazed native pasture on marginal land at Tel Hadya at three rates of stocking, 0 (stippled histogram), 25 (solid histogram), and 60 (open histogram) kg of P_2O_5 per ha. Bars represent L.S.D. at P<0.01

Grasses and herbs are also essential components of the pasture since they make a significant contribution to available biomass especially during winter. In fact they showed a better winter growth rate (Table 2.5) than the legumes, although, as legume numbers increase, so will legume growth rate.

Table 2.5. The winter and spring growth rate of grasses, legumes and others (kg per ha per day) in marginal land pasture at Tel Hadya in Year 3 as affected by phosphorus application.

GROUP	SEASON	P_0	P_{25}	P_{60}	L.S.D.[1]
GRASSES	winter	0.868	1.452	1.056	0.498
	spring	8.495	7.700	6.737	n.s.
LEGUMES	winter	0.210	0.357	0.630	0.258
	spring	3.492	11.950	14.756	4.635
OTHERS	winter	2.497	1.678	2.826	0.841
	spring	6.415	6.584	7.395	n.s.

(1) L.S.D.'s significant at P<0.01.
(n.s.) F-test not significant.

The above comments apply to available pasture. However it is possible to calculate total production by integrating the growth rates in Table 2.5. The results are illustrated in Fig. 2.3 which shows that total production reached more than 2.5 t per ha in Year

3, and in Fig. 2.4 which shows that legume production reached about 1 t per ha in Year 3. Both Figs illustrate that the response to phosphorus is increasing with time: there is also an upward trend in growth at P0 apparently not associated with rainfall, which was 373 mm, 316 mm, and 358 mm in Years 1, 2 and 3 respectively. This trend occurs probably because of the grazing management used in the experiment: continuous grazing allows for greater seed set and hence greater plant numbers than traditional management.

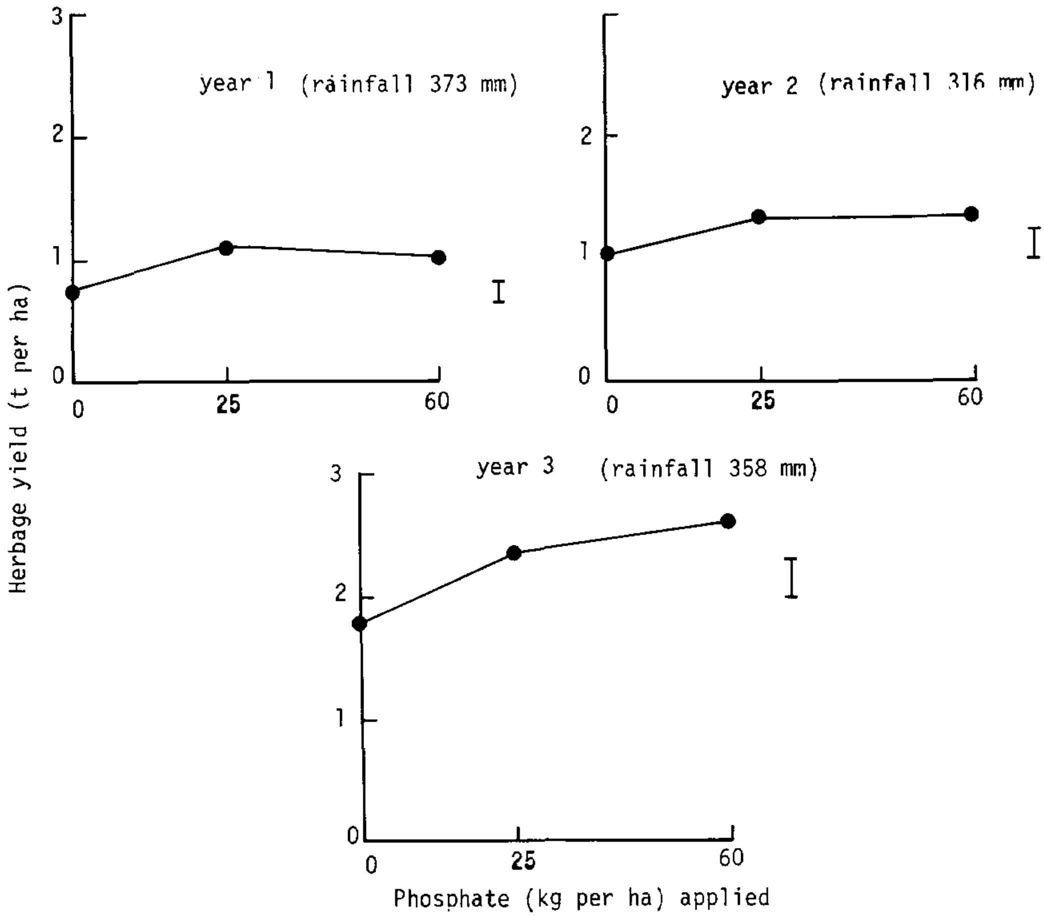


Fig. 2.3: The response in total productivity of native pasture on marginal land to superphosphate in years 1,2, and 3 (average of high and low stocking rates). The fertilizer was first added in 1984/85, and has been applied each year at the same three rates. Bars represent L.S.D. at $P<0.05$.

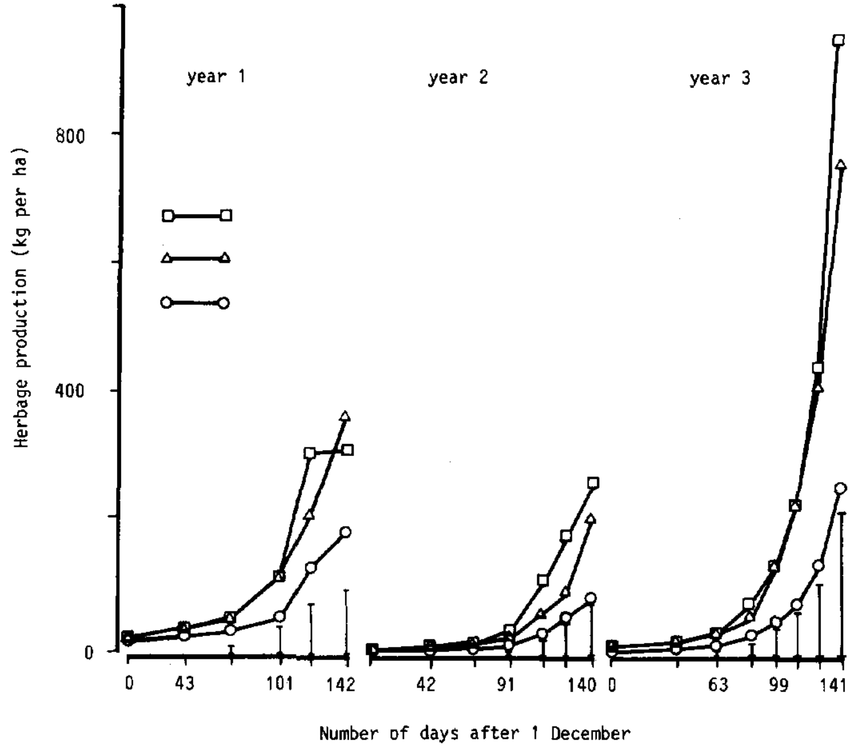


Fig. 2.4: Total herbage yield of legumes (kg per ha) in grazed native pasture on marginal land at Tel Hadya in years 1,2, and 3 at three levels of phosphate, 0 (circles), 25 (triangles) and 60 (squares) kg of P_2O_5 per ha. Bars represent L.S.D. at P<0.01. For rainfall see Fig. 2.3.

Effect of stocking rate on pastures: Grazing reduces plant density which in turn is highly and positively correlated with biomass. No grazing occurred during Year 1, the sheep being introduced in July 1985. In that year, mean plant density in February was over 8,500 plants per m^2, in Year 2 it was 3370 rising to 5680 in Year 3. Although these values in part reflect seasonal variations (Year 2 was a year of lower rainfall) there is evidence that the grazing of dry residues from May onwards also results in the loss of seeds: important in re-establishing pasture in the following autumn. As will be seen later (Chapter 3), heavy grazing is likely to result in natural selection in favour of small-seeded species.

Table 2.6. The population density (total number of plants per m^2) and herbage yield (kg per ha) in marginal land pasture at Tel Hadya during Year 3 as affected by two levels of stocking rate (SR): low (0.8 sheep per ha) and high (1.7 sheep per ha).

	DENSITY			HERBAGE YIELD		
MONTH	LOW SR	HIGH SR	L.S.D.(1)	LOW SR	HIGH SR	L.S.D.(1)
Dec 1	2705	1747	534	63	47	12.56
Jan 8	3802	3022	771	100	77	17.99
Feb 1	4941	3525	977	190	146	34.17
Feb 22	6487	4863	1120	419	312	59.07
Mar 9	5193	3882	705	540	432	71.67
Mar 22	4499	3601	601	698	516	87.46
Apr 5	3730	2821	517	971	824	109.37
Apr 20	2676	2377	n.s.	1441	1269	142.98(2)

(1) F-test significant at P<0.01 to 0.001 and L.S.D.'s are quoted for P<0.01.

(2) L.S.D.'s significant at P<0.05.

(n.s.) F-test not significant.

In Year 2, when grazing commenced, High SR showed lower plant densities then Low SR, this difference becoming marked in Year 3 (Table 2.6). Each pasture component has shown the same trend with time, more quickly in grasses (since Year 2 significant differences P<0.01) than herbs (differences at P<0.01 in Year 3) and legumes (only a trend in Year 3).

Observations suggest that, as seed numbers increase, there is increased activity of seed- harvesting ants.

Livestock productivity: In Year 3 sheep grazing fertilized pasture were heavier than the controls (Fig. 2.5a). Sheep at low stocking rate (Fig. 2.5b) were always (from November to May) significantly heavier (P ranging from <0.05 to <0.001) than sheep at high stocking rate, the differences becoming more marked with time. These patterns are almost identical to those in Year 2, except that, in Year 3, mean liveweights were higher. The fall in liveweight at the end of January was caused by lambing.

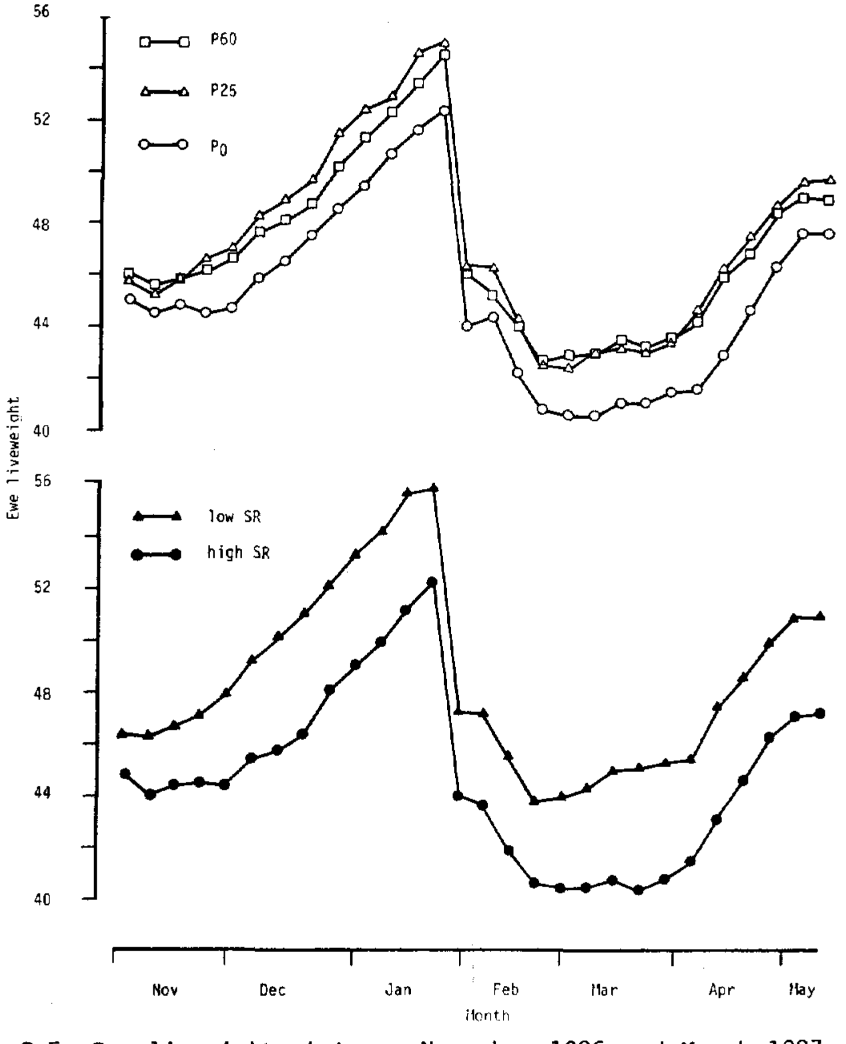


Fig. 2.5: Ewe livewights between November 1986 and March 1987, the ewes grazing native pasture at (a) three rates of phosphate (mean of two stocking rates) and (b) two rates of stocking (mean of three phosphate rates).

Lambs were weighed each week from birth to 8 weeks. Lambs born at low stocking rates grew faster than those at high stocking rates (Table 2.7). Further analysis has shown that female lambs have a lower growth rate than males (0.303 vs. 0.332 kg per day, P<0.01) and female growth rate seems more strongly affected by pasture availability (0.320 vs. 0.291 kg per day at low and high SR., P<0.01).

Table 2.7. Lamb liveweight (kg) on weekly basis and changes under low and high stocking rate (mean of three P levels).

Date	Low SR	High SR	L.S.D.(1)
Birth	4.83	4.78	(n.s.)
week 1	6.81	6.68	(n.s.)
week 2	9.13	8.73	(n.s.)
week 3	11.44	10.90	0.421(2)
week 4	13.76	13.01	0.659
week 5	16.08	15.12	0.762
week 6	18.39	17.24	0.872
week 7	20.69	19.34	0.978
week 8	23.01	21.45	1.092
Growth rate (g per day)	330	302	17

(1) L.S.D.'s significant at P<0.01.
(2) L.S.D.'s significant at P<0.05.
(n.s.) F-test not significant.

During mating it was necessary to feed ewes grazing the P0 treatments more than those grazing the P60 and P25 treatments (barley grain: 18.9 vs. 9.1 and 9.5 kg per ewe, $P<0.01$). Similarly sheep grazing at high SR needed to be fed more than those at low SR (18.7 vs. 6.3 kg per ewe, $P<0.01$). No supplementary feeding was necessary for sheep grazing fertilized pasture at low SR a repeat of the previous year's results.

Unlike liveweight, milk production per ewe was not significantly affected by phosphorus or stocking rate, showing only a general trend and confirming the results of Year 2. This means that the yield of milk per ha at high stocking rate was double that at low stocking rate.

Three years of data have produced encouraging results. The conclusions we can draw at this stage are summarized as follows:

- of the various pasture components legumes respond most strongly to phosphate producing more herbage and seed. This results in better quality grazing and in time will alleviate nitrogen deficiencies in the soil. The presence of grasses and weeds is important during winter when they are more available than legumes to grazing animals;

- generally grazing reduces plant density and herbage yield; and

- more available herbage, whether due to application of phosphorus or low stocking rate, increases ewe and lamb liveweight and decreases the need to feed during stress periods. In terms of individual ewe production the effect of stocking rate is greater than phosphorus. - **L. Russi, M. Pagnotta**, A. Osman

Experiment 2.2: productivity of wheat/pasture rotations compared with alternative forms of land use (Preschedule L13, M37)

The objective of experiment 2.2 is to assess the productivity of a wheat/medic rotation and to compare its profitability and stability with other rotations.

There is no data from WANA on the profitability of a medic/cereal rotation compared with alternative rotations. This is because such experiments are expensive and the results tend to be specific to the experimental site. Nevertheless without such data it is difficult to provide evidence to NARS that the rotation will be profitable. Accordingly an experiment was designed at Tel Hadya (average rainfall 332 mm) to compare a medic/wheat rotation with four other rotations. This kind of experiment, where systems are compared, is useful also because it forces the researcher to face problems similar to those faced by farmers: how to feed livestock on a year-round basis, how to deal with the relatively unproductive first year of the rotation, how to control weeds, and so on. A similar experiment has commenced at Breda (rainfall 279 mm) in which barley replaces wheat. Indeed it is possible that, ultimately, the medic system will be more appropriate to the drier areas growing barley than to the wetter areas growing wheat.

A series of medic pastures was established at Tel Hadya in the winter of 1986/7 and managed at three stocking rates. In all there were seven land-use treatments, all of which rotated with wheat:

- medic (M. rigidula selection 716) grazed at 4 sheep per ha;
- medic grazed at 7 sheep per ha;
- medic grazed at 10 sheep per ha;
- fallow;
- watermelon;
- lentil; and
- vetch.

These treatments were imposed on land which had been used to grow wheat in the previous year (1985/86). Similarly, land which had been used for these seven treatments in 1985/86 was used for wheat in the current year. The rotations thus have "a two-phased entry": both alternative crops for each rotation start in each of the first two years. The design is a randomised block with three replicates. Flock size is five sheep resulting in plot sizes of 1.25 ha (4 sheep per ha), 0.71 ha (7 sheep per ha), and 0.50 ha (10 sheep per ha). Rotations involving lentil, watermelon, and fallow are established on plots of 0.3 ha, while vetch plots have an area of 0.17 ha.

For phase 2 the main events of 1986/87 are summarised in Fig. 2.6. Phase 1, which had been used in the previous year to establish medic pastures, or to have the alternatives listed above, was used exclusively to grow wheat in the second year.

These replicates in time (phases) and space (replicates) enable an assessment to be made of short-and long-term effects of variability in establishment from year to year. The value of this is illustrated below for pasture establishment. Variability arises from management changes in such factors as sowing depth and climatic change, both types of change operating between years and having a far-reaching influence on botanical composition and productivity of the pasture.

Pasture establishment

It was decided to avoid two difficulties which had been encountered in the first year: poor seedling emergence due to shallow sowing followed by an adverse pattern of rainfall, and poor growth due to root knot nematodes (see Chapter 4). The soil was therefore treated with Carbofuran prior to sowing, and seed was drilled instead of being broadcast. Both of these procedures were successful in producing a good stand of medic.

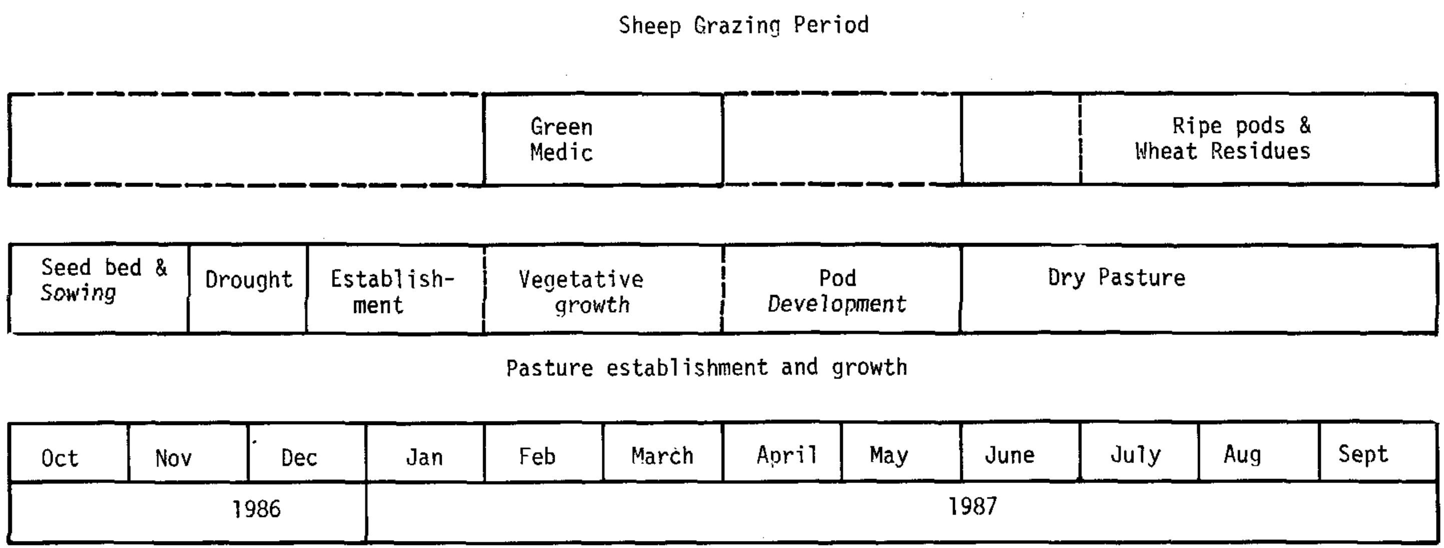
Sowing was carried out using an Amazone drill into a seedbed prepared by a power harrow after cultivation with a ducksfoot cultivator to a depth of 10cm. Medic seed was therefore placed more deeply, probably at a mean depth of 5cm, deeper than the 1-2 cm which had resulted from broacasting and rolling in the previous year. The sowing date was 18 November, by which date there had been 65 mm of rain (between 1 October and 8 November) of which 16 mm occurred about 2 weeks before sowing. Sowing occurred on day 10 of a 39-day drought which lasted from 9 November to 17 December. Germination was apparently stimulated by the occurrence of 23 mm of rain on 18-22 December, as emergence was observed on the fifth wet day. A further 74 mm between 26 December and 9 January ensured the survival of the seedlings during a 12 day drought period starting 10 January, and there was subsequently no problem of water shortage.

This experience contrasted with that in the previous year (Phase 1) when germination was stimulated under conditions where there was inadequate moisture in the soil to maintain the seedlings.

Grazing of green medic pastures

The start of grazing was delayed until March in order to avoid retardation of the young medic plants and 'poaching' (the effects of trampling) during a wet period. Grazing was at three stocking rates, initially at a reduced level (as in 1986) and later increased to the intended rates of 4, 7 and 10 ewes per ha (with a single lamb each). The mean stocking rates for the grazing period are given in Fig. 2.7 which shows that increasing stocking rate gave a reduced quantity of herbage consumed per ewe and a lower potential "meat gain" (the total change in liveweight of the ewe and lamb). Fig. 2.8 gives the herbage and animal production per ha: with increasing

Fig. 2.6: Events during the establishment of first year medic pasture (phase 2 of experiment 2.2), and the periods available for sheep grazing.



stocking rate less herbage was consumed and productivity was lower per ewe, but the greater number of stock present per ha resulted in total output per ha increasing with stocking rate. Meat gain was expressed as lamb growth, the fall in liveweight of the ewes corresponding to lambing and lactation.

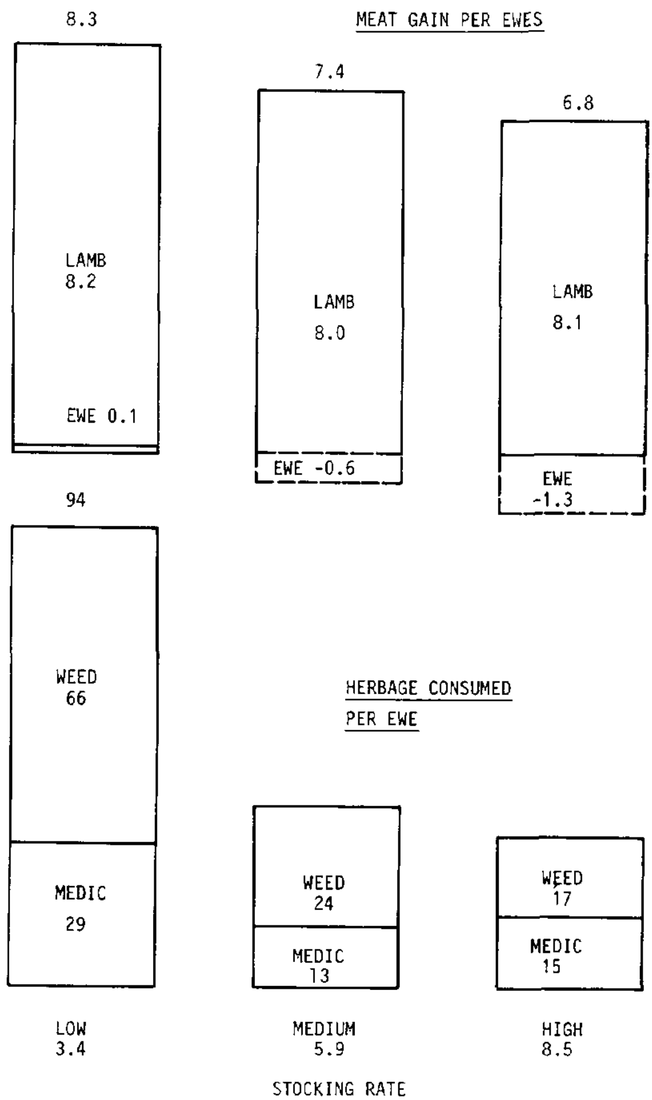


Fig. 2.7: Productivity per ewe (pregnant, or including its lambs) of first year medic pasture during March at three stocking rates. Quantity of herbage dry matter consumed (kg) and growth of animals (potential meat gain, kg) expressed per ewe or ewe-lamb unit.

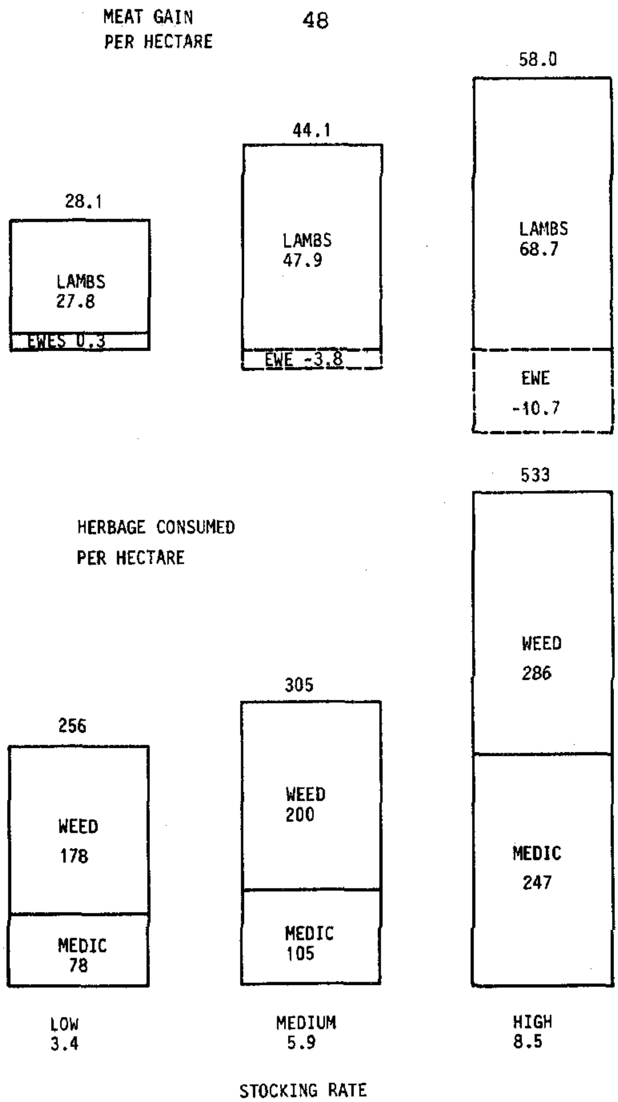


Fig. 2.8: Productivity of first year medic pasture at three stocking rates. *The data show total quantity of herbage* (kg) consumed (bottom) and of potential meat gain (top).

One consequence of increasing stocking rate was that less herbage remained in the pasture when stock were removed in April to allow flowers and pods to develop (Fig. 2.9). There were conspicuous differences in recovery growth. When this was added to the growth harvested by grazing (Fig. 2.8) it was clear that herbage production per ha was highest at the low stocking rate (Fig. 2.10). Herbage production was measured at the end of April, before the seasonal dry period. Subsequent measurement of pod and seed yield showed a similar influence of stocking rate (Fig. 2.11).

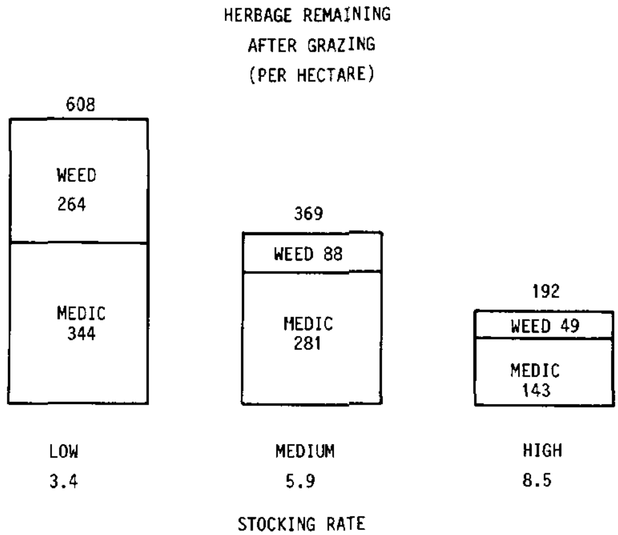


Fig. 2.9: Quantity of herbage remaining in a medic pasture (kg per ha) after grazing in March at three stocking rates, prior to a period of recovery during which flowers emerged and pod formation took place.

The high proportion of weeds is a typical result in first year medic pasture. In regenerating pasture however, weeds are easily controlled by grazing in winter, when they are susceptible to heavy grazing because of their erect habit.

Grazing pressure under all stocking rates could be regarded as low, for in Fig. 2.10 the quantity of medic (or weed) grazed was very small in comparison with total production. This was an outcome of first-year management decisions to graze in a way which would allow pastures to produce enough medic seeds to ensure the future self-regeneration of the pastures.

Nevertheless, the results indicate (1) that there is great scope for manipulation of herbage production, particularly in regeneration years, to feed animals, and (2) that there is a need for optimisation or compromise between feeding stock on green pasture and producing medic pods for grazing during the dry summer.

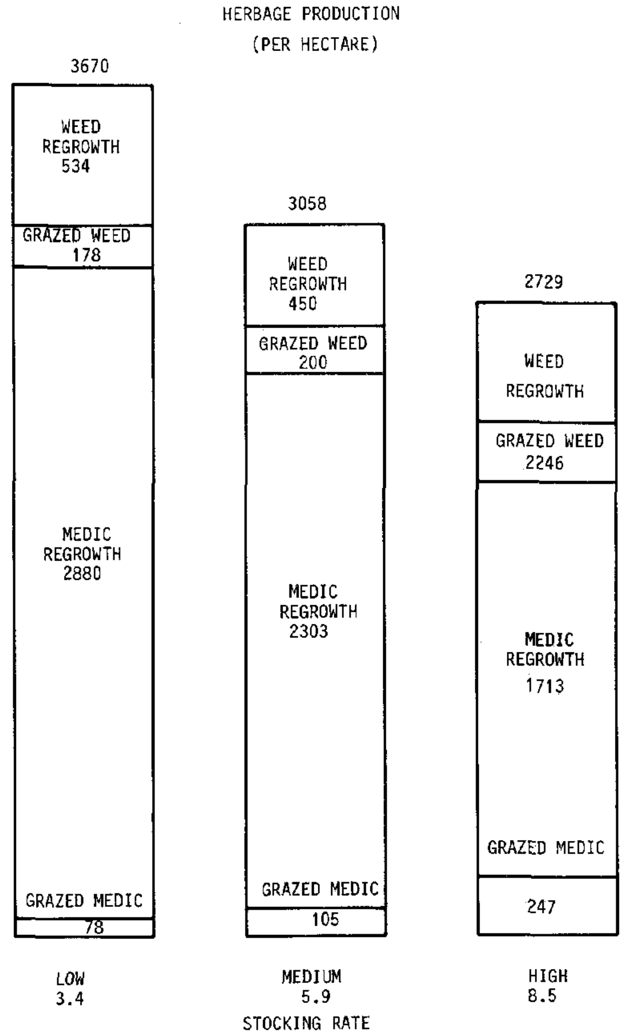


Fig. 2.10: Total quantity of herbage produced by a medic pasture grazed by sheep at three stocking rates during March and then allowed to grow ungrazed to produce the maximum standing biomass. Values are given for the quantity finally available for harvesting plus the quantity grazed (kg per ha).

Lambs were weaned at 8 weeks old. Most of the milk was produced during April and May, when the stock were fed on straw and concentrates. Feeding regimes were based on liveweight, and theoretically all stocking rates received the same regime. However, liveweight differences which had developed during the green-medic grazing persisted to give differences in individual output as shown

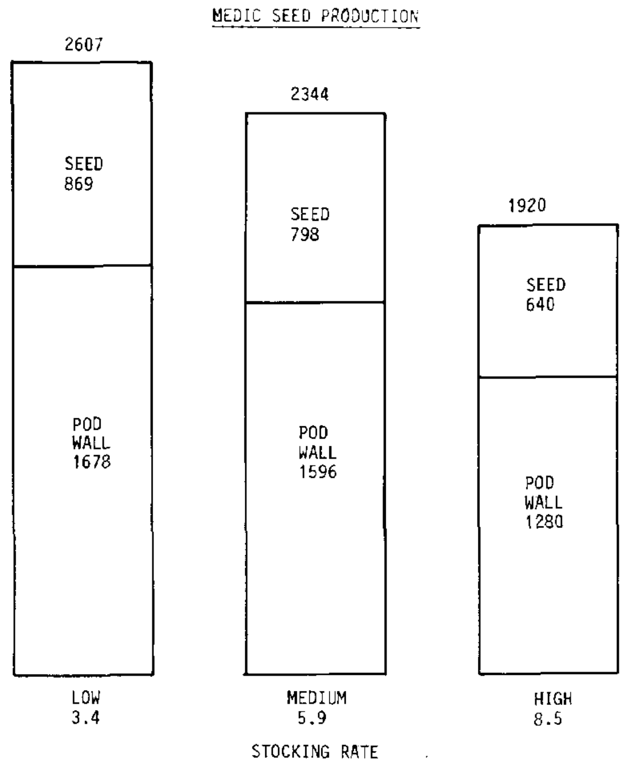


Fig. 2.11: Production of medic pods and seeds (kg per ha) after a period of recovery following the grazing of pastures at three stocking rates.

in Fig. 2.12, where milk yield has been changed into the equivalent value for meat gain using the approximate formula: 1 kg body fat loss = 5.75 kg milk.

From July onward the ewes grazed on medic pods and on cereal stubble at the three intended stocking rates. They spent only half of each day on the medic so that the protein-rich diet would supplement the stubble grazing. Results for the first 10 weeks are given in Figs 2.13 to 2.17.

The total amount of grazing from the first year pasture was satisfactory. We expect that in regenerating pasture the grazing period will be much longer for three reasons. The first is that the natural re-seeding rate will be much higher, the second that

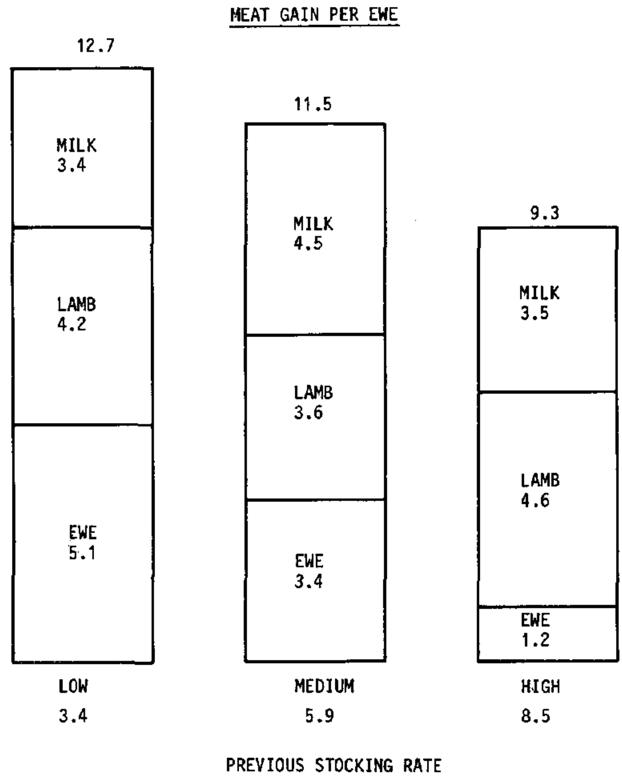


Fig. 2.12: Productivity per individual ewe-lamb unit (kg), after grazing at three stocking rates when fed with straw and concentrates for 98 days while the first year medic pasture was allowed to grow. Potential meat gain includes milk production expressed as the equivalent quantity of ewe body mass which could have been achieved.

germination will occur with the first autumn rains resulting in a longer growing period, and the third that pod grazing can be more intense because a reserve of seed will be present from preceeding years.

Fig. 2.13 shows that individual ewes increased in size at all stocking rates, the low stocking rate giving the greatest liveweight gain. There was a corresponding fall in the quantity of medic pods and seed present (Fig. 2.14), from the starting values towards the threshold value of 300 kg seed per ha, chosen to ensure that there would be abundant seed for pasture regeneration (note that the y-axis is reversed in Fig. 2.14 to facilitate comparison with Fig. 2.13).

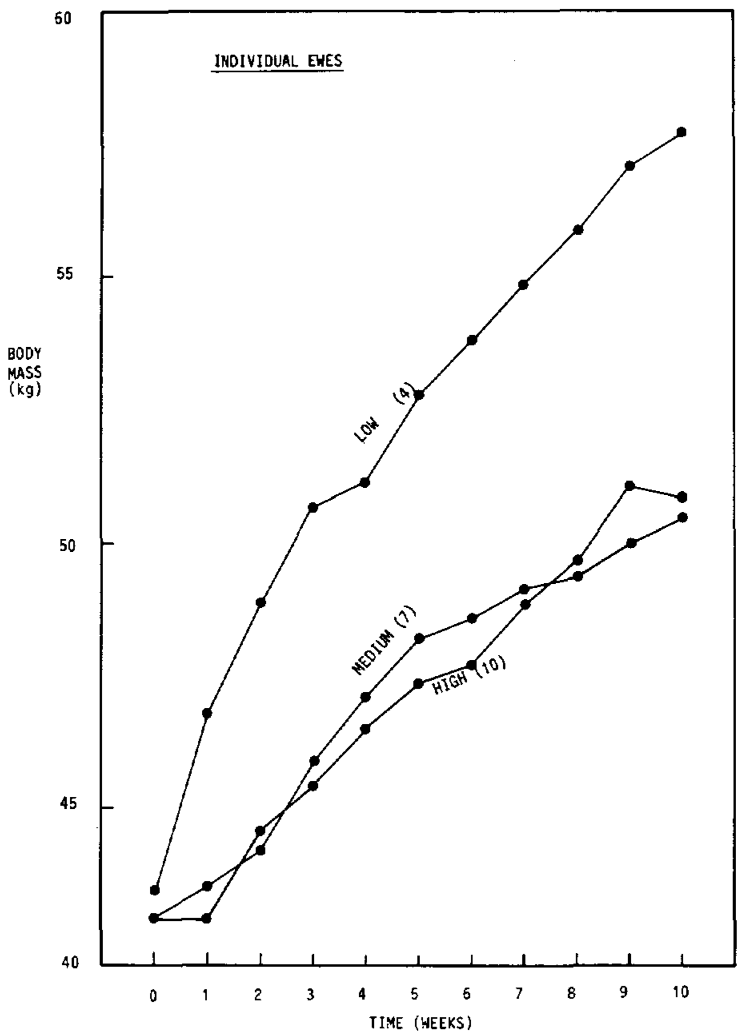


Fig. 2.13: Mean individual size (kg) of ewes grazing wheat residues (morning) and medic pods in situ (afternoon) at three stocking rates (3,7, and 10 ewes per ha) for a period of 10 weeks from 8 July to 16 September.

The quantities harvested of medic pods and seed, and of cereal stubble are given in Fig. 2.15. Pod wall contributed as much to individual intake as did stubble grazing, while medic seeds and cereal grain provided the main protein source. A relatively high quantity of loose straw was grazed from the cereal stubble, the straw having fallen from the combine-harvester.

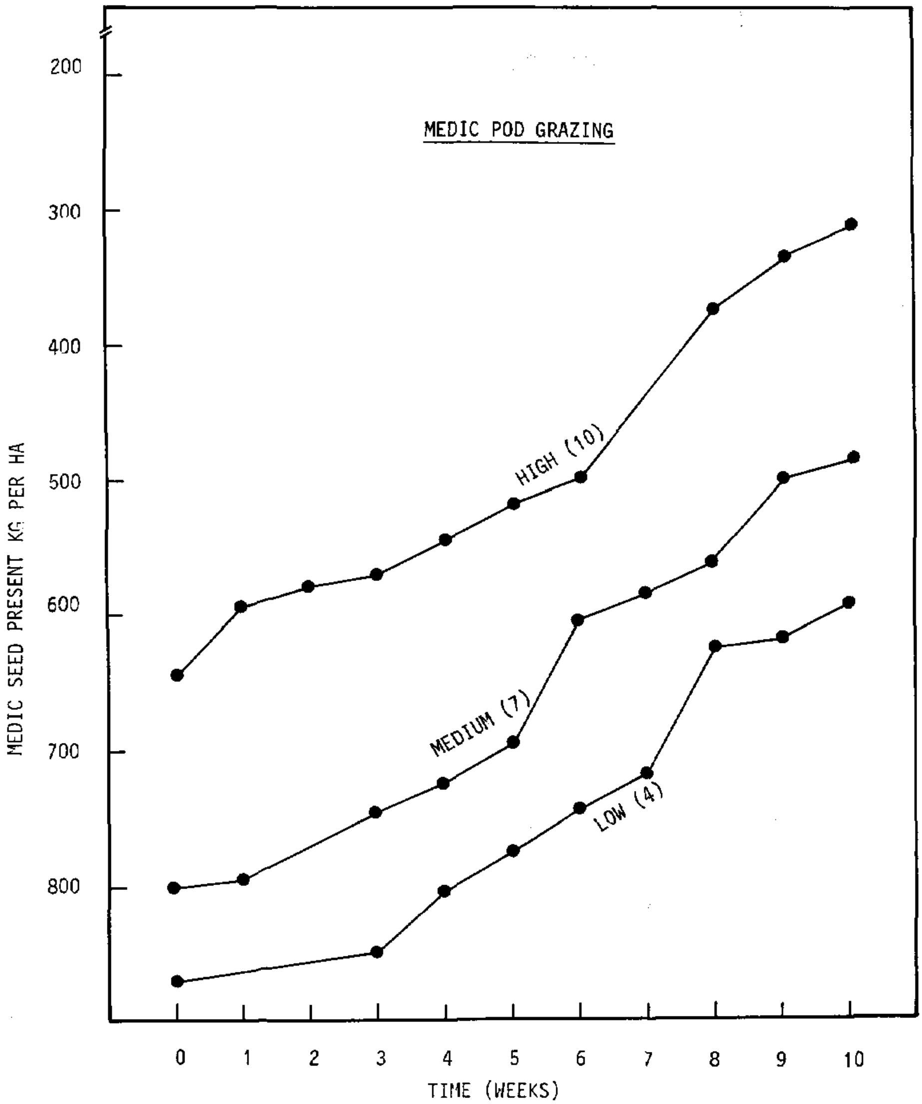


Fig. 2.14: Quantity of medic seed present (kg per ha) during grazing of pods at three stocking rates (4,7, and 10 ewes per ha) for a period of 10 weeks from 8 July to 16 September. The vertical scale is reversed to faciliate comparison with Fig. 2.13.

The differences in intake of pods apparently arises from the greater ease of obtaining them when there are more present, and the reduced competition among sheep at lower stocking rate. The latter would also explain the different intakes from the wheat stubble.

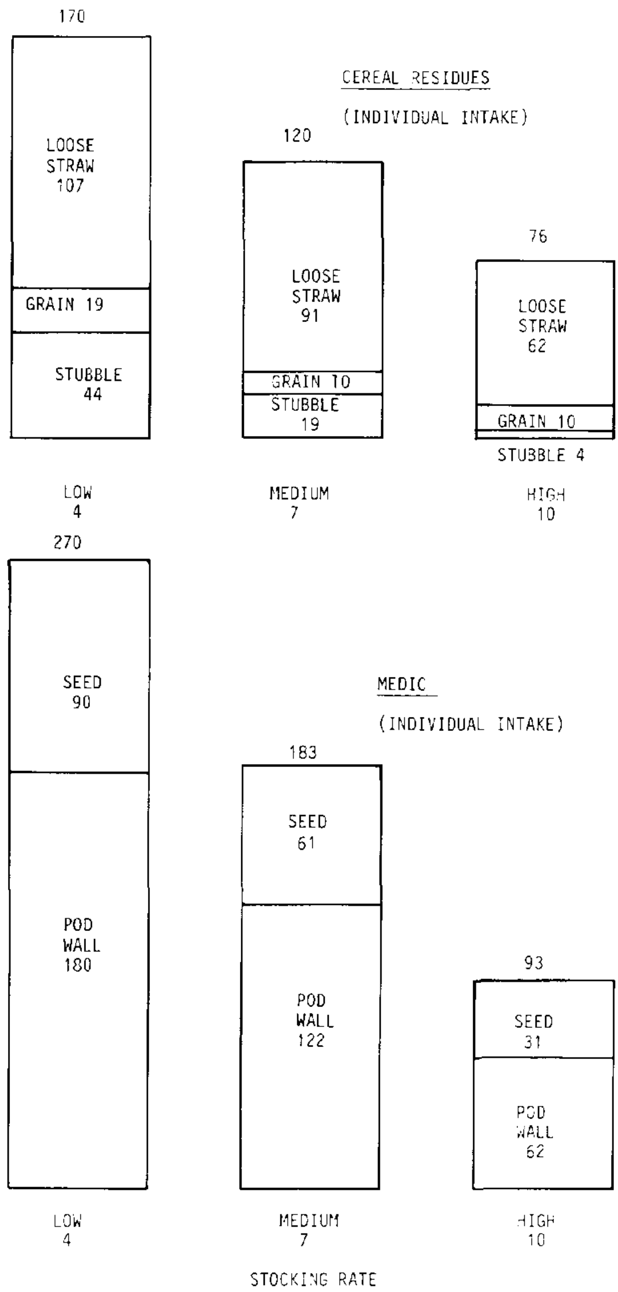


Fig. 2.15: Individual herbage intake by ewes (kg) in a period of 10 weeks during which they grazed wheat residues (morning) and medic pods (afternoon) *in situ* at three stocking rates from July to September.

Individual liveweight gain was conspicuously greater at the low stocking rate. Nevertheless, animal ouput per hectare increased with stocking rate (Fig. 2.16), although this did not correspond to the results for plant material harvested (Fig. 2.17). Measurements of the intake of medic trash, currently incomplete, may explain the discrepancy.

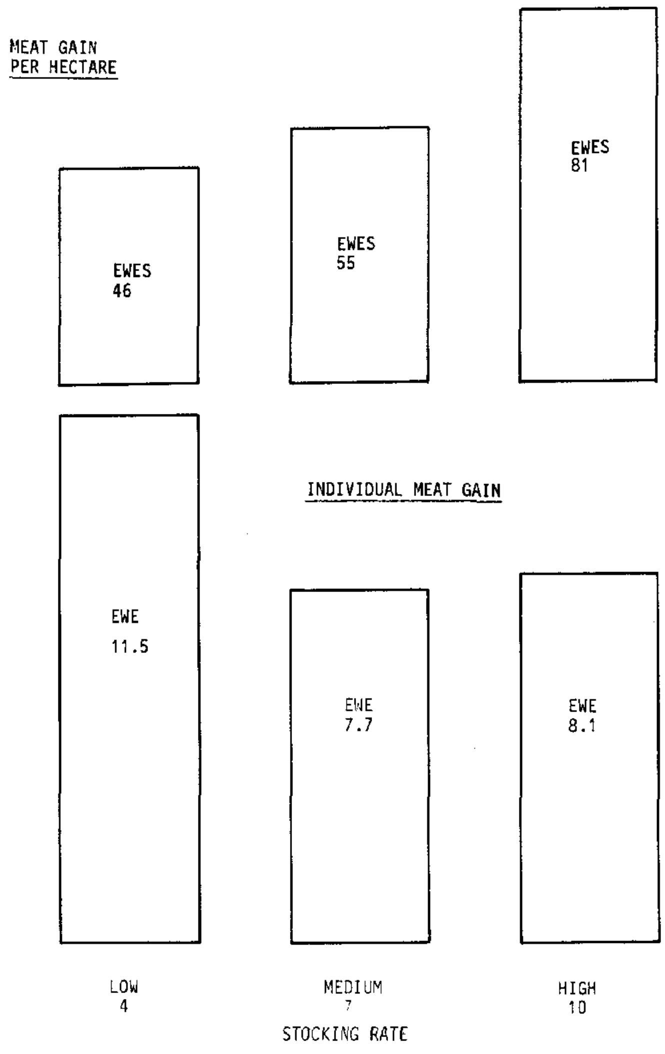


Fig. 2.16: Animal productivity: the increase in liveweight (meat gain) per ha (top) and per individual ewe (bottom) grazing wheat residues and medic pods for 10 weeks at three stocking rates. The small quantity of milk produced has been included in terms of potential body growth (<0.1 kg in each case).

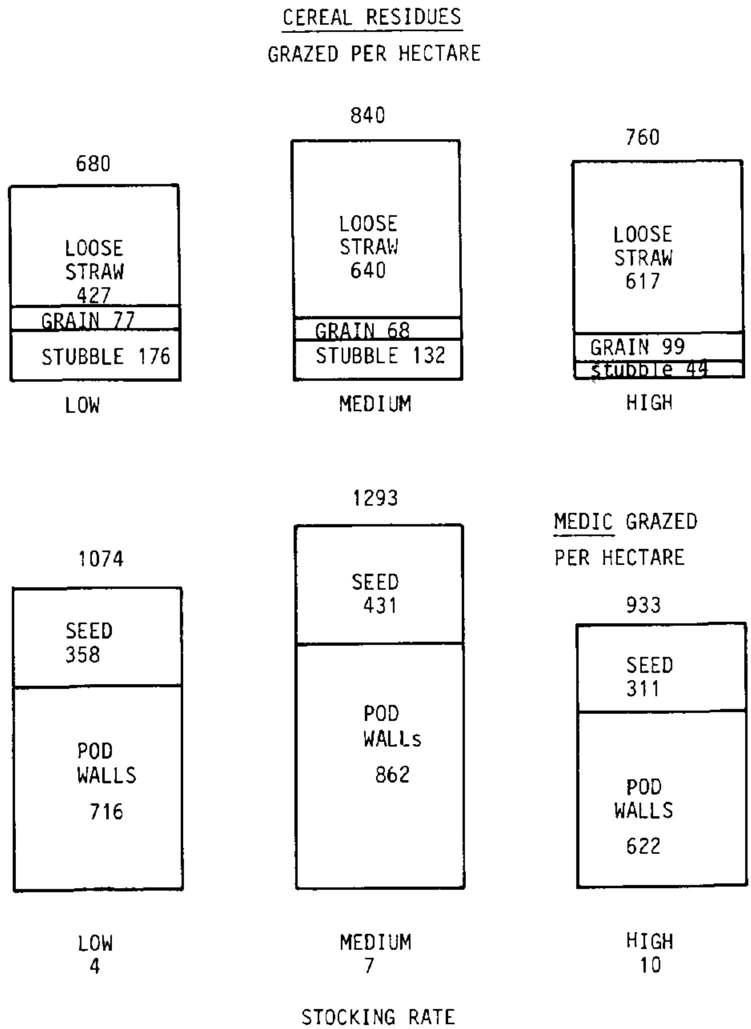


Fig. 2.17: Quantity of herbage (kg) harvested per hectare by ewes grazing wheat residues and medic pods at three stocking rates from July to September.

Yield of wheat and other crops

Table 2.8 gives the yield of wheat grain and straw. Wheat was grown in rotation after medic, fallow, melon, lentil or vetch in 1986. The results quoted are for wheat which was sprayed once in February for the control of weeds (including medics), and which either had no fertilizer nitrogen or received 60 kg N per ha in two applications.

Table 2.8. Relative yield of wheat grain and straw in 1987 following five alternative types of land use in the previous year. Results are expressed relative to those for wheat receiving 60 kg/ha fertilizer N growing on land which was previously fallowed (= 100%).

Land use 1986	Wheat yield 1987			
	Grain		Straw	
	+N	-N	+N	-N
Medic	61	57	55	46
Fallow	=100	102	=100	100
Melon	93	96	90	82
Lentil	81	75	60	54
Vetch	77	70	74	63
	100% = 2456 kg/ha grain		100% = 5474 kg/ha straw	

The yield of both grain and straw was higher after fallow, and declined considerably where land had previously been used for pasture or crops. The results quoted for medic are the means for medic previously grazed by sheep at three stocking rates. The 1985/86 pastures were in their first year and had a high incidence of volunteer cereals and legumes resulting from experiments conducted in 1985, and weeds were also abundant. There was also a problem with nematodes and the results cannot therefore be regarded as typical. By contrast when a dense, closely grazed regenerating medic pasture will in future be grazed continuously for a complete season, it is expected that there will be a build-up of soil N to be transferred to the following year. The pattern of yields quoted for the early years probably represents an atypical situation.

Table 2.9 gives the yield of melon, lentil and vetch (fallow, of course, yielding nothing). For lentil and vetch there is a problem of losses during hand-harvesting. Values for these are quoted in Table 2.9. The results will be used in economic analyses of the various rotations.

Table 2.9. Yields of melon, lentil and vetch in 1987. For lentil and vetch the yields refer to the standing crop, a percentage of which lay on the ground after hand harvesting (values in brackets).

	Yield (kg/ha)	
	Seed/Fruit	Straw and stubble
Melon	2810*	-
Lentil	2100	3540
	(3.9%)	(1.8%)
Vetch	2080	3660
	(8.6%)	(9.0%)

* 630 melons/ha

Grazing behaviour

A supplementary experiment using the same plots was conducted with the objective of determining the preference of grazing sheep for medics, cereals, and weeds.

Although choice of stocking rate influences grazing pressure which in turn affects the frequency and severity of grazing, farmers have little control over the sheeps' grazing preferences: ewes and lambs are free to choose among the plant material available. It is important to know what they eat in order to assess their influence on the plant population. There is also a need to control volunteer cereals and weeds, the ideal being that sheep, through grazing, will change the population balance in favour of medic.

Table 2.10 shows that with increasing stocking rate, greater percentages of cereal and weeds were grazed in March while they were still growing: indeed half or more of these plants showed signs of grazing at the high stocking rate, but few were grazed at low stocking rate.

Table 2.10. Percentage of plants of volunteer wheat and weed species observed to have been grazed by late March, in medic pastures grazed continuously by ewes and lambs at three stocking rates.

Stocking rate	Volunteer wheat	Weed species
High	86	48
Medium	45	32
Low	9	21

* Mainly of _Sinapis_, _Saponaria_, _Adonis_, _Anthemis_, _Silene_, _Tordylium_, _Papaver_, _Anchusa_ and _Galium_.

Sheep were admitted to the pastures briefly in mid May to see whether they would remove the weeds and volunteers. However, as is shown in Table 2.11, they were also attracted to the young medic pods and so it was considered better to allow the pods to mature without grazing.

Table 2.11. Percentage of bites taken from various types of plant material by ewes grazing a medic pasture in mid May (observations meaned for 3 stocking rates).

Medic pods	Medic leaves	Weeds	Cereal heads	Cereal leaves	Unidentified	Total
35	19	26	12	5	3	100

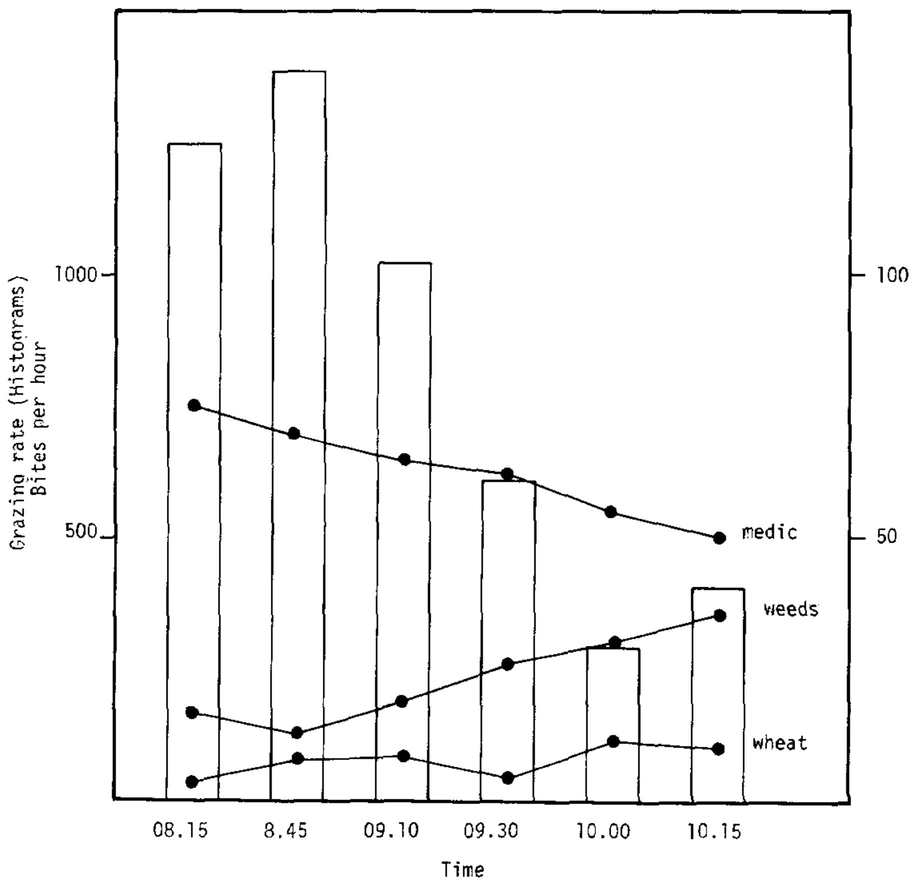


Fig. 2.18: Rate of grazing (number of bites per hour) of individual ewes taken at random within a flock of 15 ewes on 13 May at six times during a two-hour period (histogram), and the percentage of bites taken on medic, volunteer wheat or weed species (a further 7% of bites were unidentified, and are not shown).

The selection among species also varied with the grazing time. For example, Fig. 2.18 illustrates how the number of bites per hour may fall as grazing and rumen-fill proceed: the sheep changed toward eating less medic and more weeds. This study was made at the low stocking rate.

Specialisation by sheep is not simply confined to selection of small structures such as pods. Observations made in a nearby pasture, a few weeks earlier, showed that they sometimes preferred to graze the young tips of medic shoots in preference to taking a larger mouthful consisting of a major piece of shoot i.e. a branching system (Table 2.12).

Table 2.12. Percentage of bites taken by sheep from medic and weeds when observed on a single occasion in late April while they were grazing a dense pasture. Observations on the defoliation of weeds have been subdivided into 'low' grazing of herbage near to the ground ('short') and the grazing of elevated herbage ('tall'), often 0.5 m or more above the surface.

Medic		Weeds		
Shoot tips	Whole shoots	Short	Tall	Total
26	6	24	44	100

The implications to productivity of selective grazing, both between and within species, are examined in Chapter 7. - **A. Smith, N. Nersoyan, M. Touma**, E. Thomson, and F. Bahhady

Experiment 2.3: yield of wheat in six rotations at Tel Hadya

In 1983/84 an experiment was established to study the long-term effect of pasture and forage crops on wheat yield. There were five treatments initially: wheat after clean fallow, wheat after weedy fallow, wheat after medic, wheat after wheat, and wheat after a forage mixture comprising vetch and barley. There was a two-phase entry into the experiment, both crops in the rotation being present each year.

The varieties used in the experiment were: Mexipak wheat, M. rigidula selection 1295, common vetch selection 2541, and Badia barley, the latter being an equal mixture with common vetch. In 1985/86 and 1986/87 the wheat after medic plots were further split into plus weed control and minus weed control: previously weeds had been controlled in the whole plot.

Plot size was 8 x 21 m, and were consequently too small for grazing. The experiment was laid out in a randomized complete block design with three replicates. Soil fertility was monitored. The experiment received superphosphate each year, but no nitrogen was applied.

Wheat yields in the final three years of the experiment are shown in Table 2.13. In both 1984/85 and 1986/87 wheat yield was highest after medic - but only if weeds were controlled. In 1985/86 wheat yielded best after clean fallow, followed by wheat after medic and wheat after the forage mixture. Wheat after weedy fallow was only better than continuous wheat.

It is clear that, in contrast to experiment 2.2 (see Table 2.8), wheat was best after medic. Weed control is clearly vital if the

Table 2.13. Wheat yields (t per ha) at Tel Hadya in six rotations during 1984/85, 1985/86, and 1986/87.

	1984/85	1985/86	1986/87
Wheat after clean fallow	1.98	1.70	1.08
Wheat after weed fallow	1.39	0.95	0.75
Wheat after medic with weed control	2.48	1.26	1.44
Wheat after medic without weed control	NA	0.94	0.80
Wheat after wheat	1.34	0.72	0.60
Wheat after vetch and barley	2.24	1.26	1.05
Rainfall (mm)	373	316	358

benefits of medic are to be expressed. An important point in this experiment is that no nitrogen was applied to the wheat. Presumably had it been applied wheat after fallow would have been at least as good as wheat after medic. - **N. Nersoyan, A.E. Osman, and P.S. Cocks**

Experiment 2.4: productivity of medic pasture at Kamishly, in north-east Syria (Preschedule L34)

In October 1986 a collaborative experiment was initiated with the Livestock Research Division (LRD) of SMAAR with similar objectives to experiment 2.2. The experiment is being conducted on the LRD Station near Kamishly in north east Syria at the northern border of Al-Djazerah region where, even though annual rainfall is about 500 mm, wheat/fallow and continuous wheat rotations predominate. The experiment was established on about 40 ha.

The objective of the work is to compare the productivity of wheat/medic, wheat/vetch, wheat/wheat and wheat/fallow rotations, and measure the effect of three stocking rates (5, 9, and 12 sheep per ha) on the productivity of medics. The experiment differs from experiment 2.2 in that continuous wheat replaces wheat-lentils and wheat-summer crop. A mixture of M. rigidula genotypes were sown in November 1986. Flocks of 12 Awassi ewes were allocated to the respective pastures and sheep grazed the medics before seed production and then again once seeds were mature. An important objective is to introduce the concepts of grazing management to the scientists of SMAAR. It is in fact an example of an attempt to transfer a methodology to a NARS.

The main activities during the first year were establishment of the rotations and sheep flocks. Yield data were not collected, but seed set of medics was satisfactory, with about 300 to 500 kg per ha being produced. Ewes on all treatments gained 75 to 90 g per day from March to June during which time they received a combination of concentrates, hay and medic pasture. In early June ewes were moved to medic residues till mid- September when stocking rate effects on the ewes became apparent. Liveweight gains of ewes on the low, medium and high stocking rates were 55, 39 and 15 g per day, respectively.

In 1987-88 the second phase of the rotation will be established and more detailed monitoring of pasture, crop and sheep productivity will begin. This project should become a model of collaboration between SMAAR and ICARDA in the field of sheep and pasture research. - **F.A. Bahhady, E.F. Thomson, A. Swaid (LRD, SMAAR)**

Experiment 2.5: medics on farmer's fields - adaptating ley farming to farming practice in northern Syria

The objective of experiment 2.5 is to introduce the concept of ley farming to farmers with the view of testing its impact on farming systems and identifying the constraints faced by farmers.

In all our work certain assumtions are made about the management of ley farming and the self-regenerating pastures therein. For example we expect farmers to use a two-course rotation in which cereals alternate with grazed pasture. We expect cultivation for the cereal to be to no greater depth then 10cm, for the pastures to be set stocked (continuously grazed for most of the year), and the main products to be meat and milk. Without making these assumptions we would make no progress in developing the system (the philosophy of on-farm experimentation is discussed fully in experiment 2.6).

However it is not ICARDA scientists who develop farming systems, but farmers. We therefore expect west Asian and north African versions of ley farming to evolve in which the assumptions we make may no longer be valid. This evolution will depend on many factors, but most importantly on the farmers themselves. We believe that the role of ICARDA is to introduce concepts and, by working closely with farmers, solve problems associated with implementation. Accordingly a three-way collaborative project, involving ICARDA, SMAAR, and local farmers, has been established and is described below.

In 1984/85 we conducted a survey of farmers at Tah, near Aleppo, with the objective of establishing a socio-economic basis for introducing ley farming, and sowed one ha of medic pastures (M. rigidula, M. polymorpha and M. truncatula) on each of six fields. Local machinery was used, and subsequent grazing was carefully monitored. The productivity of sheep on the original farm was measured, and careful assessment was again made of herbage and seed production. Several small experiments were established to test which of the various medic species was best adapted, measure their response to superphosphate, and determine the need for inoculation with rhizobia.

In 1985/86, having explained the concepts of ley farming, we gave the original farmers the choice of sowing a wheat crop or leaving the pasture for a second year. Five chose the former and one decided on a second year of pasture. On the five farms we split each field into four: half of the crops received nitrogen fertilizer, and half were sprayed to control weeds to give a total of four treatments. In addition we imposed the same treatments on control crops: that is crops which were sown in the traditional manner, in rotation with watermelons, lentils, or cumin in this village. All crops were sown by the farmers using machinery available to them.

A further five fields were sown to medic in Tah itself and in two neighbouring villages, Deir Sharky, and Jarjanaz. With one exception (3 ha) these fields were one ha in area, the same as the original fields. A further two fields were sown: one near Kamishly (in the north east of Syria) and one near Izraa (in the south): both these fields were approximately 3 ha in area. All fields were sown at 30 kg per ha of a mixture of medics including *M. rigidula* and *M. rotata*.

In 1986/87 the project expanded still further (Table 2.14). The new fields are larger than the original one ha fields because experience has taught us that the small fields cannot support farmers' whole flocks, and most farmers prefer not to split flocks. To date no farmer has dropped out of the project.

Table 2.14. Expansion of on-farm medic between 1984/85 and 1986/86

Season	Number of farmers	Area (ha)
1984/85	7	10
1985/86	8	15
1986/87	5	16
Total	20	41

The original fields, on which the project was based, continued to be monitored, especially in terms of livestock production. Seed populations of all medic fields were monitored, and grazing days measured. Crop yields, both after medics and in traditional rotations, were recorded. Responses to phosphate and inoculation were measured at selected sites, and also the seed production of eight potentially useful species.

Last season was the first which gave us the opportunity to measure the performance of regenerating pasture. Of the five fields which grew in 1985/86, three produced more than 1000 medic seedlings per ha after the November rains (Table 2.15), a figure normally considered to provide productive pasture (Puckridge and French 1983). The pasture on farms 3 and 5 were less satisfactory and reflect over-grazing in 1984/85, the year of sowing. Note that the owner of Farm 2 chose to have two consecutive years of medic: his field was therefore wheat in 1986/87.

Herbage production and digestibility of pastures on Farm 1, 4, and 6 are shown in Fig. 2.19. Total herbage yields (of which 94% was medic) approached or exceeded 7 t per ha, of which 65% was the

Table 2.15. Residual seed in 1985/86 (kg per ha) and regeneration of medics in autumn 1986 (seedlings per m^2) after a cereal crop in 1985/86.

Farm	Residual seed in 1985/86	Seedling number in 1986/87
1	447	1640
3	148	520
4	449	1920
5	73	390 (1)
6	769	1850

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

average digestibility throughout the growing season. Even the residues were 50% digestible (with 12-15% protein), presenting a diet capable of maintaining or even increasing liveweight of ewes.

Annual stocking rates were calculated by dividing the number of grazing days by 365 and are shown in Table 2.16. Note that on Farms 1, 4, and 6 stocking rates exceeded 6 ewes per ha reaching nearly 11 per ha on Farm 6. Stocking rate was approximately proportional to seedling number (Table 2.15), Farms 3 and 5 supporting less than 3 sheep per ha. In Table 2.17 the stocking rates of first year pasture are seen to be markedly less than for regenerating pasture, except on Farms 16 and 18 which were again severely overgrazed. As with the 1984/85 sowings, between 20 and 40% of the farmers failed to realize that short term profit has a long term cost.

Milk production and liveweight of ewes were measured in two flocks, the first grazing medic pasture, the second grazing native pasture supplemented with grain and straw. Both milk production and

Table 2.16. Grazing provided by regenerating medic pasture (ewes per ha per year) and seed set after grazing (kg per ha), sown in 1984/85 after wheat in 1985/86.

Farm	Stocking rate	New seed
1	9.2	259
3	2.7	n.m[2]
4	6.7	298
5	2.2	n.m
6	10.6	115
8	4.9[1]	50
9	7.5[1]	175

[1] Second year pasture - the remaining farms were regenerating after cereal.
[2] not measured

Table 2.17. Grazing provided by first year pasture, sown in 1986/87 (ewes per ha per year) and seed set after grazing (kg per ha).

Farm	Stocking rate	Seed set [1]
15	3.1	224
16	6.3	39
17	1.3	283
18	4.2	14
19	2.4	116

[1] Measured to 4 cm depth only.

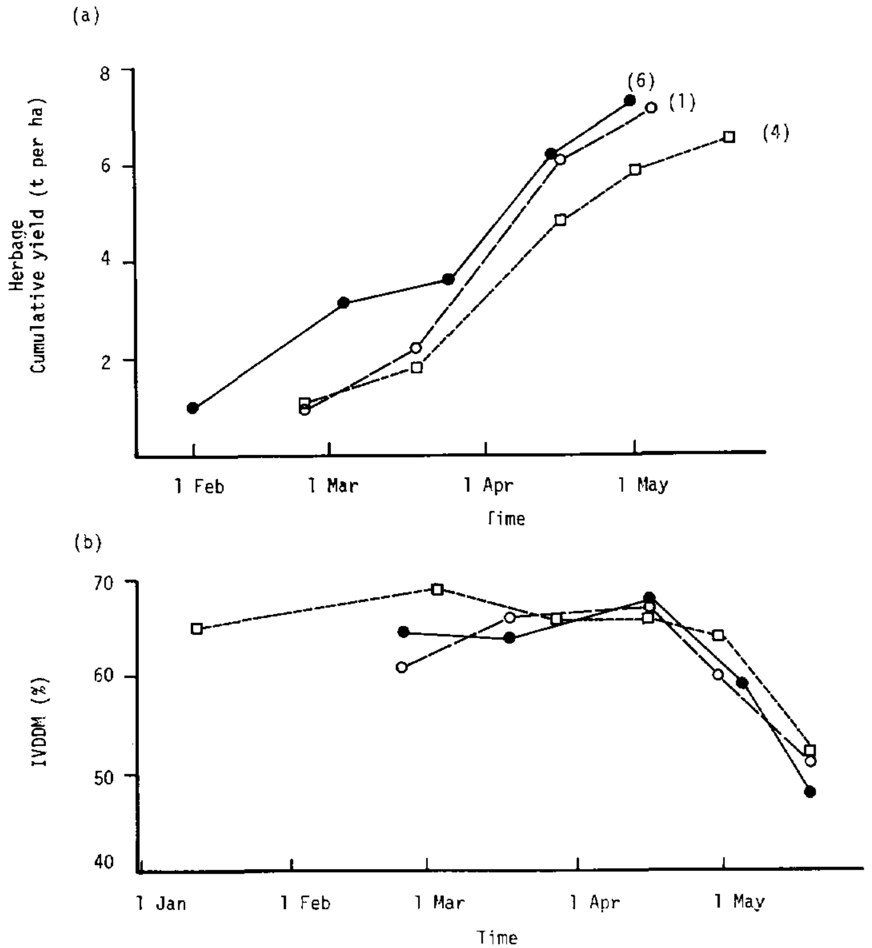


Fig. 2.19: (a) Cumulative yield of medic pasture on Farm 1 (open circles), 4 (squares) and 6 (closed circles) with time, and (b) change in *in vitro* digestibility (IVDDM) of pasture on the same four farms.

liveweight were higher on the flock grazing medic, a result consistent with earlier years (Fig. 2.20). Total milk production from medic was 1700 kg per ha: at 7 Syrian pounds (SL) per ha the farmer's return from milk was 11900 SL per ha. It should be pointed out that the land on which these measurements were taken was poor, being highly calcareous and with marked slope and barely suitable for arable agriculture.

On slightly better land the yield of wheat after medic pasture was compared with the yield of wheat after the farmers' chosen

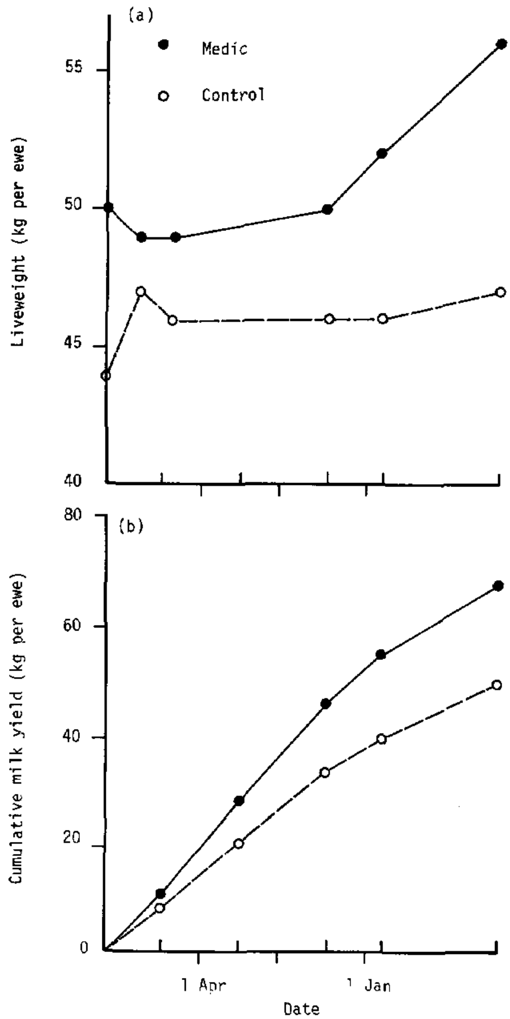


Fig. 2.20: (a) Change in liveweight and (b) cumulative milk yield of ewes grazing medic pasture (closed circles) and fed using traditional feedstaffs and grazing (open circles).

alternatives: watermelons, lentils, barley, and cumin. The results (Table 2.18) show that yields were higher after medic, regardless of whether or not weeds were controlled, and whether or not nitrogen was applied. There was also a weak response to weed control, but no response to nitrogen. These results support those of the previous year, except that, in the earlier year, wheat in the control rotations responded to nitrogen.

Table 2.18. Comparison of wheat yields sown after medics and in traditional rotations (kg per ha).

	No nitrogen	Nitrogen
No herbicide		
After medic	1343	1307
After control	996	1018
Herbicide		
After medic	1425	1523
After control	1100	1206

The results on wheat yields should be treated with caution. In more closely controlled experiments at ICARDA headquarters (eg experiment 2.2), wheat yields after medic have tended to be lower than most of the alternative crops (but see experiment 2.3). The reasons are obscure, but it is possible that farmers are able to adapt their management after medic better than scientists who are constrained by the rigid conditions imposed by experimental designs. In any event the matter is being further investigated at Tel Hadya.

As in previous years selected medic ecotypes were compared at four of the farms. This year M. scutellata cv. Robinson produced the highest amounts of seed, and, among the six best ecotypes was another Australian cultivar, M. truncatulla cv. Cyprus (Table 2.19). Both these cultivars are extremely sensitive to frost (Cocks and Ehrman 1987) and their success reflected the relatively mild winter of 1986/87.

Table 2.19. Seed yields (kg per ha) of 14 medic accessions on farmers' fields (mean of four locations).

M. scutellata cv. Robinson	608
M. aculeata sel. 2008	476
M. truncatula cv. Cyprus	433
M. rotata sel. 2119	358
M. rigidula sel. 716	328
M. rotata sel. 2116	303
M. truncatula cv. Jemalong	272
M. rigidula sel. 1865	269
M. rotata sel. 1943	260
M. rotata sel. 2123	235
M. rigidula sel. 1900	184
M. rigidula sel. 1868	101
M. noeana sel. 2125	69
M. noeana sel. 2124	68

This work will continue unchanged in 1987/88. At the end of the season the results will be examined for the four years of the project and subjected to economic analysis. - **H. Sawmy, B. Malawi (SMAAR), P.S. Cocks, and S. Muller (University of Hohenhiem)**

Experiment 2.6: on-farm experiments with forage legumes - six years of results from Breda (Preschedule L9)

The objectives of experiment 2.6 were firstly to measure the effect, on whole-farm productivity, of replacing fallows with common vetch and common chickling, secondly to measure, on farmers' fields, the growth rate of lambs and milk production of ewes grazing vetch and chickling in spring, and thirdly, to compare the returns from grazing the forage legumes with those from seed and straw when the crops are harvested by farmers at the mature stage.

On-station research to replace fallows with forage legumes has been a major thrust of ICARDA since it was established in 1977. It soon seemed important to begin research on farmers' fields in order to identify weaknesses in the technology not apparent on-station. As will be seen this proved to be the case.

The degree of involvement of farmers can vary from little to complete and the terms 'scientist-managed' through to 'farmer-managed' cover the spectrum. Our on-farm research started as 'scientist-managed', but, as plot sizes increased, farmers became increasingly involved in the management. However, even at the beginning, farmers' used their own tractors and cultivators to prepare and sow the land. Farmers were also responsible for labour and supplied the sheep.

Before the experiments started the farmers were interviewed to get background information about the way they fed and managed their flocks, farm and flock size, and crop rotations. At the conclusion, open-ended discussions were held to get their views about forages and the constraints they saw to sowing forage crops.

Incentives were used as little as possible, to ensure that the farmers collaborated because of their interest in the new technology, and its potential benefits to them. Farmers received from ICARDA seed, phosphatic fertilizers, 100 kg of wheat at the end of each season, and medicines for sheep. As time passed farmers increasingly paid the costs of sowing and harvesting.

The project started in October 1981 at Breda, 30 km south-east of Aleppo in the heart of the barley/livestock zone of north Syria. Barley is grown either continuously on the more fertile soils, or alternating with fallow on the poorer stony soils. The characteristics of the Breda area (rainfall 250-300 mm) have been described by Maerts (1987). The project has now completed six cropping seasons and will end once the final barley crops are sampled in June 1988.

In November 1981 common vetch and peas were sown (with 50 kg per ha of P_2O_5) in 10 X 10 m plots on one farm at each of two locations. Because the seed rate (80 kg per ha) was too low for hand broadcasting, dry matter yields were low (Table 2.20). In the second year the same forages were sown at two sites at Deir Qaaq, a similar area north of Aleppo, and four sites at Breda. In this year phosphate was applied to only half the plot area, the remainder receiving no P in accordance with farmer practice. Because seed was sown at 160 kg per ha, dry-matter yields were much higher than in the previous year (Table 2.20). At one site in 1981/82 plot area was increased to 1500 m^2 so that lambs could graze the crops (Thomson, 1984). The second year's trials, as well as giving the scientists their first experience of on-farm grazing experiments, substantiated other evidence that peas are unpalatable (see experiment 2.8).

In 1983/84 the research was expanded with several modifications. Firstly, plot sizes were increased to between 0.7 and 1.0 ha to facilitate grazing, secondly, because farmers had grown it in the past, common chickling was introduced, and, after 1984, peas were excluded, and thirdly, because farmers expressed concern about it, fallow strips were left to make it possible to compare the effect of forages with that of fallow on the subsequent barley. Finally, farmers were given the option of using the forages for grazing, allowing them to mature to be harvested for seed and straw, or making hay. The question of whether to graze the green crops to fatten lambs or to milk the ewes was also given attention.

Table 2.20. Dry matter yields (kg per ha) of common vetch and chickling vetch harvested before grazing in April, with (+P) and without (-P) the application of 50 kg P_2O_5 per ha.

Year	No. of farms	Common Vetch		Chickling		Rainfall (mm)
		-P	+P	-P	+P	
1981 - 82	2	-	534	-	636[1]	324
1982 - 83	6	982	1082	1238[1]	1492[1]	285
1983 - 84	9	237	388	343	447	204
1984 - 85	6	765	1288	489	835	277
1985 - 86[2]	6	-	1005	-	894	218
1985 - 86[2]	4	209	359	269	378	218
1986 - 87	7	469	824	421	622	245

[1] Peas.
[2] During 1985-86 the P0 treatment was excluded at six of the sites and included at the remaining four sites: yields are given separately.

The experiments continued in this form for four seasons (1983/84 to 1986/87) with results from both the forage and barley phases of the rotations being gathered each year. Soil samples were taken at the end of the forage phase and will be taken after the final barley crops are harvested in 1988. More details about procedures are reported by Tully, Thomson, Jaubert and Nordblom, (1985).

In 1984/85 and 1985/86 we considered it necessary to fence the plots used for grazing, but in 1986/87 we reverted to no fencing (Thomson et al. 1985). One of the problems we believed would be limiting, that neighbouring flocks might graze our plots, proved unfounded, provided that they were sown near the farm house. A "boundary fence" of barley was used in the initial years of the project but dropped after 1983/84.

Agronomy results

Hay yields: yields from common vetch and chickling are shown in Table 2.20. There was considerable year-to-year variation, not entirely associated with rainfall. Peas tended to yield more than common vetch, and vetch tended to yield more than chickling. Low yields in 1983/84 were due to below average rainfall (204 mm versus an average of 280 mm).

Hay yields were so low that hay production would appear to be uneconomic. There is also the problem that no seed can be harvested for the coming season.

Grain and straw yields: harvesting for seed and straw appeared to be a most attractive option, in spite of the problem of finding labour at harvest time. For this reason farmers preferred to limit the area of forage to less than 2 ha, which could be harvested by members of the family. The other major advantage of grain and straw is that total dry matter is higher than if harvested as hay (experiment 4.9), seed is provided for the next season, and the straw and surplus grain provide good feed for autumn and winter.

Chickling always yielded more grain than vetch, whether or not phosphate was applied (Table 2.21). This immediately puts chickling at an economic advantage over vetch and indicates also that chickling may be better adapted to the prevailing poor soils. It may also be that chickling fixes more nitrogen, which could be an attribute of the species per se, or be a result of better nodulation.

Table 2.21. Seed and straw yields (kg per ha) of common vetch and chickling harvested at maturity, with (+P) and without (-P) the application of 50 kg P_2O_5 per ha.

Year	Common Vetch		Chickling	
	-P	+P	-P	+P
Seed yield				
1984 - 85 (8)[1]	351	659	734	975
1985 - 86 (2)[2]	82	242	306	555
1985 - 86 (9)	-	574	-	895
1986 - 87 ( )	239	330	385	477
Straw yield				
1984 - 85	906	1404	810	888
1985 - 86	1276	2106	1416	2283
1985 - 86	-	1268	-	1413
1986 - 87	608	857	670	1009

[1] Number of farms.
[2] See Table 2.20, note 2.

There seemed to be little difference in straw yields between the two species. We also know that straw quality is similar (experiment 4.9). However, farmers report that it is easier to harvest chickling than vetch.

Barley grain and straw yields: as we mentioned previously farmers were initially concerned about using fallows to grow forages because they feared that barley yields would be reduced. In the case of barley following unfertilized forage crops there were small reductions in yield (rarely significant), but where barley followed fertilized forage crops yields were substantially higher: 27% in the case of seed yield and 31% in the case of straw yield (Table 2.22). Yields after chickling were higher than after vetch, whether or not phosphate was applied. Although not always statistically significant, if real these differences are relevant to the farmer in terms of profits: a difference of 200 to 300 kg in straw yield alone would more than cover the cost of the phosphate fertilizer.

Table 2.22. Yields (kg per ha) of barley grain and straw in the year after fallow (F) or of growing common vetch (V) and chickling (C), with (+P) or without (-P) 50 kg P_2O_5 per ha.

Year (P<0.5)	Preceding crop				
	F	V - P	V + P	C - P	C + P
Seed yield					
1984 - 85 (4)[1]	693	546	803	653	857
1985 - 86 (9)	835	819	1129	978	1325
1986 - 87 (3)	971	719	1186	643	1039
Straw yield					
1984 - 85					
1984 - 85 (4)	-	-	-	-	-
1985 - 86 (9)	1049	1034	1364	1133	1426
1986 - 87 (3)	1381	1137	1621	1245	1958

[1] Number of farms.

Sheep results

Lamb fattening: fattening appeared to be more attractive to farmers than the grazing of lactating ewes, firstly, because farmers want to wean lambs early so that they can sell more milk, secondly, because they need to finish lambs before summer, and thirdly, because communal grazing, either near the village or in the steppe, provides feed for ewes at no apparent cost. Even though forage yields were low in April fattening lambs was profitable (PFLP Program Report, 1986, page 70), but, to achieve reasonable liveweight gains farmers were feeding 400 to 700g per day per lamb of a barley-concentrate ration. The forages were grazed for about 30 days at stocking rates of 20 to 30 lambs per ha.

Milk production from forages: most ewes were in mid- to late-lactation when the forages were grazed in April. Thus milk yields were relatively low - in the range of 400 to 600 g per day, similar to that on native pasture - and unlikely to respond to good quality pasture (Thomson et al. 1985). However the observed liveweight gain of ewes while grazing is of value because it allows the ewes to recover from the stress of early lactation and thereby enhance the chances of conception (Thomson and Bahhady, unpublished data). We believe that lamb fattening will be the more appropriate method of using forage crops while, for lactating ewes medics, with a longer period available for grazing, will be preferred.

At the end of the project five of the farmers were interviewed. They were no longer concerned about the negative effects of forages on barley, and appreciated the importance of phosphate on both the forage crop and its residual effect on barley. However, they have difficulty finding cash to buy the fertilizer and the price and availability of seeds were seen as constraints.

Those farmers who had harvested seed in June 1987 were willing to continue growing forages. However if, for any reason, they could not harvest their own seed they stated that they could not afford to buy more seed. They definitely preferred the mature crop option to grazing because it produces seed and straw, and stated that they would only grow forages on land that produced profitable yields. Their comments re-inforce PFLP's concern about the availability and price of the seed of pastures and forages. - **E.F. Thomson, M. Oglah (Farm Resource Management** Program)

Experiment 2.7: on-farm forage and grazing trials at El Bab (Preschedule L24)

The objectives of experiment 2.7 were firstly to test the results of experiment 2.6 in a higher rainfall environment where deep and shallow soils can be compared, secondly to simultaneously introduce both forage and pasture legumes to farmers, and thirdly to assess farmers' reactions to forage and pasture legumes and to obtain feedback from farmers as to their most appropriate use.

Only minor changes to the approach used at Breda (experiment 2.6) were made in the design of experiment 2.7. Most important was to involve SMAAR, lack of which was a major weakness of the Breda research. A second was to apply phosphate fertilizer to the barley depending on the phosphate status of the soil, rather than including phosphate as a treatment. Thirdly nitrogen is being applied to half of the barley crop to measure the residual effect of the forages.

The experiments are replicated on six farms, two on deep soils of the valley bottom, two on shallow soils, and two on intermediate soils. Before sowing in November 1986, soils were analysed for P and gross differences between sites eliminated by applying fertilizer. Each site covers about 2 ha, and is divided into two areas separated by 10 m of fallow land. The two areas are split and common vetch and chickling sown in each strip. One 10 X 10 m medic plot, with 10 x 10 m barley plots on each side, is nested 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 2 ha piece of land is sown to barley and completes the second phase of the rotation. At one site 2 ha medic was sown on deep soil.

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 three farms, starting in early April lambs grazed the forages.

As expected, at the start of grazing, there was more vetch (1170 kg per ha) than chickling (920 kg per ha) and barley (520 kg per ha). Standing biomass of mature crops were high (Table 2.23), mainly due to the high yield of straw, which was slightly higher for vetch then for chickling (NS). Straw yields are about 40% higher than they were at Breda but the yield of grain from chickling was only 66% that at Breda, and below that of common vetch at El Bab (NS) the different relative yields of the two species possibly being due to the slightly higher rainfall at El Bab (260 mm and 245 mm at El Bab and Breda respectively in 1986/87). Biomass of barley was considerably more than that of the forages. Except on one farm pod production of medics was low, probably due to poor establishment.

The adjacent barley crop, to be used for forages in the coming season, responded slightly to nitrogen (NS), mostly in the straw (NS) (Table 2.24).

Table 2.23. Straw and seed yields (kg per ha) for common vetch and chickling grown on fallow land. Values in parenthesis are barley yields (kg per ha) in 10 X 10 m plots nested between the forage crops.

	Common vetch[1]	Chickling	SEM[3]	Sign.[4]	(Barley)[2]
Straw yield	1992	1789	65.9	ns	(3461)
Seed yield	663	589	30.5	ns	(1641)
Total	2656	2379	90.4	ns	(5103)

[1] 30-50 kg per ha P_2O_5 applied to both legumes depending on content of Olsen-P in the soil before sowing.
[2] No nitrogen applied, only P_2O_5.
[3] Standard Error of Mean.
[4] Significance.

Table 2.24. Yields (kg per ha) of barley crops[1], with and without ammonium phosphate as a spring dressing.

	- N	+ N	S.E.[2]	Sign.[3]
Straw yield	2023	2672	100	*
Seed yield	946	1025	62	ns
Total	2969	3697	139	ns

[1] Forages will be sown on this land in 1987-88.
[2] Standard Error
[3] Significance: * = P<0.05; ns = not significant.

On the three farms where the forages were grazed, gains in lamb liveweight over 30 to 35 days ranged from 130 to 290 g per day, the farmers offering about 300 g barley grain per day in addition to the grazing. At 30 lambs per ha, liveweight gain was between 100 and 300 kg per ha, and even at the lower rate of gain the variable costs of production would be covered by revenue.

The results are encouraging. They indicate that forages can be profitably grown even on poor land, whether utilized as seed or straw or as grazing for lambs. The successful establishment of medic on the one farm is also encouraging. - **F.A. Bahhady and E.F. Thomson**

Experiment 2.8: screening of forage peas for palatability (Preschedule L30)

The objective of experiment 2.8 was to assess the palatability of forage peas at the pre-bud stage of development and compare it with that of common vetch and woollypod vetch.

Compared with common vetch the low palatability of the local variety of pea (accession 205) has been clearly established (Thomson, Rihawi and Nersoyan, unpublished data). Since this pea becomes more palatable as it matures, it suggests that the anti-palatability factor decreases with time. This contrasts with the usual decrease in VFI as herbage becomes more fibrous and lower in protein. Fresh herbage of woollypod vetch is also less palatable than common vetch: however, when offered as hay, it too becomes more palatable.

Because peas are known to have high potential yield and nitrogen fixation, it is important to see whether all of the pea germplasm at ICARDA is equally unpalatable. The germplasm collection is large, and so screening using conventional feeding trials is clearly out of the question. A study was therefore conducted to test a simple screening procedure based on giving sheep free access to standing herbage. The species and genotypes used in the experiment are shown in Table 2.25. Each plot was 5 x 10 m with three separately fenced replicates. Groups of five Awassi sheep were allowed two hours access to each fenced area for 12 consecutive days. Each sheep had a different coloured ear-tag and, using this to identify the sheep, the species being grazed was recorded every two minutes. Palatability of a genotype was the percentage of the time spent grazing its herbage averaged across the five sheep. The amount of time spent grazing weeds and not grazing was also recorded. Sheep were introduced to the plots each morning without prior feeding but were fed hay in the afternoon.

Herbage yields are shown in Table 2.25. Common vetch was the most palatable species, being completely consumed very quickly. Of the other species between 1110 and 1360 kg per ha remained after grazing, with the exception of one pea (accession 46/61), its final yield reflecting low initial yield.

Sheep grazed the common vetch first, but spent less time doing so as it became less available. They then turned to woollypod vetch spending an increasing amount of time grazing it from day 6 onwards as the common vetch disappeared. On about day 6 they started on pea accession 46/61 for 10 to 20 percent of the time, but only from day 11 did they graze pea accessions 205 and 3211/323. By far the most palatable herbage among the peas were weeds, mainly wild mustard (Synapis sp).

The results reveal that, as expected, common vetch is the most palatable. They also indicate that there is some variation in pea palatability accession, 2903/325 appearing to be the least palatable, accession 205 slightly more palatable, and accession

Table 2.25. Dry matter yields (kg per ha) of common vetch and woollypod vetch, and four genotypes of peas before and after grazing.

Forage species, (accession/selection)	Yields	
	Before grazing	After grazing
Common vetch (2541/-)	432	0
Woollypod vetch (683/-)	806	1113
Pea (2903/325)	678	1364
Pea (205/-)	645	1179
Pea (3211/323)	813	1769
Pea (46/61)	348	642
LSD (P<0.05)	135.7	411.2

46/61 partially palatable. The technique was a useful method of detecting differences in palatability.

In 1987/88 a new PhD study, with the objective of identifying the anti-palatability factor in peas, will begin. If successful it will be possible to rapidly screen ICARDA's complete collection of peas. - E.F. Thomson

Experiment 2.9: nutritive values of lentil, common vetch, chickling and medic straws (Preschedule L20)

The objective of experiment 2.9 was to compare the voluntary intake and digestibility of medic residues with straws of lentil, common vetch, and common chickling.

The straws of lentil, common vetch and chickling are important winter feeds for small ruminants while the residue ('straw') of annual medics complements cereal stubbles. There is no published information comparing the voluntary intake and in-vivo digestibility of these straws.

An experiment was conducted in which chopped straws from mixed varieties of lentil (Lens culinaris), common vetch, common chickling and M. rigidula were offered to four individually caged male Awassi castrates at 1.2 times the mean intake of the previous three days. Voluntary intake, digestibility and chemical composition of the straws were measured using classical procedures, and, together with liveweight changes, are shown in Table 2.26. Differences in voluntary intakes of the straws and daily liveweight gains of the sheep failed to reach significance even though the DOMD of chickling straw was significantly higher ($P<0.05$) than the other straws.

Table 2.26. Chemical composition, digestibility and voluntary intake of four legume straws, and liveweight changes.

	Medic	Lentil	Common vetch	Common chickling	Standard error
Chemical composition (g per kg dry matter)					
Ash	89	144	118	83	-
Crude protein	63	69	66	72	-
ADF	451	360	386	446	-
ME (MJ per kg dry matter)	6.8	6.4	6.9	7.6	-
Digestibility (%)					
Dry matter (IVDDM)	49.0	49.3	48.8	51.6	1.51
Organic matter (IVDOM)	49.8	49.4	51.9	55.2	1.50
DOMD	45.1	42.9	45.7	50.6	1.29
ADF	47.4	35.1	40.7	52.4	1.89
Daily intake					
Dry matter (g)	1424	1585	1513	1607	170.3
Dry matter (g per kg MBS)	83.3	94.1	89.4	93.1	9.84
Liveweight change (g per day)	98	53	80	152	52.2

Daily voluntary intakes were about 3.5% of liveweight. The estimated intakes of ME, which ranged from 9.7 to 12.2 MJ, were sufficient to leave 2.7 to 5.2 MJ additional to maintenance needs which could produce up to 700 ml milk per day. The straws could therefore cover the energy and protein needs of genetically unimproved Awassi ewes at all times with the possible exception of early lactation. *It is clear that farmers who give so much value to legume straw know what they are doing.* - **E.F. Thomson**

Experiment 2.10: nutritive value of straws from nine varieties of barley (Preschedule L27)

The objectives of experiment 2.10 were firstly to compare the voluntary intake and digestibility of nine barley straws harvested by hand or combine, and secondly, using the nylon bag technique, measure their rumen degradability.

The collaborative research with ODNRI has shown large genetic variation in leaf and stem proportion, stem height, days to maturity, and CP, ADF, and IVDOM of barley and wheat straws. However, these in vitro parameters, at least for low quality roughages such as cereal straws, have been shown to be poor predictors of in vivo digestibility and feed intake. Therefore it is still considered necessary to conduct in vivo measurements of *straw quality with the ultimate objective of providing cereal* breeders with simple in vitro parameters which can be used to screen cereal germplasm.

Hand harvested (1985) or combine harvested (1984) straws were chopped to 2-3 cm lengths and offered ad-libitum to 12 Awassi male castrates. A balanced 3 x 3 lattice design with four replicates was used (3 sheep in each row, and 3 periods as columns). Each feeding period continued for 28 days, feed intake and faecal output being measured for the last 14 days. The straw was fed unsupplemented.

The morphological characteristics of the nine varieties are shown in Table 2.27. In contrast to what we expected stems were shorter in 1985 than in 1984 even though rainfall was higher (373 mm in 1985 compared with 292 mm in 1984). However leaf proportion showed little variation between years, a surprising result as previously there has been a correlation between leaf proportion and stem length. The inconsistency suggests that stem length may have less value in predicting straw quality than we had believed. The earlier maturity in 1983/84 was expected and is a reflection of the lower rainfall in that year. However, early maturity may be difficult to assess when the range of maturities in some years is very narrow (just 17 days in 1984/85).

The digestibility and VFI of the straws are shown in Table 2.28. In both years there were significant differences between varieties in DOMI, the ranking however not being consistent from year to year, perhaps explained by the method of harvest: combine harvested, which cuts at 10-15 cm above the ground, in 1984, and hand-pulled, which includes the whole plant, in 1985. However method of harvest is unlikely to be the only factor causing variation in ranking, the results clearly suggesting that we should pay more attention to the effect of environment.

Nevertheless some straws were consistently of high or low feeding value. Thus Badia, ER-Apam and Beecher had the lowest DOMI in both years and Rihane and Antares were consistently higher. Indeed the latter was outstanding in 1985: this straw also had the highest leaf proportion, the highest CP and the lowest ADF, all factors which, in the past, have been associated with good quality.

Table 2.27. Morphological characteristics of barley varieties harvested in 1984 and 1985 (data based on hand-pulled plants).

	Badia	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

Table 2.28. Organic matter digestibility, organic matter intake and digestible organic matter from straws of barley genotypes harvested in 1984 and 1985. (harvested by machine and hand respectively).

	Badia	Apam	Beecher	Arabi Abiad	Arabi Aswad	C63	Rihane	Arar	Antares	L.S.D.	Sign.[1]
Organic matter digestibility (%)											
1984 harvest	43.0	45.8	45.2	49.8	-	45.7	47.7	47.7	43.5	0.51	ns
1985 harvest	45.1	44.1	46.3	45.3	49.2	49.5	49.9	50.0	51.8	1.94	*
Organic matter intakes (g per MBS)											
1984 harvest	39.2	34.9	35.6	47.5	-	45.9	36.6	31.0	40.8	0.82	**
1985 harvest	34.9	33.2	36.3	37.8	41.9	41.1	41.6	40.5	48.3	3.37	*
DDMI (g per MBS)											
1984 harvest	17.0	15.9	16.1	23.7	-	21.0	17.4	14.7	17.8	0.50	*
1985 harvest	15.7	14.9	16.9	17.1	20.7	20.4	19.1	21.5	25.1	2.65	*

[1] Significance: ** = P<0.01; * = P<0.05; ns = not significant.

In the 1984 material we had previously measured high correlations between DOMI and days to maturity (r = 0.77). In 1985 this relationship was weak (r = 0.30), as was the relationship between DOMI and leaf proportion (r = <0.10). In 1985 DOMI was correlated most closely with dry matter digestibility and crude protein, r = 0.94 and r = 0.92 respectively. The good correlation with CP is particularly interesting: it has hitherto been assumed that the limited amounts of protein in straw have low availability and will not therefore affect intake. Such was apparently not the case in 1985 suggesting that the protein is in fact available: if so it could be expected to have a marked effect on VFI (Van Soest, 1984). More attention should be given to nitrogen supply in future.

In addition to the *in-vivo* study just described, the degradation characteristics of the nine straws were determined using the nylon-bag technique (Orskov *et al*. 1980). In this simple method straw, contained in a bag of nylon filter cloth, is incubated directly in the rumen, thus being subjected to microbial attack in the exact conditions of the rumen (Hovell *et al*. 1986). It should be a good method for measuring degradability because the relationship between time and degradation can be measured. The nine straws were incubated in 3 fistulated Awassi castrates previously offered a hay diet for periods of 12, 24, 48 and 72 hours. The percentage disappearance of dry matter were fitted to the exponential equation $\mathbf{P = a + b\ (1 - e^{-ct})}$ where **P** is the disappearance of dry matter at time **t** and **a**, **b**, and **c** are constants (Orskov and Macdonald 1979).

The results are shown in Table 2.29. The constants gave a good fit to the equation, with 98% of variation explained. Furthermore, straw with the lowest DDMI, Badia, and straw with the highest DDMI, Antares, had the lowest and highest percentage of dry matter disappearance respectively.

Table 2.29. Intake of digestible dry matter (DDMI) and percentage disappearance _in sacco_ of straws from nine varieties, at four incubation times in the rumen.

Variety	DDM1	Incubation time (h)				R^2	Constants[1]			R.S.D.
	(g per MBS)	12	24	48	72		a	b	c	
Beecher	17.0	22.7	34.6	54.0	61.2	0.995	3.316	68.141	0.027	1.306
Apam	16.6	29.8	46.2	58.0	64.8	0.993	4.739	62.044	0.044	1.259
Badia	16.4	21.5	38.0	49.2	59.3	0.980	1.417	62.177	0.034	2.274
Arabi Abiad	18.2	34.7	48.2	62.3	70.8	0.998	16.974	61.130	0.029	0.645
Arar	22.1	30.2	43.8	64.8	71.3	0.993	7.021	72.739	0.031	1.559
C63	21.4	30.0	45.2	61.2	66.3	0.999	4.462	65.486	0.041	0.384
Antares	27.3	33.8	51.0	62.7	71.8	0.985	10.373	64.251	0.039	2.012
Arabi Aswad	21.3	30.3	47.8	60.0	70.3	0.983	8.976	66.070	0.034	2.236
Rihane	21.5	30.2	46.6	63.3	71.5	0.999	5.936	71.040	0.035	0.414
Correlation with DDMI		0.598	0.647	0.681	0.731	-	-	-	-	

[1] The constants a,b and c were obtained by fitting the measured values for percentage diappearance of dry matter to the exponential equation $P = a + b\,(1-e^{-ct})$ where P is the dry matter loss at time t (Orskov and McDonald, 1979).

The results indicate that the nylon-bag technique has potential in identifying differences in feeding value. However although a high correlation between DDMI and dry matter disappearance was found (r=0.60 at 12 h and r=0.73 at 72h), only 50% of the variation in intake at 72h was explained, still not good enough to use as a predictor of intake. Furthermore, since the nylon-bag technique does not measure the physical characteristics of straw and since the effect of chewing, rumination and removal of undigested material from the rumen may be limiting factors in controlling intake, it is unwise at this stage to depend on results from the nylon bag technique alone.

In future we will give more attention to understanding the mechanisms controlling variation in feeding value. Firstly we will attempt to identify the physical and chemical factors within straws responsible for variation, secondly understand how these factors relate to animals, and finally understand the relative effects of physical breakdown and degradability. - **F. Herbert (Wye College, University of London), E.F. Thomson, B.S. Capper (ODNRI), and R.C. Campling (Wye College)**

Experiment 2.11: barley straw in ewe production diets (Preschedule L28)

The objective of experiment 2.11 was to assess the voluntary intake of straws from four barley varieties offered to pregnant and lactating Awassi ewes receiving a basal concentrate diet.

Although we have demonstrated variability in straws eaten by male castrates there has been no research to assess the significance of this variation on the productivity (as opposed to maintenance) of ewes. The variation in straw quality may be masked or of little importance when ewes receive generous amounts of concentrate. In addition, ewes usually have appetites well above those of male castrates.

Chopped straw from Arabi Abiad, Beecher, C63 and ER/Apam was offered ad-libitum to four groups of 9 Awassi ewes. The experiment began when the ewes were about 16 weeks pregnant and continued through lactation into the dry period. During late pregnancy (42 days) and early lactation (42 days) ewes received the same basal diet of whole barley grain, soyabean meal, wheat bran and minerals. During mid - to late lactation (42 days) the ewes were further divided into sub-groups receiving low (L), medium (M) or high (H) levels of concentrate. To compensate for differences in the nitrogen content of straws, the concentrate contained different amounts of nitrogen, such that the nitrogen content of all diets was similar. At the end of the experiment the dry ewes were offered straw alone for 28 days.

The yields and morphological characteristics of the four varieties are shown in Table 2.30. The local landrace, Arabi Abiad, gave the highest grain and straw yields, indicating that it has high potential in good conditions. Straw morphology data show that Arabi Abiad and ER/Apam are short varieties with thinner stems while Beecher and C63, are taller with slightly thicker stems. Except for Beecher leaf proportions were similar, experimentally useful because it offered us the opportunity to compare the varieties unconfounded by differences in leaf proportion. DOMI of the diets (including concentrates) were similar (Table 2.31). The VFI of Arabi Abiad was similar to ER/Apam, both of which were greater than the six-rowed varieties, themselves similar. Concentrate intakes were also similar differing by just over one standard error across treatments.

Table 2.30. Grain and straw yield, straw morphology and days to maturity of four barley varieties harvested in June 1986.

	Arabi Abiad	ER/ Apam	Beecher	C63
Yield (kg per ha)				
Grain	5472	5151	4286	4363
Straw	5461	5006	4592	5297
Harvest index (%)	50.0	50.7	48.3	45.2
Straw morphology				
Row type	2	2	6	6
Stem height (cm)	68	67	103	91
Stem width (cm)	0.41	0.40	0.43	0.49
Leaf proportion (%)	0.43	0.44	0.39	0.43
Days to maturity	183	183	186	194

The ewes lost liveweight even though there was enough concentrate to cover 90% of ME needs: low appetite must have prevented ewes ingesting straw to cover the ME deficit. However, the liveweight losses, which often occur in early lactation, were only 2 to 4 kg during the six week period and are not excessive. Although daily milk yields were similar ($P>0.05$) farmers would notice the difference in the ewes' voluntary intake (19%) and milk yield (23%), resulting from the Arabi Abiad straw compared with C63.

Having established that varietal differences in quality are expressed in lactating ewes we examined the interaction between variety and level of concentrate. A summary of the results is in Fig. 2.21.

Table 2.31. Dry matter digestibility of the whole diet and of straw alone, voluntary intakes of straw from four barley varieties, and daily concentrate intake, daily liveweight changes and milk yields of Awassi ewes from week two to week six of lactation.

	Barley variety				S.E.D.[3]	Sign.[4]
	Arabi Abiad	ER/ Apam	Beecher	C63		
Number of ewes	9	9	9	9	-	-
Dry matter digestibility						
Whole diet	61.4	64.3	63.6	63.0	2.62	ns
Straw[1]	41.9	46.3	44.6	41.8	4.71	ns
Intake of dry matter						
Straw (g per day)	794	767	678	600	64.7	*
Concentrate (g per day)	794	783	783	698	43.3	ns
Straw (g per MBS)	44.9	44.3	37.2	36.2	2.81	**
Concentrate (g per MBS)	45.0	43.1	45.6	42.6	2.46	ns
Liveweight change (g per day)	-39.7	-50.3	-95.2	-52.9	34.05	ns
Milk yield (g per day)[2]	1635	1584	1581	1264	45.6	ns

[1] Concentrate dry matter assumed to be 80% digestible: 3 observations per treatment.

[2] Weeks 3 to 6 of lactation. Ewes hand that milked and suckled by lambs added.

[3] Standard Error of Difference.

[4] Significance: * + P<0.05; ** = P<).))1; ns = not singificant.

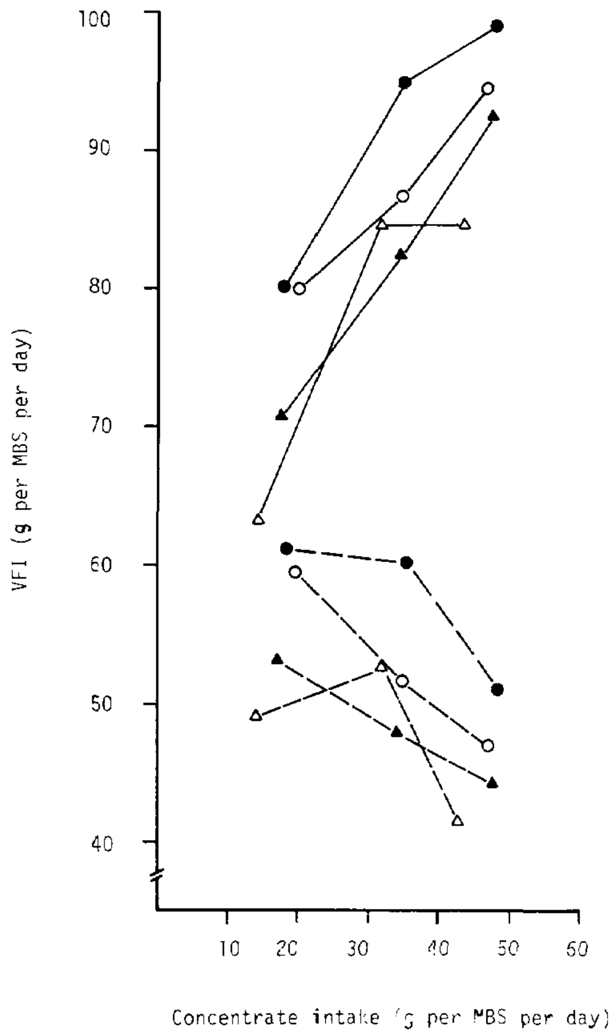


Fig. 2.21: Total VFI of straw and concentrate (continuous lines), and VFI of the straw component (broken lines) of Arabi Abiad (closed circles), ER/Apam (open circles), Beecher (closed triangles), and C63 (open triangles) barley varieties in ewes offered three levels of concentrate.

The overall ranking of the straws remained the same at the three levels of concentrate suggesting that there were interactions (the high intake of C63 straw at the medium level of concentrate was probably an artefact). It is clear that the energy density of the diets was limiting intake even at the high level of concentrate which was expected to cover about 100% of ME needs. Other studies

(Bahhady, unpublished data) show that Awassi ewes offered <u>ad-libitum</u> concentrate and 100 g chopped barley straw could ingest up to 140 g per MBS.

To compare the appetites of dry ewes with male castrates, the digestibility and intake of the straws was measured using the same ewes after lactation ended. Intake (in g per MBS) of Arabi Abiad was 7% (NS) higher than ER/Apam and 16 to 19% higher than Beecher and C63 ($P<0.05$) (Table 2.32). There were no significant differences in loss of liveweight, the small differences being due to gut-fill adjustments which occurr when ewes change from a straw/concentrate diet to a pure straw diet. Since there is some evidence that appetite recovers after a period of adaptation, it is also likely that liveweight losses would have declined (Thomson and Termanini, 1988).

Table 2.32. Dry-matter digestibility and voluntary intake of the straw of four barley varieties when offered to dry Awassi ewes. The change in liveweight (g) during that time is also given.

	Arabi Abiad	ER/ Apam	Beecher	C63	R.S.D.[1]	Sign.[2]
Number of ewes	9	13	11	11	-	-
Dry matter digestibility	45.4	44.9	49.7	48.3	3.82	ns
Intake (g per day)[3]	757	678	597	596	102.3	**
Intake (g per MBS)[3]	43.8	40.7	35.6	36.7	5.49	**
Liveweight change (g)	-15.1	-19.8	-18.6	-11.3	10.03	ns

[1] Residual standard deviation.
[2] Significance: ** = $P<0.01$; ns = not significant.
[3] Dry matter.

The experiment has shown that differences in straw quality are expressed in the production of lactating ewes, even up to quite high levels of concentrate confirming the importance of straw quality. Unfortunately the results pose more questions than they answer. For example why did the two-rowed varieties have such low digestibilities in the dry sheep? What are the reasons for the different rankings of straw quality in various experiments over the last five years? The experiments will continue in 1987/88 to help answer these and other questions. Special emphasis will be given to the digestibility of straw, rate of passage, and rate of degradation. - **E.F. Thomson**

CHAPTER 3: PHYSIOLOGY AND ECOLOGY OF SEED PRODUCTION AND DORMANCY IN ANNUAL PASTURE LEGUMES

The main objective of the work reported in Chapter 3 is to develop selection criteria for the genetic improvement of medics. It is aimed at two important (probably the most important) physiological processes: seed production and seed survival.

The principal advantage of the ley farming system over one using annually resown forages is that, by using appropriate pasture species there is no need to resow after the initial year of establishment: the 'appropriate' species can self-regenerate as a result of seed dormancy. Not only does this save farmers the expense of re-sowing but also the natural re-seeding rates are much higher than farmers can afford to use, resulting in rapid early establishment and a much longer period of grazing.

Productivity and stability of ley farming depend on several factors. Firstly the time of greatest feed shortage is usually autumn and winter, when low temperatures and low light intensity ultimately inhibit plant growth. The most rapid possible pasture growth in winter, which is closely related to amount of seed set and resistance to frost, are therefore important attributes. Secondly most of the seeds must resist germination in the crop year and sufficient seeds germinate promptly in the third year to produce a productive pasture. Thirdly survival depends on ability to produce enough material, including seed, to provide grazing in summer, with enough seed remaining for dense germination two years later. Finally the pasture must fulfill its role as a source of nitrogen, and, in association with *rhizobia*, fix sufficient atmospheric nitrogen for its own and the cereal's requirements.

The last of these factors, nitrogen fixation, is discussed in Chapter 5. Most of the remaining factors involve either seed production or seed dormancy. Fig. 3.1 illustrates their importance. Of seed set in phase 1 of a cereal/pasture rotation (April 1985), half was used by grazing animals, about 10% germinated as weeds in the cereal phase, and more than 200 kg per ha remained dormant in the soil. From this reserve of seed the pasture of 1986/87 was able to re-establish naturally resulting in seed reserves of 700 kg per ha in the summer of 1987. A similar pattern is being repeated in phase 2.

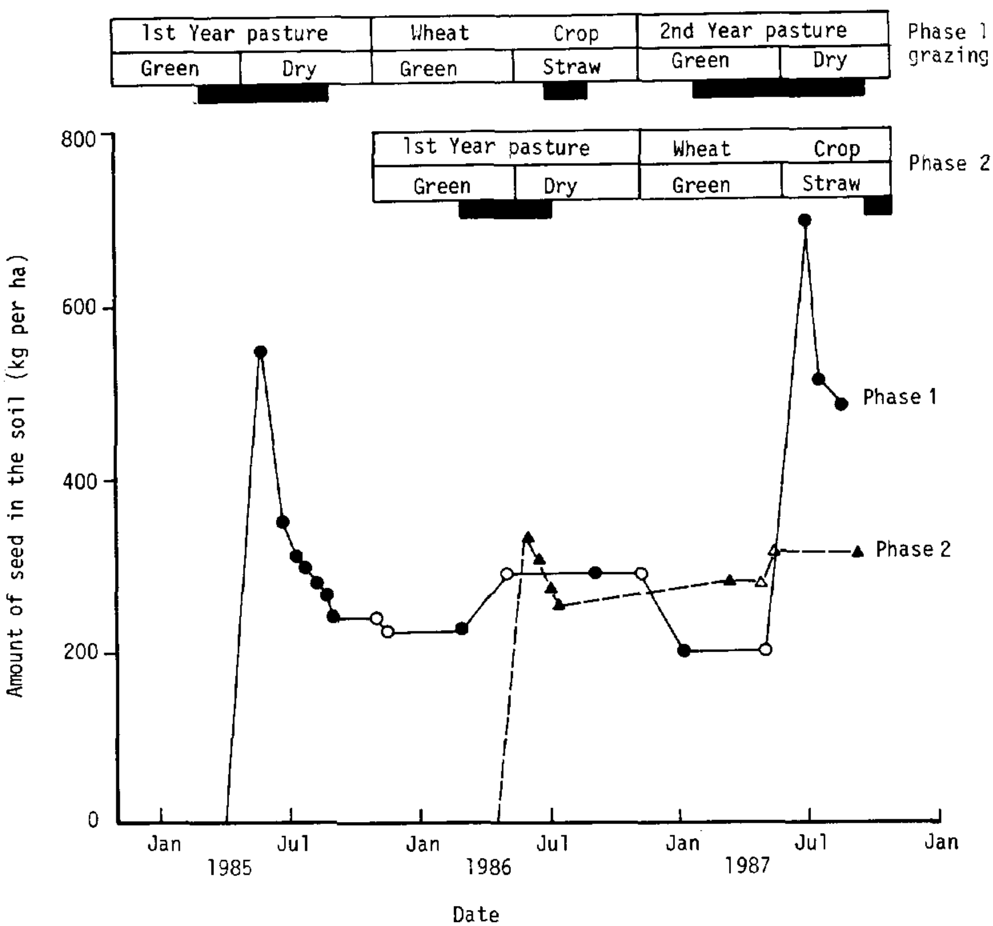


Fig. 3.1: Residual medic seed in phase 1 (solid line) and phase 2 (broken line) of medic/wheat rotations at Tel Hadya. The closed circles and triangles are actual measurements, and the open ones are estimates. The horizontal black bars above the figure are the periods of sheep grazing, the sheep alternating from phase 1 to phase 2.

Clearly, if improved pasture plant varieties and management systems are to be created, a fundamental knowledge of the process of flowering, seed set, seed survival under grazing, and seed dormancy is required. Previous work (Cocks 1987) has shown that, within all the ecotypes tested, seed yield is related to the number of pods and that up to 95% of flowers are lost through either flower or pod abortion. Seeds of native species are usually less permeable (more dormant) than those of Australian cultivars, although the pattern of hardseed breakdown of the native ecotypes in Syria is similar to that of the Australian cultivars in Australia. Ewes grazing mature pods are able to increase liveweight until nearly all of the pods have been eaten, indicating that farmers will have to manage pastures very carefully in summer.

Similar comments apply to the annual legumes growing in native pasture on marginal land. Although there is no cropping phase, a seed bank is necessary for long term stability in an environment noted for variation in both distribution and total amount of rainfall. The herbage of native pastures, as with medic pastures, is dependent on seedling number, and therefore seed production. It is necessary that our understanding of seed production and dormancy includes that of native pasture.

In this Chapter we discuss research on flower and seed production, seed survival under grazing, and seed dormancy in both medic and native pasture. In experiment 3.1 the survival of flowers produced on spaced plants of eight medic ecotypes was studied, in experiment 3.2 more than 60 ecotypes of 14 medic species were surveyed to determined variability in flower retention, in experiment 3.3 the effect of artificially tripping seeds to increase self-pollination was examined, while in experiment 3.4, seven ecotypes of 5 species were sown at two densities to simulate the effects of growing the ecotypes in swards. In experiment 3.5 the seed bank of native pasture was monitored, and the germination of seedlings counted at monthly intervals. In experiment 3.6 medic seeds and pods were fed to sheep to measure digestibility and the ability of seeds to survive ingestion. In experiment 3.7 the breakdown of hardseeds of several species was observed after being produced at two densities. Finally, in experiment 3.8 the economics of commercial seed production was assessed by analysing ICARDA's own seed production process and measuring the effect of weed control on commercial seed crops.

Experiment 3.1: flower production and seed survival on spaced plants of annual medics (Preschedule M28)

Productivity of a particular medic species depends on plant number (Abd El Moneim and Cocks 1986) which in turn depends on the number of viable seeds in the soil when the first rains occur in autumn. The necessary number of plants will vary with location and with the use for which the pasture is intended: for example Puckridge and French (1983) cite the need for 1000 plants per m^2 in southern Australia but it is likely that in the colder conditions of west Asia an even greater population will be required to achieve satisfactory growth rates. Assuming 90% of seeds are dormant, a plant population of 1000 per m^2 requires a seed population in excess of 400 kg per ha for most species, depending on seed size (larger seeded species probably need less plants). If the farmer also requires the seed for grazing in summer it is clear that high seed yields are essential for the successful utilization and regeneration of medic pastures.

Seed production in any legume depends on production and survival of flowers and pods, number of seeds per pod, and individual seed size. For Vicia faba, flower and pod abortion are common, occurring at budding, flowering and podding (Gates *et al*. 1983), abortion at podding accounting for up to 50% loss of fertilized flowers. For medics, recent work at ICARDA has shown that seed yield is dependent on pod number, and that survival of flowers can be as low as 5% (95% abortion) a figure far lower than that recorded for *Vicia faba* and subterranean clover (Donald 1954; Collins *et al* 1976), the latter being the only Mediterranean pasture species in which flower production and survival have previously been monitored. It is therefore of great interest to study the extent and variability of flower abortion in medics and to understand the reasons for its occurrence.

In experiment 3.1 the objective was to accurately monitor flower production and survival of several medic species. To do this it was necessary to count flower numbers at each node, and subsequently harvest the pods. Flower survival was calculated and total numbers of flowers and pods were counted.

The following entries were included in the experiment:

M. minima accession 3/C
M. polymorpha variety Tah
M. coronata accession 25/2
M. noeana accessions SA 15845 and SA 15497
M. turbinata accession 7/6
M. rigidula selections 716, 1900, and 1919
M. rotata selections 1943 and 2123
M. truncatula cultivar Jemalong

The entries were sown in 'Jiffy' pots and later transplanted to the field. There were 30 plants in each entry planted in one row, the rows being 1.5m apart with 0.5m between plants within rows. There were three replicates. Allocation of rows to entries within each replicate was at random.

Weeds were controlled as necessary, using both chemicals and hand weeding.

The following parameters were recorded:

- flowering time - day on which each plant began to flower;

- number and survival of flowers - two primary branches were tagged on each of two plants within each replicate and the date of appearance of each inflorescence, the number of flowers on each inflorescence, and the number of developing pods on each inflorescence were recorded at three-day intervals. Flowers on secondary branches were ignored;

- pod size, seed size, and seeds per pod were measured at each flowering node on the branches used above. Because pods fall from the plants at maturity, they were placed in small bags attached to the plants so that pods from each node could be identified; and

- plant mass and total number of flowers and pods: at weekly intervals from the beginning of March, two plants per replicate were harvested, the number of flowers and pods per plant were recorded, and dried plants weighed.

The exponential growth rate illustrated in Fig. 3.2 is expected since the plants grew as spaced plants and competition between plants was not severe. Fig. 3.2 shows the mean mass of all species (solid line) and that of the largest (*M. rotata* selection 1943) and, with the exception of cv. Jemalong, smallest (*M. coronata* accession 25/2) at the final harvest. Those species with plants larger then the mean were (from the largest) *M. rotata* selection 1943, *M. rigidula* selection 716, *M. rigidula* selection 1919, *M. turbinata*

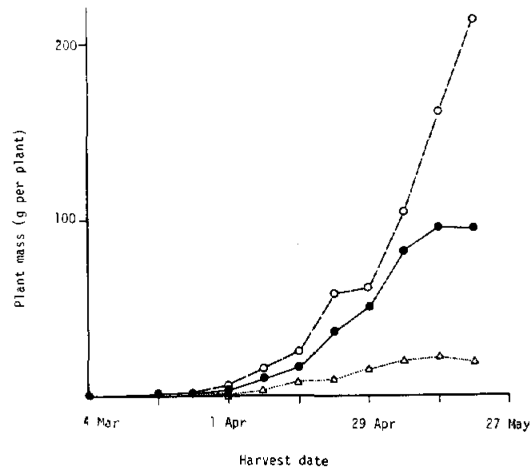


Fig. 3.2: Accumulation of herbage (solid line is the mean of eight genotypes) and that of the largest (M. rotata selection 1943) and next to smallest (M. coronata accession 25/2) genotypes with time.

accession 7/6, and M. noeana accession SA 15497. Those species smaller than the mean (beginning from the smallest) were M. truncatula cv. Jemalong, M. coronata accession 25/2, M. minima accession 3/C, M. rigidula selection 1900, M. polymorpha variety Tah, M. noeana accession SA 15845, and M. rotata selection 2123. No special significance is given to the ranking.

The pattern of flower production in two species is illustrated in Fig. 3.3. In M. rigidula selection 1919 (Fig. 3.3a) flowering commenced on 25 March, reached a peak on 21 April, the last new flowers appearing on 6 May. The greatest number of pods occurred on 21 April, and there was a continuous decline until 20 May. In M. polymorpha (Fig. 3.3b) flowering commenced three weeks earlier, reaching a peak however, only one week earlier on 14 April. As in the case of M. rigidula the last new flowers of M. polymorpha appeared on 6 May. Pod numbers continued to increase until 6 May, but in the following two weeks there was a decline of 35% in pod numbers. The pattern of flowering in M. rotata was similar to M. polymorpha, while that of the other ecotypes of M. rigidula and M. noeana were similar to M. rigidula selection 1919. M. minima accession 3/C was strikingly different in that there was a steady increase in pod numbers with only a slight decline after 13 May.

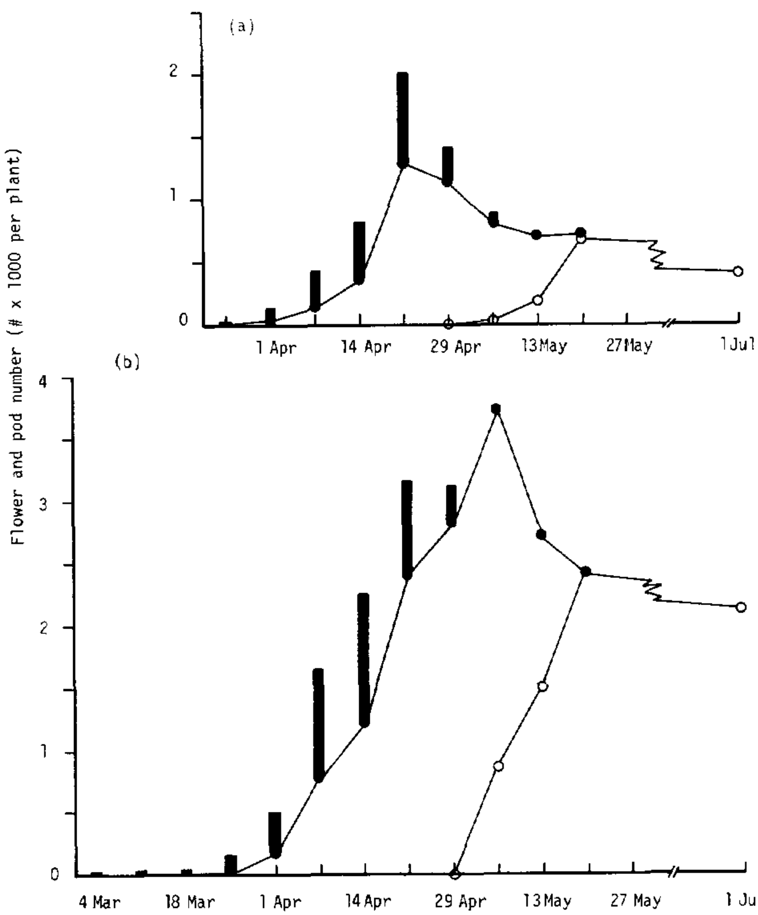


Fig. 3.3: Flower number (histograms), immature pods (closed circles) and mature pods (open circles) of (a) M. rigidula selection 1919 and (b) M. polymorpha variety Tah during flowering in spring.

The small decline in mature pod numbers after 20 May represents losses associated with wind and cracking soils, and has no biological significance.

The numbers of flowers (solid circles) and pods (open circles) at each node of primary stems on M. rigidula selection 1919 (Fig. 3.4a) and M. polymorpha (Fig. 3.4b) are shown in Fig. 3.4. The node numbered one for each ecotype is the node at which the first flower appeared, and thereafter each node is numbered consecutively. The first node of M. rigidula appeared on the same day as the 7th node of M. polymorpha (25 March) hence the relative positions of the two species on the Figure.

In the case of M. rigidula the greatest number of both flowers (4.3) and pods (1.7) per node appeared at the second node, there being a gradual decline thereafter such that the last nodes rarely had more than one flower, which usually did not mature to form a pod. The greatest survival of flowers appeared to be around node 7. In M. polymorpha the greatest number of both flowers and pods occurred on nodes 10 and 11 where nearly all flowers matured to pods. Both the early-produced flowers, and those produced late (where moisture may have been limiting) had higher mortality, especially those produced early.

Most of the remaining species had patterns similar to M. rigidula, the exception being M. minima which produced 2 flowers per node at all but the last few nodes, and where flower survival was around 80%, again at all nodes.

Fig. 3.4 also shows seed size at each node. The largest seeds (9 mg in M. rigidula selection 1919) were from the first 4-5 nodes, while seeds from late-produced flowers were smaller in all species except M. coronata. Indeed in M. rigidula selection 1919 late-produced seeds were barely 40% of the mass of seeds produced by

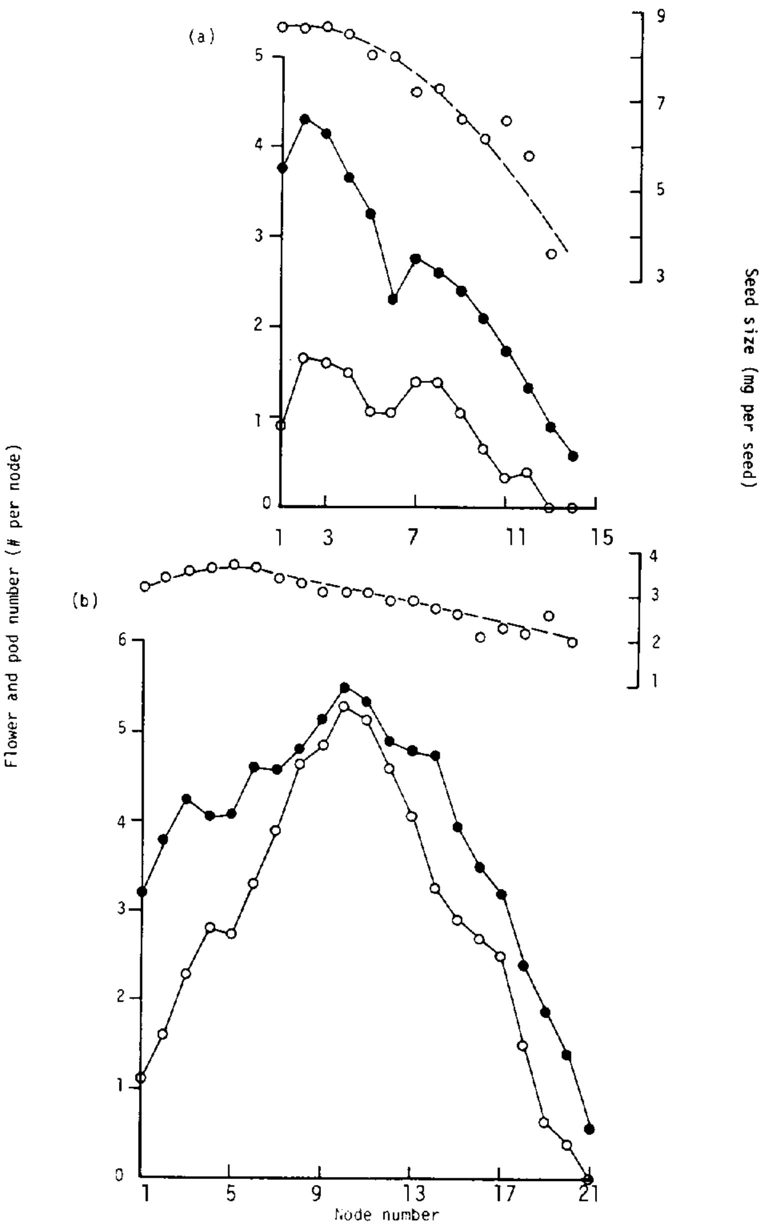


Fig. 3.4: Number of flowers (closed circles) and pods (open circles) at each node (the node numbered one is the first node at which flowers appeared) along a primary stem of (a) M. rigidula selection 1919 and (b) M. polymorpha variety Tah. The broken lines at the top of (a) and (b) represent the mass of individual seeds at each node of each species respectively.

early flowers probably indicating an ever-increasing level of stress. The significance of stress on hardseededness will be discussed later (experiment 3.7). Mean seed size varied from 0.5 mg (M. coronata) to 8.6 mg (M. rigidula selection 1919), the large seeded ecotypes being M. rigidula selection 716 (7.2 mg), M. rotata selection 1943 (6.6 mg), M. rotata selection 2123 (6.2 mg), M. turbinata accession 7/6 (5.9 mg) and M. noeana accession SA 15845 (4.9 mg), and the smaller seeded being M. rigidula selection 1900 (4.2 mg), M. noeana accession SA 15497 (3.7 mg), M. truncatula cv. Jemalong (3.5 mg), M. polymorpha variety Tah (3.1 mg), M. minima accession 3/C (1.5 mg) and M. coronata accession 25/2 (0.5 mg).

Flower survival was calculated by dividing the total number of flowers which appeared at all nodes on primary stems by the number of pods which survived to maturity: since the plants also produced secondary and tertiary stems it is possible that on these stems flower survival differed from that shown in Table 3.1. In any event flower survival varied from 37% (M. rigidula selection 1919) to 81% (M. minima accession 3/C), and, over all species, was related to pod mass (Fig 3.5, r^2=0.77, P<0.001). An equally close relationship exists between survival and what we have termed the potential sink at each node-the number of flowers multiplied by the pod mass. It will be seen later that this term predicts flower survival more accurately than pod mass when larger numbers of species and ecotypes are taken into account.

The results show that considerable variation in flower survival exists in the medics suggesting that selection for survival will result in gains in seed production. Furthermore it is clear that small pods are an indicator of high flower survival. Flower production and pod survival within genotypes varies with time (Fig. 3.4), and it therefore may also be possible to select for genotypes with high early flower production and survival when environmental stress would appear to be least.

Table 3.1. Number of pods per plant, pod mass (mg per pod), number of seeds per pod, number of flowers per node, and flower survival (%) of the twelve medic ecotypes in experiment 3.1.

Species and ecotype	Pods/plant	Pod mass	Seeds/pod	Flowers/node	Flower survival
M. coronata 25/2	2732	2.7	1.70	15.6	69
M. polymorpha Tah	2069	26.9	3.50	4.5	69
M. rotata 2123	1011	72.4	4.82	5.3	56
M. noeana SA15497	831	45.1	3.86	4.2	70
M. noeana SA15485	656	61.5	3.93	3.8	67
M. rotata 1943	651	90.8	5.28	4.5	54
M. turbinata 7/6	633	142.9	4.84	6.3	38
M. rigidula 716	626	173.5	6.98	2.7	46
M. rigidula 1900	489	100.2	7.94	3.7	34
M. rigidula 1919	387	155.2	6.63	3.0	37
M. minima 3/C	287	31.4	5.92	2.0	81
M. truncatula cv. Jemalong	110	133.1	8.45	2.4	45
Mean	874	86.3	5.32	4.8	56
LSD ($P<0.05$)	774	12.3	0.79	0.57	11.8

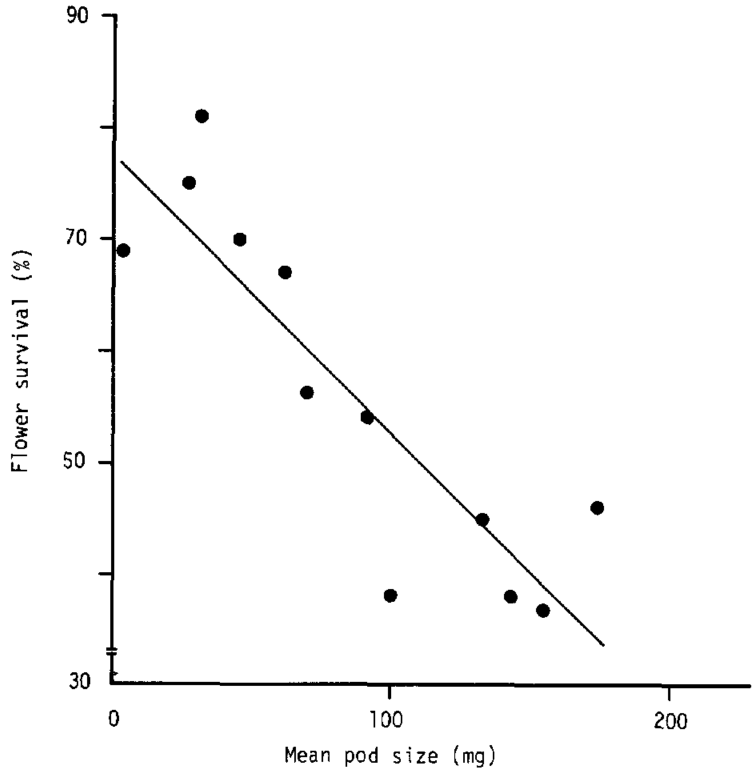


Fig. 3.5: The relationship between flower survival (percentage of original flower number) with pod mass. The linear relationship is significant at P<0.001.

Experiment 3.1 illustrates the Program's attempts to introduce objective selection criteria to its medic improvement work. Such criteria are badly needed if we are to achieve rapid progress and avoid the long studies necessary where genotype survival within rotations is the only reliable criteria (as is the case at present). - P.S. Cocks

Experiment 3.2: phenology of 63 medic accessions (Preschedule M28)

The objectives of experiment 3.2 were threefold: firstly to see whether the detailed results obtained in experiment 3.1 have wide

Table 3.2. The species tested in experiment 3.2, and their origins.

Species	Number of entries	Origins
M. aculeata	2	Syria
M. blancheana	4	Syria
M. constricta	1	Syria
M. coronata	4	Syria
M. granadensis	2	Syria
M. littoralis	2	Syria
M. minima	2	Syria
M. noeana	4	Syria, Iraq, Turkey
M. orbicularis	3	Syria
M. polymorpha	9	Syria, Australia
M. radiata	5	Syria
M. rigidula	10	Syria, Turkey
M. rotata	10	Syria, Turkey
M. scutellata	2	Syria, Australia
M. truncatula	1	Australia
M. turbinata	2	Syria
Total	63	

generality among medics, secondly whether variation in flower survival exists within species, and finally to relate flower survival to other characteristics of flower and seed production.

In most cases, the entries (Table 3.2) were selected from accessions collected during studies on the distribution of medics (Cocks and Ehrman 1987). Many of the Australian cultivars were included, as were the most promising accessions selected at ICARDA over the last 5 years. There were more accessions of M. rigidula, M. polymorpha, and M. rotata than of other species: experience has shown that these species are well adapted to cereal/pasture rotations in west Asia and north Africa. Species such as M. coronata were included because they have small pods and apparently a low rate of pod abortion. Within species an attempt was made to select accessions with diverse pod sizes and flowering times.

The entries were sown in 'Jiffy' pots in the greenhouse and transplanted to the field at appearance of the first trifoliate leaf. There were 10 plants per entry in each replicate and three replicates. Row spacing was 1.5 m and the space between plants within rows was 0.5 m. Allocation of rows in each replicate to entries was at random except that three controls (M. rigidula selection 716, M. rotata selection 2123 and M. truncatula cv. Jemalong) were planted every 15 rows.

Grass weeds were controlled with Fusillade, and other weeds mechanically.

The following parameters were recorded:

- flowering time - day on which each plant began flowering;
- number of flowers and pods per inflorescence - as in experiment 3.1;
- mass of randomly selected pods;
- number of seeds per pod; and
- individual seed mass.

The results confirm that flower and pod abortion in medics is widespread. Flower survival varied from 27% (one accession of M. blancheana) to 93% (for one accession of M. radiata). Those accessions common to both experiments gave similar results with *M. coronata* (79%), *M. minima* (83%), and *M. polymorpha* (70%) having substantially greater flower retention than *M. rigidula* (49%), *M. rotata* (54%), and *M. truncatula* (46%). Within species there was wide variation - in *M. rigidula* (33 - 70%) and *M. polymorpha* (58 - 87%).

In looking at the flower and pod characteristics of the 63 ecotypes it is useful to order the data in such a way that it can be considered in groups. For that reason the data was subjected to several forms of multi-variate analysis: K-means clustering (Engelman & Hartigan 1983), principal factor analysis, and step-wise multiple regression. The following parameters were included in the analyses: date of flowering, node number of first inflorescence, mean number of flowers per node, rate of flowering, pods retained per node, pod mass, seeds per pod, individual seed mass, mass of seeds in pods as a percentage of pod mass, mass of pods per plant, mass of seeds per plant, and the potential sink at each node (pod mass x number of flowers per node).

In K-means clustering it is possible to select the number of clusters formed by the data. After examining the composition of groups, a result which produced 10 clusters was selected. The composition of the clusters is shown in Table 3.3, the characteristics of each cluster in Table 3.4, and the relationships between clusters (in terms of statistical distance) in Fig. 3.6.

In Fig. 3.6, the ability of flowers to be retained increases from left to right (Table 3.4). Groups to the left in Fig. 3.6 are also characterized by large pods, large seeds, and high values of 'potential sink'. *M. scutellata*, *M. orbicularis*, *M. aculeata*, and *M. turbinata* are restricted to these groups, while *M. coronata*, *M. minima*, *M. radiata*, and *M. littoralis* are restricted to groups characterised by high flower retention, and small pod and seed mass.

Table 3.3. Composition of the 10 groups formed by K-means clustering based on 13 flower and seed characteristics.

Species (number of ecotypes)	Group No.	No.ofcases
M. scutellata (1); M. orbicularis (1)	1	2
M. turbinata (2)	2	2
M. aculeata (2)	3	2
M. blancheana (2); M. rotata (2); M. rigidula	4	5
M. orbicularis (2); M. scutellata (1); M. constricta (1); M. rigidula (1)	5	5
M. rigidula (3); M. rotata (2); M. granadensis (2); M. blancheana (1)	6	8
M. rotata (4); M. rigidula (3); M. polymorpha (2); M. noeana (1); Jemalong	7	11
M. polymorpha (3); M. noeana (3); M. rotata (2); M. blancheana (1); M. rigidula (1); M. littoralis (1)	8	11
M. polymorpha (4); M. radiata (3); M. rigidula (1); M. littoralis (1)	9	9
M. coronata (4); M. minima (2); M. radiata (2)	10	8

Some species, most notably *M. rigidula*, are distributed widely across the groups, being absent only from the extremities. *M. polymorpha* is present only in groups 7, 8, and 9, while *M. noeana* is restricted to groups 7 and 8. *M. rotata* and *M. blancheana* are only slightly less variable than *M. rigidula*.

Principal factor analysis was less helpful in distinguishing the groups than K-means clustering. However the correlation matrix (Table 3.5) reveals some interesting relationships. If $r = 0.7$ ($r_2 = 0.49$) is taken as the criterion for selecting useful relationships

Table 3.4. Characteristics of the 10 groups formed by K-means clustering.

Character	Group 1	2	3	4	5	6	7	8	9	10
Date of flowering	86	83	63	90	78	90	84	86	74	80
Node 1st flowering	7.6	6.7	5.9	10.4	6.6	9.4	7.6	7.8	5.8	5.8
Flowers per node	2.9	6.3	1.3	3.9	2.1	3.4	3.4	3.2	2.9	7.1
Date of flowering	0.38	0.34	0.28	0.42	0.37	0.40	0.39	0.39	0.33	0.34
Pods per node	0.96	2.34	0.72	1.71	0.89	1.73	1.88	2.16	2.27	5.69
Pod mass	308	140	423	161	215	129	106	68	48	16
Seeds per pod	14.0	5.2	5.9	7.5	11.6	6.6	6.9	5.3	4.8	3.7
Seed weight	14.5	6.4	13.2	6.8	8.4	7.5	5.3	4.4	3.9	1.2
Seed percentage(1)	38	24	18	32	37	34	35	40	36	
Pods per plant	99.4	103.6	116.8	71.0	65.6	65.5	78.8	64.1	55.5	20.6
Seeds per plant	38.7	26.6	21.2	23.2	26.2	24.9	27.1	22.8	21.1	7.5
Potential sink(2)	880	884	560	571	443	410	322	204	114	54
Flower retention	34	37	55	44	42	51	54	64	79	82

(1) The percentage of the total pod mass which comprises seed.
(2) Potential sink = pod mass x flowers per node (see text).

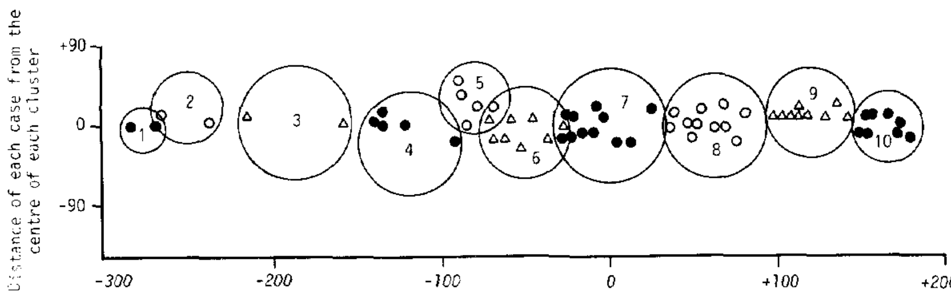


Fig. 3.6: The statistical distance between the 10 clusters formed by K-means clustering. The composition and characteristics of each cluster are shown in Tables 3.3 and 3.4 respectively (see text). The symbols differ so that each adjacent cluster can be clearly seen.

only seven of 78 possible relationships emerge. Of these probably four are expected: date of flowering and node of first inflorescence, flowers per node and pods per node, pod mass and seeds per pod, and pods per plant and seeds per plant. The remaining three deserve further consideration.

There is a close relationship between rate of flowering and date of flowering. Closer examination of the data reveals that rate of flowering is strongly dependent on ambient temperature, and that variability in rate of flowering is an expression of mean temperature during flowering. Pod mass is closely related to potential sink, a not surprising result since pod mass is a component of potential sink. The most interesting result however is that percentage flower retention is more closely related to potential sink ($r = -0.775$) than to pod mass ($r = -0.636$).

Fig. 3.7 illustrates this relationship. Although, as described earlier, the linear correlation coefficient is highly significant, a goodness of fit test indicates that a higher degree (quadratic) polynomial should be used. The multiple r^2 value of a quadratic

Table 3.5. Correlation matrix of 13 variables measured in experiment 3.2

Character	1	2	3	4	5	6	7	8	9	10	11	12	13
1 Date of flowering	1.000												
2 Node of first inflorescence	0.742	1.000											
3 Flowers per node	0.060	-0.133	1.000										
4 Inflorescence per day	0.762	0.692	0.003	1.000									
5 Percentage flower retention	-0.111	-0.340	0.222	-0.148	1.000								
6 Pods per node	-0.006	-0.242	0.945	-0.072	0.478	1.000							
7 Pod mass	-0.099	0.139	-0.435	-0.076	-0.636	-0.521	1.000						
8 Seeds per pod	0.147	0.204	-0.411	0.176	-0.485	-0.479	0.465	1.000					
9 Seed mass	-0.027	0.204	-0.358	0.010	-0.529	-0.449	0.754	0.065	1.000				
10 Percentage seeds in pods[1]	0.234	0.160	0.056	0.258	0.122	0.096	-0.363	0.174	-0.123	1.000			
11 Pods per plant	-0.210	0.053	-0.176	0.063	-0.396	-0.295	0.420	0.239	0.345	-0.127	1.000		
12 Seeds per plant	-0.066	0.147	-0.124	0.205	-0.328	-0.234	0.189	0.370	0.221	0.308	0.874	1.000	
13 Potential sink[1]	0.144	0.344	-0.153	0.187	-0.775	-0.402	0.736	0.451	0.632	-0.248	0.541	0.410	1.000

[1] See Table 3.4

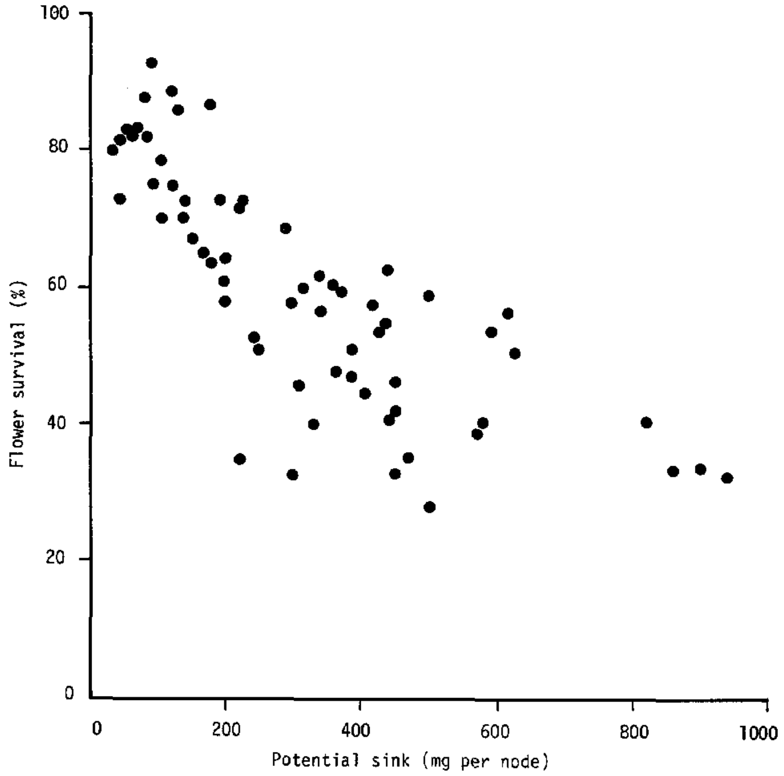


Fig. 3.7: The relationship between flower survival and the mean potential sink (flower number per inflorescence x pod mass) at each flowering node for 63 medic accessions. The linear relationship is significant at $P<0.001$, $r^2=0.60$, and curvilinearity improves the fit ($P<0.001$) such that $r^2=0.69$.

polymonial is 0.69, compared to 0.60 for the linear, the improvement in fit being highly significant ($P<0.001$).

However, even more of the variation in flower retention can be accounted for using step-wise multiple regression. Of the 12 variables that can be entered, eight account for some of the variation in retention; in order of entry they are potential sink, pods per node, flowers per node, pod mass, seeds per pod, seed mass, percentage seed in pods, and node of first inflorescence. When all eight variables are included $r^2 = 0.92$ (Table 3.6), a high figure indeed.

Table 3.6. Order of entry of regression coefficients, and F tests to enter and remove variables, after step-wise multiple regression using the 13 variables measured in experiment 3.2. The five remaining variables did not significantly affect the relationship.

Variable	Multiple r	r^2	Change in r^2	F to enter	F to remove
Potential sink	0.7751	0.6008	0.6008	91.81	46.8
Pods per node	0.7962	0.6340	0.0332	5.43	169.1
Flowers per node	0.8661	0.7501	0.1161	27.41	169.1
Pod mass	0.9244	0.8546	0.1045	41.69	5.75
Seeds per pod	0.0364	0.8769	0.0223	10.32	40.2
Seed mass	0.9444	0.8918	0.0149	7.73	24.4
Percentage of seeds in pods	0.9558	0.9136	0.0218	13.85	17.1
Node of inflorescence	0.9591	0.9199	0.0063	4.26	4.26

Since potential sink is derived from pod mass it is interesting to conduct a second step-wise regression in which potential sink is not a factor. *In this case only node of first inflorescence* increases the multiple r^2 value, increasing it from 0.40 (for pod mass alone) to 0.47. It seems that potential sink is a far more valuable predictor of a species ability to retain flowers than is pod mass.

The results show that if flower survival is important in obtaining high seed yield, it can be predicted in nursery rows by simply counting the number of flowers at each node, and weighing the pods. Of these two parameters, pod mass is the more useful, and the easiest to measure. - **P.S. Cocks**

Experiment 3.3: effectiveness of self-fertilization (Preschedule M28)

The objective of experiment 3.3 was to determine whether one of the reasons for flower loss in medics is incomplete self-fertilization of the flowers.

Annual medics are predominantly self-fertilized, fertilization usually occurring before the flowers open. If flowers fail to self-fertilize they will drop from the plant and hence may constitute part of the loss of flowers referred to earlier. Those flowers which fail to self-pollinate can be induced to do so by mechanically 'tripping' them.

Two entries (early and late flowering) of *M. polymorpha* (cv. Circle Valley, variety Tah), *M. rigidula* (selections 716 and 1868), *M. rotata* (selections 1943 and 2123), and *M. noeana* (accessions SA 15845 and SA 15497) were included in the experiment. On selected plants all flowers on one stem were tripped each morning and flower survival compared to that on a control stem. There were four replicates.

As in Experiments 3.1 and 3.2, the entries were sown in 'Jiffy' pots and later transplanted to the field. There were ten plants per row, rows being 1.5m apart and 0.5m between plants within rows. Allocation of rows to entries was at random.

As before, weeds were controlled as necessary.

The parameters measured were:

Table 3.7. Flower retention (as a percentage of flowers produced) for eight ecotypes of four species with and without artificial tripping of the flowers to induce self pollination.

Species and ecotype	Flower retention	
	Without tripping	With tripping
M. rotata selection 1943	40	43
M. rotata selection 2123	55	53
M. polymorpha variety Tah	72	72
M. polymorpha cv. Circle Valley	81	79
M. noeana accession SA15485	68	65
M. noeana accession SA15497	62	65
M. rigidula selection 716	50	50
M. rigidula selection 1868	54	52
Mean	60	60

- number and survival of flowers - the date of appearance of each inflorescence, the number of flowers on each inflorescence, and the number of developing pods on each inflorescence were recorded at three-day intervals; and

- pod size, seed size, and seeds per pod were measured as in Experiment 3.2.

The results showed that were no effects of tripping on flower retention in any species (Table 3.7). - P.S. Cocks

Experiment 3.4: seed production of promising medics at two densities (Preschedule M28)

The objective of this experiment was to relate seed yield in swards to the physiological data collected in experiments 3.1, 3.2, and 3.3.

The following medics were sown at low (10 kg per ha) and high (200 kg per ha) densities.

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

There were 4 replicates of a randomized complete block. Plot size was 2m x 15m.

The whole area was cultivated to obtain a good seed bed. After the first rains seed, which had previously been inoculated and lime pelleted, was sown with a plot seeder. Grass weeds were controlled with chemicals and by handweeding. The site received a dressing of 60 kg per ha of P_2O_5.

The following data were collected:

- herbage yield at 2 week intervals beginning in early March in quadrats of 1m x 1m. Herbage was dried at 90^{o}C and weighed;

- plant numbers at the first harvest by counting the number of plants in a subsample of the sample used to measure herbage yield;

- seed yield at the end of the growing season in an area of 2m x 1m. The number and mass of pods and seeds were measured, and the mass of individual seeds recorded;

- after appearance of the first flowers, the number of inflorescences, number of flowers, and number of pods; and

- at each harvest, the number of flowers and pods on each node of 10 randomly selected stems.

Herbage yield responded strongly to density at all harvest times (Fig. 3.8). Biomass on 5 May reached 6.4 t per ha at high density and 2.2 t per ha at low density. Between ecotypes herbage yield ranged between 5.3 t per ha (M. rotata selection 2123) and 7.3 t per ha (M. noeana selection 1938) at high density, and 1.3 t per ha (cv. Jemalong) and 2.9 t per ha (M. noeana accession SA 15845) at low density.

Seed yields, mean seed size, and the number of seeds per pod are shown in Table 3.8. In both total seed yield and number of seeds per pod there were strong interactions between ecotype and density. For example, at high density, M. polymorpha variety Tah was the highest yielding ecotype with 801 kg per ha, while at low density four ecotypes yielded more seed than variety Tah, with M. rigidula selection 716 giving the highest yield. Only variety Tah and cv. Jemalong yielded more at high density than low. Indeed M. noeana selection 1938 failed to produce seed at high density. However, because individual seed mass was less at high density, seed numbers were relatively greater.

Table 3.8. Seed yield (kg per ha), mean seed size (mg per seed), seeds per pod, and number of seeds (No per $m^2 \times 10^3$) 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 1938	266	0	2.46	NA[2]	4.1	NA[2]	10.8	0
M. noeana 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 1900	397	199	2.94	2.28	8,2	7.4	13.5	8.7
M. rigidula 716	516	374	4.41	3.48	6.4	5.8	11.7	10.7
M. rotata 2123	446	418	5.09	4.77	4.2	4.1	8.8	8.8
M. truncatula Jemalong	83	472	3.07	2.70	6.2	8.8	2.7	17.5
Mean	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 ($P<0.001$) species X density effect for both seed yield and seeds per pod.
[2] Not applicable (no seeds of *M. noeana* 1938 produced at high density)
[3] Means and analysis of variance did not include date of *M. noeana* 1938

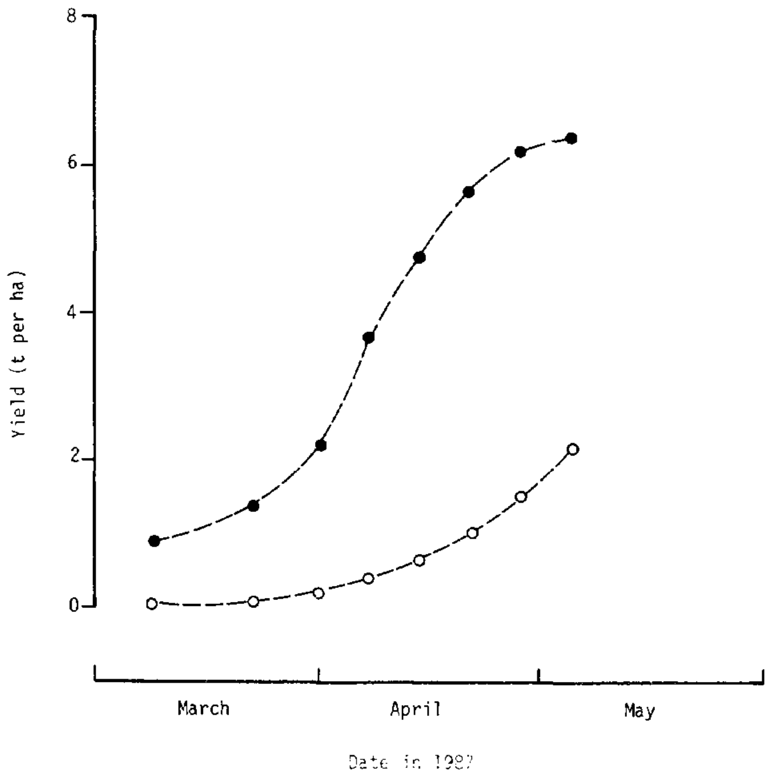


Fig. 3.8: Accumulation of herbage (mean of seven species) at low (open circles) and high (closed circles) densities.

On 21 April there were a total of 39500 flowers and immature pods per m^2 of M. polymorpha variety Tah at high density and 11200 at low density. At maturity these numbers had fallen to 10600 and 4000 pods per m^2 at the two densities, only 27% and 36% of flower and pod number present on 21 April. At high density, although nearly 8000 new flowers per m^2 were present on 21 April, very few, if any, matured into pods (Fig. 3.9): even of the immature pods present on that day (30600 per m^2) only 35% reached maturity. In contrast, at low density, many of the new flowers had become immature pods by 28 April, but by maturity most of these had apparently been lost so that the number of mature pods present were only 400 per m^2 more than the number of immature pods present on 21 April (1600 per m^2). It is clear that even at low density, flower retention is much lower than in spaced plants, where this ecotype retained 72% of all flowers produced on primary stems (eg Table 3.7).

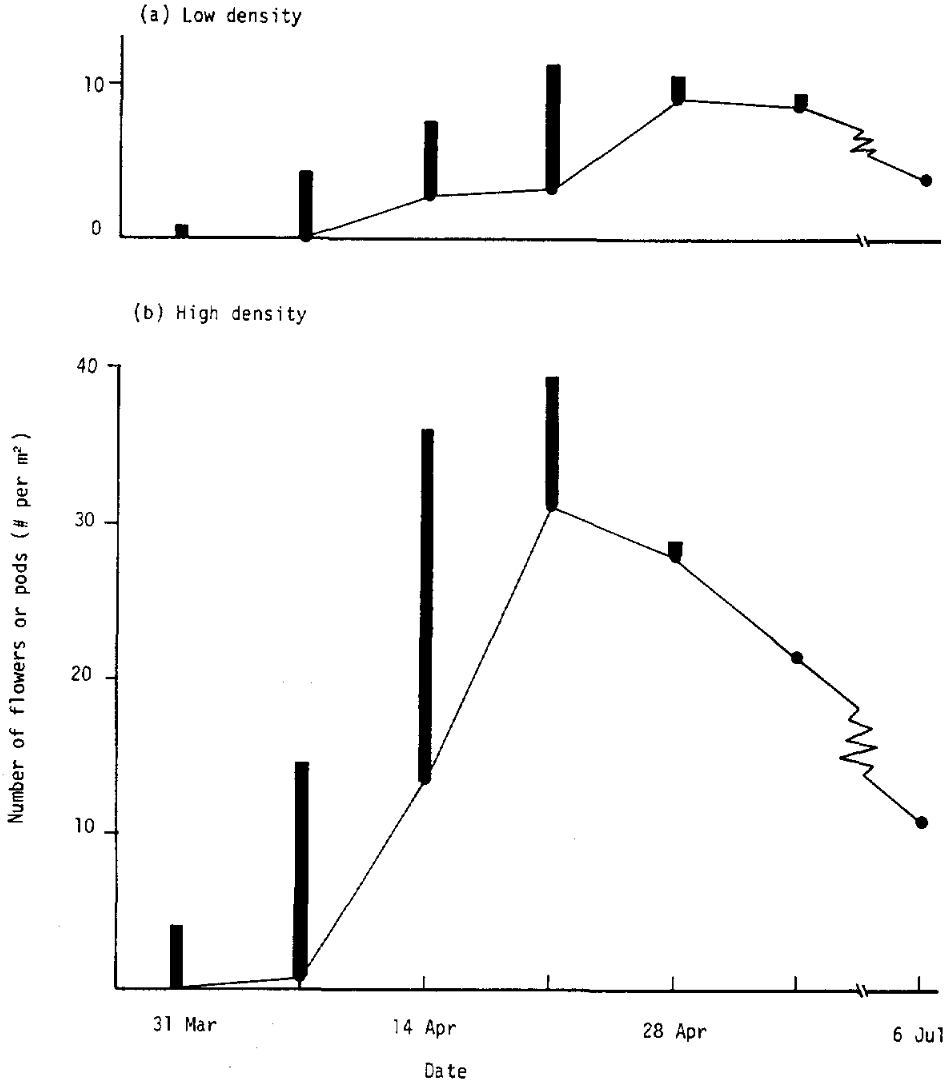


Fig. 3.9: Flower number (histograms) and immature/mature pod number of M. polymorpha variety Tah in swards at (a) low and (b) high density during flowering.

The generality of the results in Fig. 3.9 for the other species are summarized in Table 3.9. It is clear thet M. polymorpha variety Tah was by far the earliest flowering ecotype in the experiment, beginning to flower 22 days before cv. Jemalong, the next ecotype to flower. M. noeana selection 1938 was a week later than the next latest ecotype. The day on which the greatest number of flowers and pods were present occurred later at low density than at high density, usually by about one week, and the difference in time of greatest flower number was greatly reduced at low compared with high density. Of great interest is the percentage survival, which varied from only 5% (M. rigidula selection 1900 at high density) to 36% (M. noeana selection SA 15845 and M. polymorpha variety Tah at low density). In all ecotypes flower survival was greatest at low density.

In fact the difference in peak flowering between low and high density may simply be an anomaly associated with differences in plant growth rate. In Fig. 3.8 it can be seen that the most rapid growth rate at high density occurred earlier than at low density: presumably because of different shapes of the sigmoid growth curves. If flowering is expressed in terms of new flowers per g of herbage (Fig. 3.10) then there is little difference between densities: indeed M. polymorpha may reach peak flowering a few days earlier at low then at high density.

Variation in seed yield at high density can be explained by variation in flowering time (Fig. 3.11): there was a linear relationship between seed yield and flowering time with $r^2 = 0.86$ ($P<0.001$). At low density $r^2 = 0.05$ and was not significant. The data on seed size presented in Table 3.8 - where mean seed size was less at high density - indicates strongly that seed production at high density took place in a strongly stressed environment. In such environments early flowering is a stress avoidance mechanism, the plants producing seed before the onset of severe stress. This method of coping with stress is of high relevance in pasture legumes

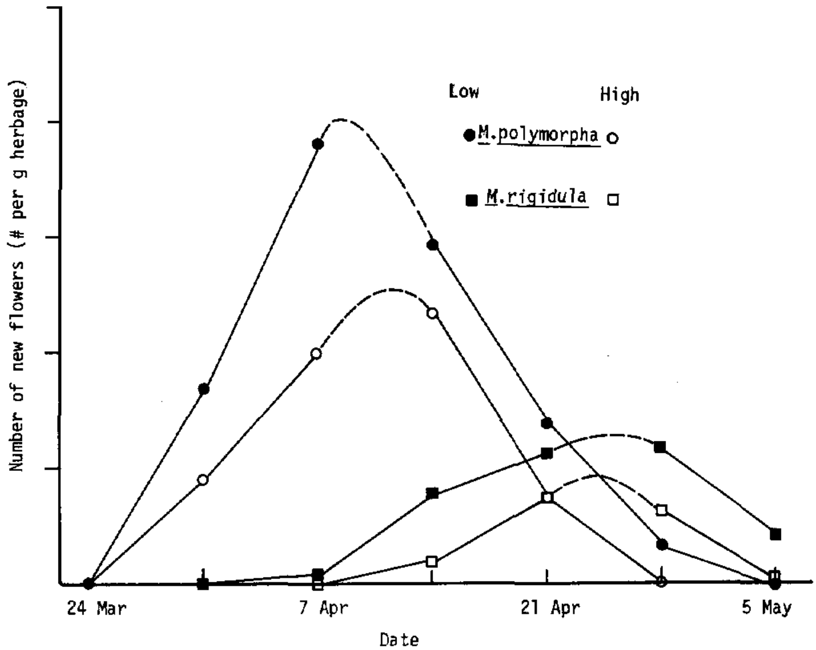


Fig. 3.10: The number of new flowers appearing on M. polymorpha variety Tah (circles) and M. rigidula selection 1919 (squares) at low and high density.

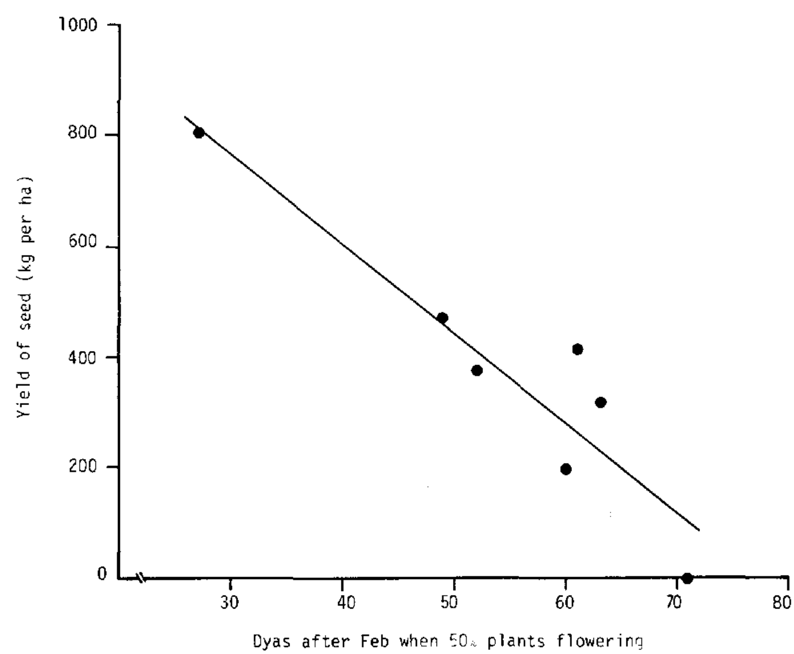


Fig. 3.11: The relationship between seed yield and flowering time of the seven medics sown at high density. The linear relationship is significant at $P<0.001$, $r^2=0.86$.

Table 3.9. Day (after 1 February) when the first flowers appeared, day (after 1 February) of peak reproductive activity, number (per m^2) of reproductive organs present at peak activity, and the percentage of reproductive organs surviving to maturity of seven medics sown at low and high density.

	Day of first flowering	Day of peak reproductive activity		Number of organs at peak date		Percentage survival	
Density		Low	High	Low	High	Low	High
M. noeana 1938	71	95	88	9440	3720	28	0
M. noeana SA 15845	63	95	88	9167	24911	36	15
M. polymorpha Tah	27	81	81	10981	39325	36	29
M. rigidula 1900	60	95	88	10878	22985	15	5
M. rigidula 716	52	88	81	6270	12027	29	15
M. rotata 2123	61	95	88	10964	22673	19	9
M. truncatula Jemalong	49	88	81	1574	8010	24	25

Table 3.10 Harvest index and percentage of seeds in pods (by mass) of seven medics at high and low density.

	Harvest index		Percentage seed	
	Low	High	Low	High
M. noeana 1938	9	0	37	NA[(1)]
M. noeana 15845	17	5	33	38
M. polymorpha Tah	15	13	33	50
M. rigidula 1900	17	3	30	36
M. rigidula 716	20	6	29	32
M. rotata 2123	34	8	38	45
Jemalong	7	7	19	32

[(1)] Not applicable, since no seed was produced

and is often quoted as the major reason for the successful penetration of pasture legumes into dry areas in southern Australia (eg Donald 1970).

However the low flower retention percentages in Table 3.9, especially at high density, reveal the potential to increase seed yields by diverting plant resources to reproductive organs.

This conclusion is reinforced by the data in Table 3.10 which shows that medics are inefficient seed producers, both in terms of low harvest index, and low proportion of seeds in pods. Paying attention to appropriate flowering time, and selecting species with smaller seeds and pods, larger number of flowers, and thinner pod walls, may lead to higher seed production and therefore greater stability in medic farming systems. The interaction of some of these factors with the ability of seeds to survive ingestion by sheep is the subject of the next section. - **P.S. Cocks**

Experiment 3.5: the survival of medic seed ingested by sheep (Preschedule L22)

Seeds either enter the seed bank or are grazed by livestock. As discussed earlier subsequent herbage production depends on the number which enter the seed bank, but grazing of seeds during summer is also important, the seeds being of high nutritive value. This conflict of interest will be partly resolved if some of the seeds survive ingestion: although nutritive value of summer pastures will be reduced, long term stability of the system will be increased.

Of the Australian medics however, it is known that only 2-5% survive ingestion (Carter 1980). We know that local medics tend to be harder seeded than the Australian cultivars and that their seed size is more variable. It is therefore important to understand the factors leading to seed survival in west Asia and north Africa, and to compare the new ICARDA selections with the Australian cultivars.

By understanding what happens to seed during grazing it may also be possible to develop criteria for selecting medics with seeds resistant to digestion. This attribute would partially remove the danger of over-grazing and greatly simplify grazing management. It would be necessary to retain the ability of seed-coats to become permeable after digestion otherwise poor regeneration would be the consequence. Using sheep to naturally distribute seed to both cropped and communal land is also an attractive idea.

The objectives of experiment 3.5 were therefore to determine the survival of annual pasture legumes ingested by sheep and to relate survival to seed characteristics. Survival was measured by three methods:

- the equal pod mass method: a single 200 g meal of pods was offered to eight Awassi male castrates with a basal diet of lentil straw. Faeces were collected at 6, 12, 18, 24, 30, 36, 42, 48, 60, 72, 96 and 120 h after feeding. The number of seeds in subsamples of faeces from each collection allowed estimation of the number of seeds voided by the sheep. As a result of the marked variation in seed size and number of seeds per pod between genotypes (Table 3.11), sheep were offered a wide range of seed numbers;

- the equal seed method: a single meal of pods estimated to contain 30,000 seeds (10,000 in the case of M. aculeata) was given to eight Awassi castrates and the same procedure applied as with the equal pod method; and

- the in vivo digestibility method: for 21 days 200 g pods from each species were offered to groups of four Awassi male castrates receiving a basal diet of lentil straw of known digestibility. This method comes closest to the field situation in which sheep ingest 300 to 400 g per day of seed, equivalent to 900 to 1200 g pods. Both the number of seed voided, and digestibility of the pods, was measured. A shortage of pods limited the group size for this method to four sheep per species.

A preliminary trial was conducted to determine the number of sheep needed per group. Sixteen sheep were offered 200 g M. rigidula selection 716 and seed survival measured using the equal pod mass method. Of the 12,900 seeds offered, 4.9% were voided (SE = 0.058). The germination rates of seeds removed from pods before ingestion, and of seed voided by sheep were also determined.

Between species pod mass varied considerably, from 32 mg for M. polymorpha variety Tah to 276 mg for M. aculeata, while variation in the number of seeds per pod and average seed mass, though considerable, was less (Table 3.11). The exception was seed mass of Trifolium campestre and T. tomentosum which were much smaller than the medics, T. stellatum being intermediate.

Because of the range in pod size, the amount of seed ingested when 200g pods were offered varied from 4200 for M. aculeata through 26000 for M. polymorpha variety Tah to 80,000 for T. campestre and over 91,000 for T. tomentosum.

There were significant ($P<0.05$) differences between methods of measuring seed survival. The equal seed method always gave higher survival rates than the equal pod mass and digestibility methods, the two latter giving similar results (correlation between these two method was $R = 0.96$, $b = 1.09$). Of these two methods the digestibility method had the lowest variation between replicates, indicating that it was the most accurate.

The higher seed survival using the equal seed method probably reflects the greater number of seeds ingested compared with the other methods and therefore the higher probability that more seeds will escape chewing and rumination and so be presented at the rumeno-reticulum orifice for passage into the abomasum. Indeed, all seeds are less than 3 x 1 mm which is well below the size at which particles are known to pass out of the rumen. However the large seeded medics probably undergo more rumination, thus exposing them to greater microbial attack. It is suggested that rumination may be more significant in determining seed survival than originally realized since undamaged seeds are highly resistant to microbial attack. Seeds with coats slightly damaged during rumination are probably completely digested post-ruminally even if they pass from the rumen before extended exposure to microbial action.

The importance of seed size as a factor determining survival is shown in Fig. 3.12. Including data from Trifolium, the square of the correlation coefficient (R^2) for the quadratic polynomial

Table 3.11. *Seed characteristics of 12 medics and three clovers, and seed survival measured* by the equal pod, equal seed and digestibility methods (see text).

Species	Seed characteristics			Seed survival (%)		
	1000 pod mass (g)	Seeds per pod	1000 seed mass (g)	Equal pods[1]	Equal seeds[1]	Digestibility method[2]
M. aculeata	276	5.81	11.88	3.95	14.32	9.03
M. polymorpha	32	4.15	3.37	14.96	18.26	16.35
M. constricta	200	7.98	6.77	1.85	8.16	2.22
M. polymorpha	99	6.01	7.15	8.08	17.88	7.22
M. rigidula	111	7.36	5.16	8.57	26.35	9.66
M. truncatula (Jemalong)	102	7.69	3.90	4.64	9.00	6.23
M. truncatula	86	5.83	4.12	2.59	8.69	3.33
M. rotata	75	5.18	6.56	12.03	27.81	13.48
M. noeana	49	4.21	4.04	7.32	14.37	10.13
M. polymorpha (circle valley)	42	5.40	3.89	18.72	24.73	23.67
M. turbinata	94	4.45	5.84	2.15	8.01	4.34
M. rigidula selection 716	101	6.51	5.07	5.92	9.04	7.32
T. campestre		42.74[5]	0.30	60.01	-	-
T. stellatum	-	-	2.01	23.12	-	-
T. tomentosum	56.03	15.52[2]	0.51	36.28	-	-
Mean	105.58	5.88	5.65[3]	7.56[3]	15.55	9.42
SEM	19.88	0.38	0.68[3]	0.37[3,4]	0.17	0.45[4]
LSD (P = 0.05)	-	-	-	3.188[3]	1.522	0.566

[1] n = 8; [2] n = 4; [3] Excludes the clovers; [4] SED; [5] Seeds per inflorescence

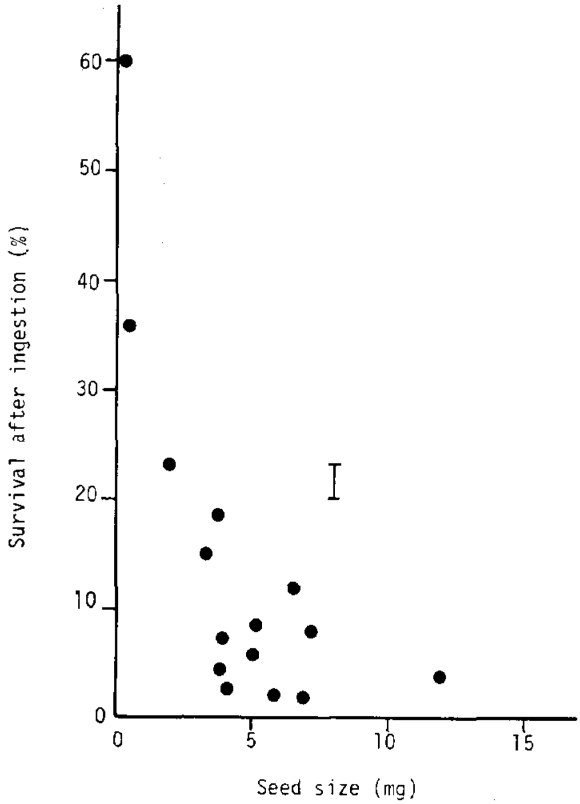


Fig. 3.12: The relationship between the survival of legume seeds after ingestion by sheep and mean seed size. The relationship was significantly ($P<0.001$) curved, and the resultant r_2 was 0.80.

indicates that 80% of the variability in survival is explained by seed size. Only 1% of undigested medic seed germinated compared with 1.5% of the seed recovered in faeces ($P>0.05$). This suggests that passage through the digestive tract of sheep had little impact on hard-seededness of the survivors.

Medic pods are rich in protein and have a high digestibility, but only the latter differed significantly between species ($P<0.05$) (Table 3.12). At these digestibilities, and at intakes of 900 to 1000 g pods daily the expected substantial gains of ewes grazing medic residues confirm those actually obtained (ICARDA, 1986).

Table 3.12. Chemical composition and dry matter digestibility of pods from 12 medics[1].

	Chemical composition (g per kg)				Dry matter digestibility[2] (%)
	Ash	CP	NDF	ADF	
M. aculeata	91.8	260.2	525.1	420.1	72.5
M. polymorpha variety Tah	80.2	273.1	546.2	456.0	61.6
M. constricta	101.1	256.2	556.0	439.5	69.1
M. polymorpha	72.5	286.0	501.9	442.4	66.3
M. rigidula	88.1	255.5	500.8	452.9	66.9
M. truncatula cv. Jemalong	101.2	246.8	52.67	476.2	70.1
M. truncatula	96.8	288.9	53.30	489.9	55.8
M. rotata	56.6	291.1	510.6	493.6	56.8
M. noeana	68.8	301.9	523.4	480.0	69.9
M. polymorpha cv. Circle Valley	71.8	323.1	529.8	491.2	58.6
M. rigidula selection 716	91.0	271.1	500.3	458.1	66.9
M. turbinata	84.4	287.3	537.8	501.4	59.3
Mean	83.69	278.43	444.82	464.28	64.48
SEM	4.04	6.39	53.09	6.98	1.67
LSD ($P<0.05$)	-	-	-	-	

1 Mean of four sheep observations

2 Calculated by difference method, using measured digestibility of lentil straw (47.94%).

The results suggest that it may be worthwhile to select species with small seed size and hence greater numbers. However, while this would probably increase survival after ingestion, it might also increase the difficulties of plant establishment, especially as small seeds would need to be closer to the surface for germination. Even in the first year this might be difficult to achieve: in regenerating pasture small seed buried after the crop may be far too deep for emergence. However these questions deserve answers, and emphasize once again, that by altering one part of the farming system there will be consequences on other parts.

What is quite clear however is that using species with small seeds and a high survival rate would remove a major constraint to the system - the danger of overgrazing in summer, especially in drought years, which will be difficult to avoid in traditional grazing systems. Even if only 25% of the seeds survived, and assuming that only one-third of the faeces were dropped back on the pasture, 10 sheep on one ha for 90 days would remove 270 kg seed and return 20 kg. If 50% of the seeds survived 41 kg would be returned. Such amounts will greatly increase regeneration from a heavily grazed pasture, and, if all seeds are grazed, enable the system to continue. Seeds not returned to the pasture would be returned to other grazing areas, especially marginal land and cereal stubbles resulting in improvement of both classes of land. The point is especially important using cereal stubbles in a cereal/pasture system: if sheep grazed medic pods in the morning, and cereal stubbles in the afternoon, about 60% of the seed would be dropped on land using the pasture/cereal rotation. - **E.F. Thomson, S. Rihawi, and** P.S. Cocks

Experiment 3.6: germination behaviour of species growing in a marginal land pasture (Preschedule ML10)

In Chapter 2 we discussed the improvement of marginal land through phosphate application and continuous grazing, where the former is enhancing the legume population of the pasture and the latter easing the grazing pressure during seed set. Most of the plants are annuals and their survival relies on seed production, which is essential for pasture re-establishment and productivity. Studies of changes in seed and plant numbers will help to understand marginal land ecosystems.

Plant density varies between seasons and within each growing season, particularly for legumes (Fig 3.13). If we attribute the drastic reduction between Year 1 (1984/85) and 2 (1985/86) to grazing we simply cannot explain the better density in Year 3 (1986/87) because Year 2 seed yield was much less than that in Year 1 (1596 vs. 2072 seeds per m^2), at the same stocking rate. Clearly total rainfall is playing a part in this variation, and its role also needs to be determined.

Legumes are well known for their hard seed coat (hardseededness) that prevents germination by preventing water uptake. The waxy cuticle, suberin, macrosclereid, and osteosclereid layers, prevent water from entering and can delay germination for many years. Hyde (1954) showed that the hilum acts as a one-way hygroscopic valve permitting water vapour to pass out when the relative humidity in the air is very low but preventing its re-entering. Daily fluctuating temperature can overcome hardseededness producing some cracks, especially in the region of the micropyle, and permitting the seed to imbibe and germinate.

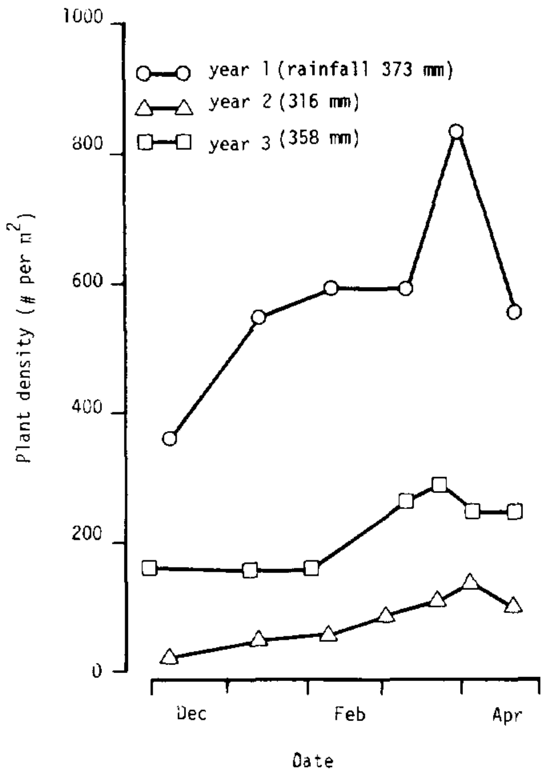


Fig. 3.13: The density of legumes (per m^2) over three years in un-fertilized native pasture. Although not grazed in year 1 the pasture was grazed in years 2 and 3 (mean of two stocking rates, see experiment 2.1).

Another explanation of the fluctuation of plant density between years concerns the role of grazing animals. Legume seeds are attractive to animals and grazing takes place in summer when legume pods are eaten by sheep. Evidence of this was the presence of clovers seeds in faeces collected during the summer of 1985 (see also experiment 3.5).

The objective of this experiment was to look at seed bank variation, monitor the germination behaviour during the season, and observe the fate of seedlings when, as occurred in 1986/87, a long period of drought follows the onset of germination. It has been carried out on two plots of experiment 2.1 described in Chapter 2.

Materials and Methods

The seed bank of the most important species in experiment 2.1 is being assessed by sampling the low and high stocking rates receiving 25 kg per ha of P_2O_5. In each plot, ten sites were selected at random along a transect and ten soil cores (7 cm diameter) were collected as subsamples from each of the ten sites. The first sampling, done before the first autumn rains, was at three depths (0-3, 3-6 and 6-9 cm), to assess the distribution of seeds down the profile (Table 3.13). At approximately monthly intervals after 11 December (Table 3.13) samples were again collected from the field, removing soil and plants with their roots. The plants were separated from soil, classified, counted and recorded. The seeds of the most common grasses and legumes (Table 3.14) were hand-sorted from the soil, divided into species, counted and recorded.

Table 3.13. Calendar of observations in Experiment 3.6.

Month	Date of seed bank sampling	Date of seedling count
October	12	7, 14, 21, 28
November	-	19
December	11	16
February	08	16
March	29	27
May	21	-
July	21	-
September	30	-

Quadrats of 50 x 50 cm spread over the same sites were fixed before the first rains, each quadrat being divided into two halves:

Table 3.14. The species under observation in experiment 3.6.

GRASSES	LEGUMES
Avena spp.	Trifolium stellatum, L.
Bromus spp.	Trifolium campestre, Schreb.
Hetherantelium spp.	Trifolium tomentosum, L.
	Trifolium angustifolium, L.
	Trifolium scabrum, L.
	Medicago coronata, (L.) Bart.
	Trigonella spp.
	Onobrychis spp.
	Ononis spp.
	Astragalus spp.
	Vicia spp.

in the first half seedlings of the most common species were recorded and removed by forceps to avoid any soil disturbance, while other seedlings and plants were left so that the soil was always covered by some plants. In the second half seedlings were counted but not removed. Dates of seedlings counts are shown in Table 3.13.

Results and Discussion

In October, just before germination, there were more than 6000 seeds per m^2 and this number decreased during the growing season reaching a minimum at the end of March when there were 1000 seeds (Fig. 3.14). From April to early May the plants set nearly 20000 seeds, most of which were still held on the mother plant. There were no significant differences between stocking rates (Table 3.15).

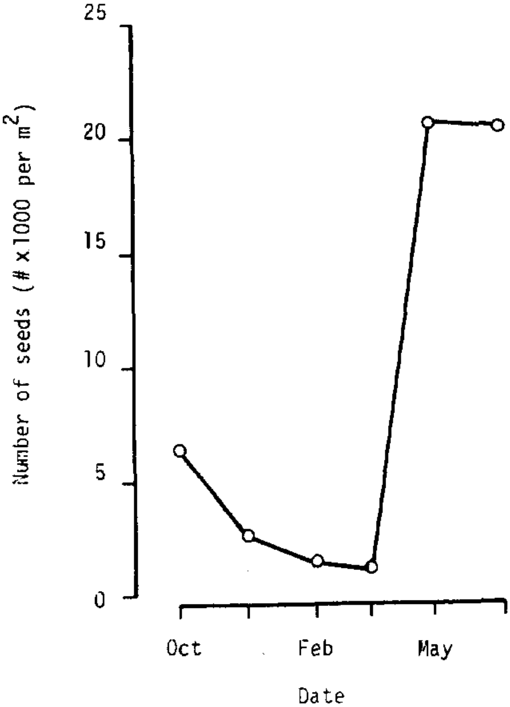


Fig. 3.14: Change in seed numbers (mean of all species) between October 1986 (before the onset of autumn rains) and July 1987 (after the last spring rains).

Table 3.15. Amount of seeds in the seed bank (number per m^2) under low (0.8 sheep per ha) and high (1.7 sheep per ha) stocking rate.

Month	Low SR	High SR	t- value
Oct 12	6,555	6,251	0.21
Dec 11	3,114	1,892	1.96
Feb 08	1,359	1,996	0.09
Mar 29	1,037	1,128	0.21
May 21	19,188	21,548	0.60
Jul 21	17,777	22,577	1.19

The nature of the experiment makes it difficult to draw conclusions on the effect of grazing, especially since the plots under study were known to be variable before the experiment began. With the collection of more data, time trends will aid interpretation. However the study strongly suggests that different species do react differently to grazing, grasses being more common at low stocking rate (Fig. 3.15), and legumes, especially T. tomentosum at high stocking rates (Fig. 3.16).

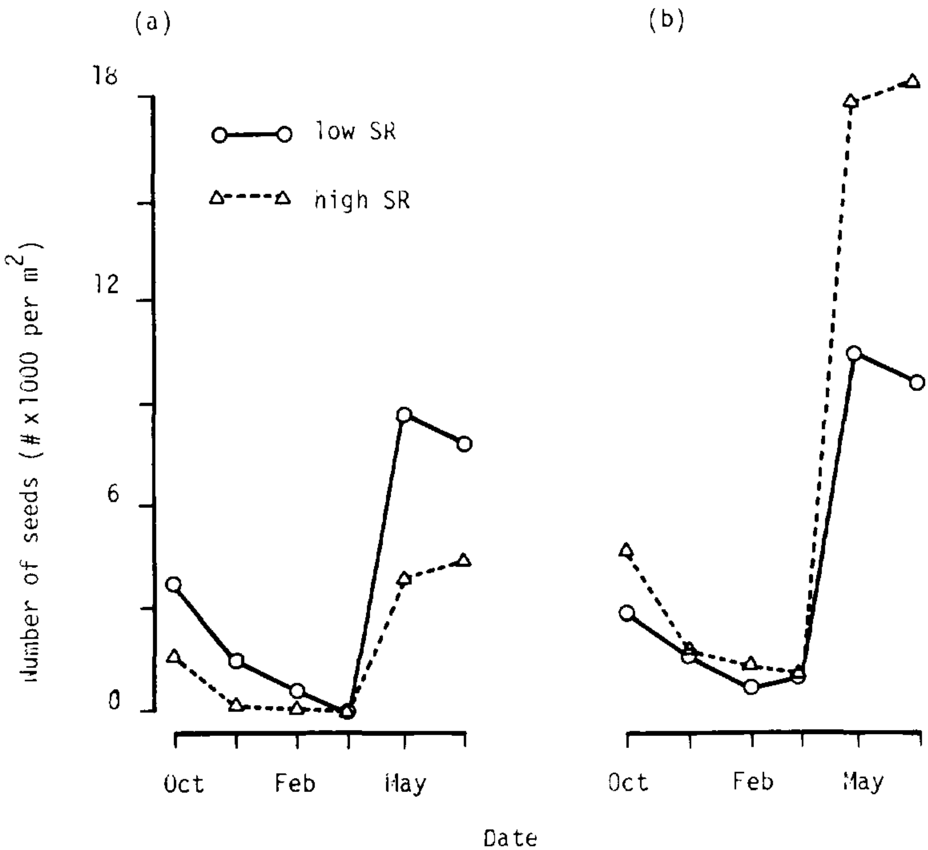


Fig. 3.15: Change in seed numbers in native pasture of (a) grass and (b) legumes at low (solid line) and high (broken line) stocking rates during the growing season of 1986/87.

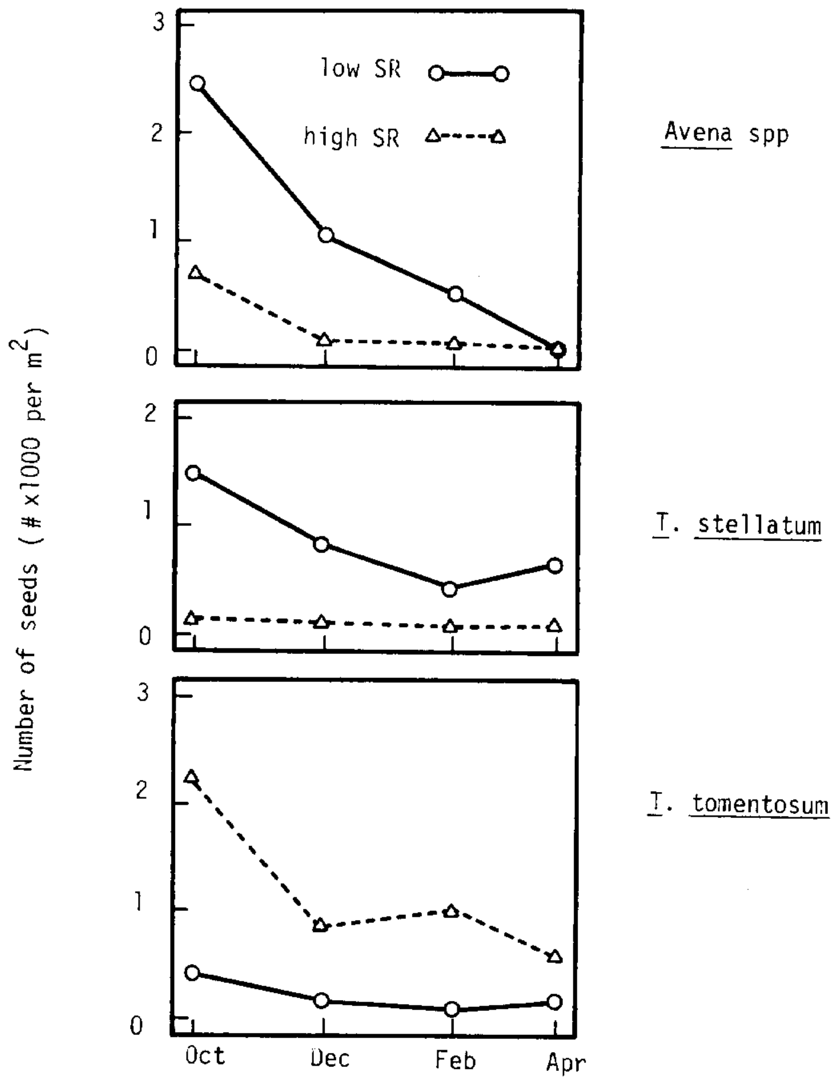


Fig. 3.16: Change in seed numbers of Avena spp (top), T. stellatum (centre), and T. tomentosum (bottom) at low (solid line) and high (broken line) stocking rates during the growing season of 1986/87.

Table 3.16 shows the observed and expected number of grass and legume seeds and the computed chi-square values assuming as a null hypothesis that grasses and legumes would decrease at the same rate.

All the chi-squared values are highly significant and the deviations of the observed from the expected number of seeds became larger and larger; these deviations are positive in grasses (their decrease was faster) and negative in legumes (their decrease was slower). In March 98.8% of seeds remaining in the soil were legumes.

At each sampling the cylindrical unit was subdivided into three depths and seeds recorded separately. Chi-square values for each depth were computed assuming as a null hypothesis that seeds would decrease equally with time at each depth (Table 3.17). However legume seeds present in the first layer (I) decreased faster then those in deeper layers (II and III) (P<0.001). In contrast, grass seeds present in layer I decreased more slowly than those in the lower layers (P<0.001) (Fig. 3.17).

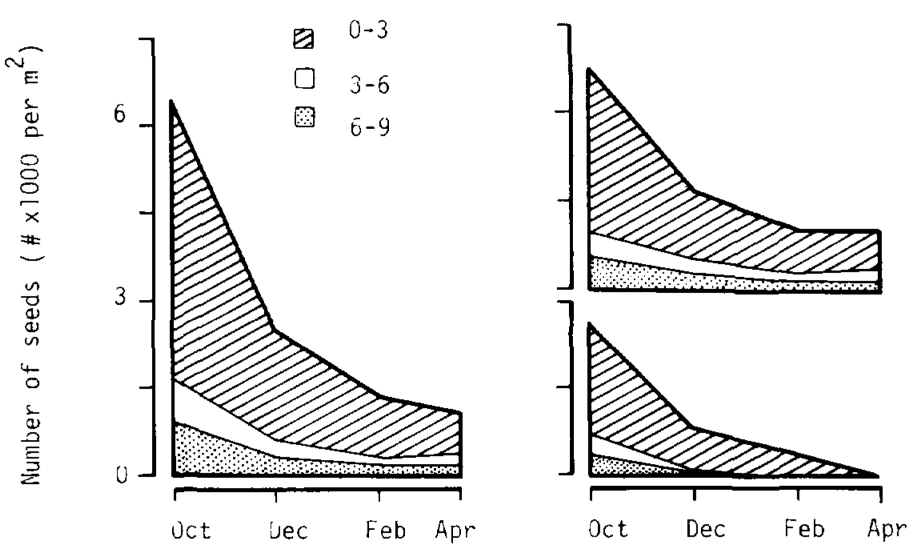


Fig. 3.17: Change in population at three depths (0-3 cm, 3-6 cm, and 6-9 cm) of the total seed bank (left), of legumes (upper right), and grasses (lower right) during the growing season of 1986/87. Data is the mean of all treatments.

Table 3.16. Chi-square test on grass and legume seeds (number per m^2) and changes in the seed bank bank from October 1986 to March 1987.

GROUP	OCTOBER		DECEMBER			FEBRUARY			MARCH		
	O[1]	%	O	E[1]	X^2	O	E	X^2	O	E	X^2
GRASSES	2637	41.18	809	1031.2	81.4***	346	567.5	147.0***	13	446.0	714.7***
LEGUMES	3766	58.82	1695	1472.8		1032	810.5		1070	637.0	
Total	6403	100.00	2504	2504.0		1378	1378.0		1083	1083.0	

*** Significant at P<0.001.

1 O : observed, E : expected.

Table 3.17. Chi-square test on grass and legume seeds (number per m^2) from three depths and their changes from October 1986 to March 1987.

GROUP	DEPTH (cm)	OCTOBER		DECEMBER			FEBRUARY			MARCH		
		O[1]	%	O	E[1]	X^2	O	E	X^2	O	E	X^2
	0 - 3	1934	73.74	722	592.6		344	253.8		13	9.5	
GRASSES	3 - 6	351	13.31	57	107.5	109.07***	2	46.0	120.34***	0	1.7	4.67n.s.
	6 - 9	352	13.35	29	107.9		0	46.2		0	1.7	
	Total	2637	100.00	808	808.0		346	346.0		13	12.9	
	0 - 3	2802	74.40	1160	1262		707	768		652	796	
LEGUMES	3 - 6	394	10.46	247	177	39.91***	163	108	33.09***	230	112	154.54***
	6 - 9	570	15.14	289	257		162	156		180	162	
	Total	3766	100.00	1696	1696		1032	1032		1070	1070	

*** Significant at $P<0.001$

n.s.: not significant

[1] O : observed, E : expected.

Some seeds germinated on 1 October after the early rain. Germination in grasses was much higher, resulting in 477 grasses seedlings per m^2 compared with only eight legume seedlings (Table 3.18). On the 28 October the surviving seedling number was compared with the total number of seedlings which had previously emerged. There was a large reduction: only 53% of the emerging seedlings had survived until 28 October. This percentage reduction was similar in grasses and legumes (53% and 43% respectively) but, since very few of the legume seeds had germinated, the absolute number that died was very low. On the other hand approximately 225 seeds per m^2 of grasses had germinated, emerged and died.

Table 3.18. Cumulative seedlings emerged and total seedlings present.

	Seedlings per m^2 emerged				Seedlings per m^2 found	
Date	07.10	14.10	21.10	28.10	28.10	Percent of reduction
Grasses	300.0	446.8	468.0	477.2	252.4	52.9
Legumes	6.4	8.4	8.4	8.4	3.6	42.9
Total	306.4	455.2	476.4	485.6	256.0	52.7

The germination of both legumes and grasses was high in November and continued throughout the season (Fig. 3.18), confirming our observations on density from the previous three seasons (Fig. 3.13). The germination pattern of the two groups was similar although there were more grass seedlings than legumes.

Fig. 3.19a combines the decrease of grass seeds with the increase of grass seedlings. It seems that the two curves

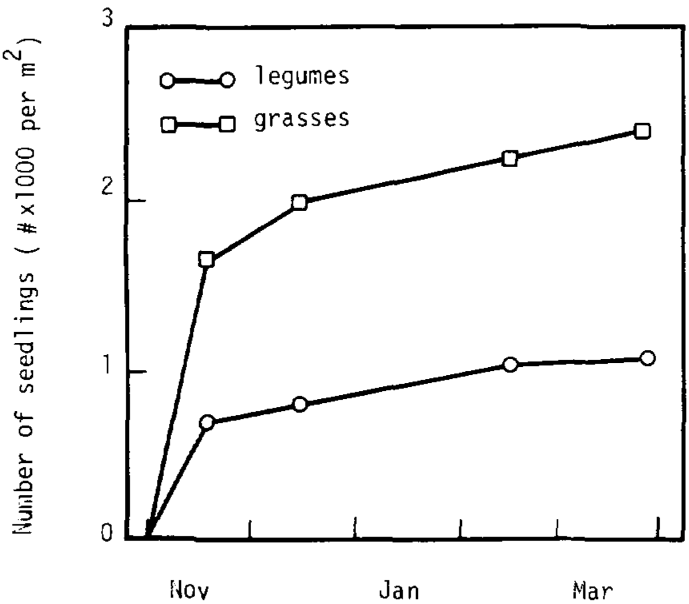


Fig. 3.18: The cumulative number of legume (circles) and grass (squares) seedlings emerging during the 1986/87 growing season.

complement each other suggesting that almost all of the grass seeds germinated and survived. In legumes (Fig. 3.19b), while seed numbers showed a decrease from 3766 (October) to 1695 (December) seeds per m^2 only 806 seedlings were counted: for legumes it is possible that seeds germinated and failed to emerge during the five weeks of drought in November/December. Nevertheless, in contrast to grasses, more than 1000 seeds per m^2 remained in the seed bank.

Our conclusions at this stage are:

- there was a reduction in the number of seeds in the soil with time and this was continuous and gradual. Grass seeds decreased quicker than the seeds of other species and only 0.5% of the original population remained in March. Legume seeds also decreased but 1000 per m^2 remained until new seeds were formed in spring. It seems that grass seeds probably germinate more from lower depths while legume seeds germinate more from the surface;

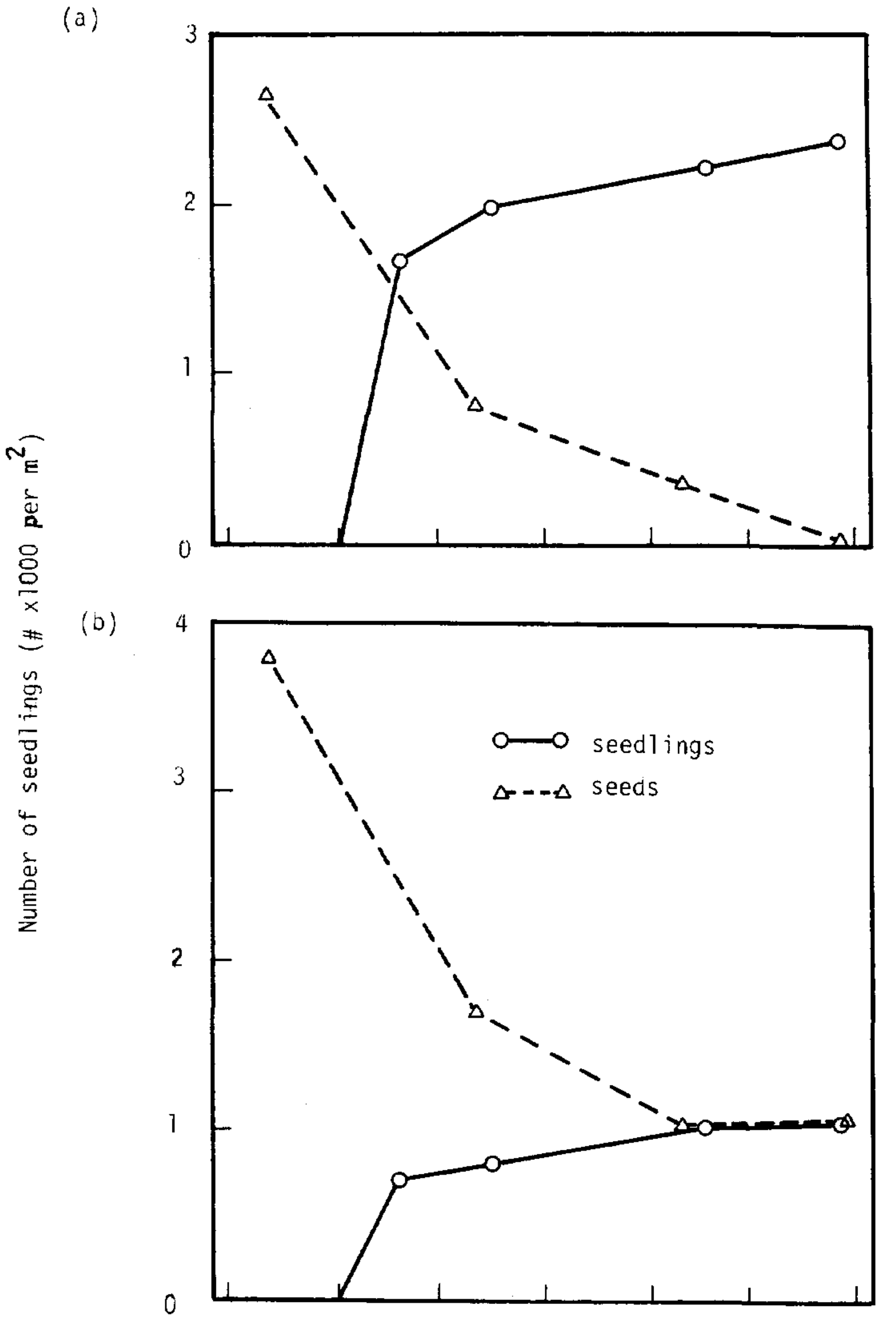


Fig. 3.19: Cumulative emergence of seedlings (solid line) and number of residual seeds (broken line) in (a) the grass and (b) the legume seedling and seed populations during the 1986/87 growing season.

- an early rain (1 October) initiated germination of grasses. The risk of a dry spell and consequent loss of seedlings is considerable, seedling mortality probably being dependent on length of the dry spell and rate of evaporation;

- it was confirmed that continuous germination occurs from the first rains until March, the rate becoming lower with time; and

- because of high variability it will be necessary to extend the study on seed banks to one, or probably two more seasons, especially to observe effects due to grazing pressures. - **L. Russi, Prof. E.H. Roberts (University of Reading)**, and P.S. Cocks

Experiment 3.7: hardseed breakdown and longevity of medic seeds (Preschedule M35)

The objectives of experiment 3.7 are firstly to determine the life-span of medic seed, and secondly to monitor the breakdown of hardseeds over several years. Results from the first year are included here.

In view of its importance to the ley farming system there is surprisingly little information about the rate of hardseed breakdown and the long term viability of hardseeds. For subterranean clover (which often replaces medics in acid soils), most of the seed becomes permeable in the first summer, and little remains after three years (Taylor et al 1984, Bolland and Collins 1987), although in mild climates the seeds may live a little longer (eg Donald

1959). The Australian medics are known to be harder-seeded than *subterranean clover (Quinlivan 1968), and the ICARDA medics even* harder-seeded than the Australian medics (Cocks 1987). However, in the case of medics, there is little published data from Australia or elsewhere on hardseededness or seed viability beyond the first summer.

In this experiment use is made of plots established in experiment 3.4 where seven medic species were sown at two seeding rates. Less than half the plot area was used in the earlier study, the remainder being available to measure rate of hardseed breakdown in the first summer after seed set, 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) seeding rates (see experiment 3.4):

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

There were four replicates in a randomized complete block. After completion of experiment 3.4 the remaining plot size is 2 X 6 m. After seed set in the first year, further seed set will be prevented by spraying seedlings with herbicide.

The following measurements are being taken:

- seed yields of each accession (as part of experiment 3.4);

- at 2-week intervals in each summer, beginning in August 1987, random samples of 30 pods are being collected from each plot. In the first summer these samples were obtained from the surface, but thereafter the plots will be sampled with soil cores 15cm deep. The site of each core will be marked to prevent re-sampling;

- hardseededness by soaking the 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

- remaining seeds in March each year except in the first year, when remaining seeds will also be measured immediately after the first autumn rain of 10mm or more. Mass of seeds in a core 15cm deep will be measured in 5 strata each 3cm deep. The sites of sampling will be marked to prevent re-sampling on the same site. Four cores will be extracted from each plot.

Germination after the summer of 1987 is shown in Table 3.19. There are strong differences due to both species and density and a strong interaction between the two factors. At low density there was 7% more germination of M. polymorpha variety Tah than the next ecotype, M. rigidula 1900, and least germination was of M. noeana and M. rotata. At high density cv. Jemalong germinated best, though not significantly better than M. polymorpha variety Tah, while germination of M. noeana and M. rotata was again very slight. The effect of density was strong indeed, 5.7% seeds produced at high density germinating compared with 20.1% at low density.

Table 3.19. Germination (percentage of total seed) of six medic species from seed set in spring 1987 after autumn rains (October 1987).

	Low density	High density
M. noeana SA 15845	10.3	0.9
M. polymorpha variety Tah	31.1	10.0
M. rigidula selection 1900	24.1	4.0
M. rigidula selection 716	20.9	4.1
M. rotata selection 2123	13.2	1.6
M. truncatula cv. Jemalong	20.9	13.3
	20.1	5.7
LSD (P<0.05)	3.9	

	Analysis of variance			
	DF	SS	MS	F
Species	5	1293.49	258.698	35.8***
Densities	1	2508.52	2508.52	347.5***
Species X Density	11	321.08	29.1891	4.04**
Replicates	3	40.33	13.443	1.86 NS
Residual	27	194.90	7.2185	
Total	47	4358.32		

Were the swards to be used as second year pastures in 1987/88 (instead of as cereal, as is normal in the ley farming system), the low density plots would be superior to the high density plots in all but cv. Jemalong (where there were markedly more seedlings at high density) and *M. polymorpha* variety Tah (where there was no difference) (Table 3.20). The situation in 1988/89 will depend on the breakdown of hard seeds in the summer of 1988, but seed reserves (and hence stability of the system), in terms of numbers, tend to be higher at high density.

Table 3.20. Number of seedlings (per m^2) and number of dormant seeds (per m^2) of six medics after autumn rains in 1987.

	Seedlings		Dormant seeds	
	Low	High	Low	High
M. noeana SA 15845	2100	130	12900	13800
M. polymorpha variety Tah	3500	3500	7800	31300
M. rigidula selection 1900	3300	350	10200	8400
M. rigidula selection 716	2400	440	9300	10300
M. rotata selection 2123	1150	140	7600	8600
M. truncatula cv.Jemalong	570	2300	2100	15200

The seeds remained completely hard (dormant) until September (Fig. 3.20): breakdown of hardseeds was most rapid between 16 September and 1 November, at which time germination took place. This pattern is considered ideal in Australia, where summer rains can cause out of season germination (Crawford 1983), but is perhaps less important in west Asia where summer rains are rare. Ironically patterns such as that in Fig. 3.20 are only rarely observed in Australia (eg Taylor *et al* 1984).

According to the literature the relatively low hardseededness of the low-density treatments compared with high density is surprising.

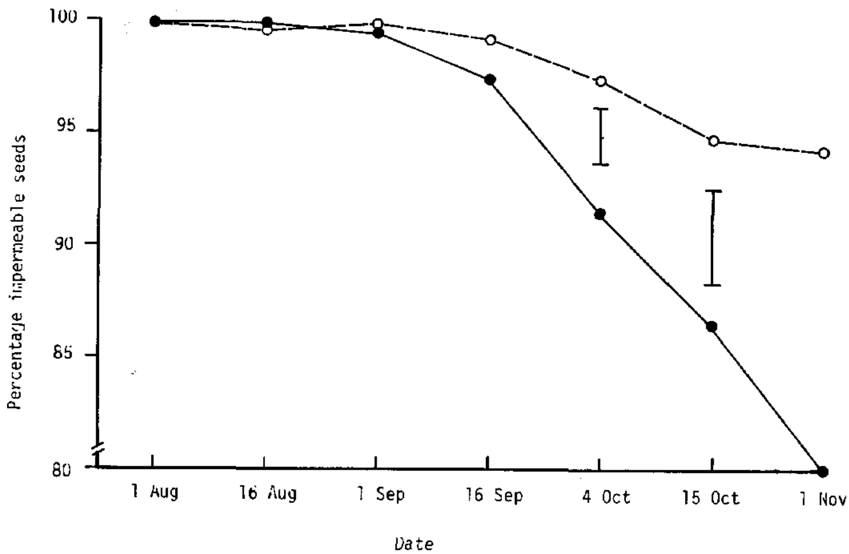


Fig. 3.20: Change in the mean percentage of impermeable seeds during the summer of 1987 of seven medics at high (broken line) and low (solid line) densities. Bars represent L.S.D. values ($P<0.05$).

It is generally considered that seeds are hardest (least permeable) when they are produced in conditions of low environmental stress. Quinlivan (1971) quotes as examples that seeds produced from early nodes are harder than those produced later (eg Yasue and Ota 1958) and that seeds produced in wet areas are harder than those from dry areas (Quinlivan 1965). At Tel Hadya the seeds produced at high density are significantly smaller than at low density, (see Table 3.8) a strong indicator that they were produced in a more stressful environment - yet they are markedly harder than the larger seeds produced at low density. Of course, this interaction will be of profound ecological value, since it is precisely in stressful environments that hardseededness is most needed.

In another experiment, other aspects of which are not reported here, 15 ecotypes of 6 medic species were sown at three locations, Tel Hadya (rainfall 340mm in 1986/87), Breda (245mm) and Salamieh (approximately 220mm). Mean seed yield was approximately proportional to rainfall: 542 kg per ha, 359 kg per ha and 280 kg per ha respectively. Seed size was similar at Breda (4.79 mg) and Tel Hadya (4.71 mg) and lower at Salamieh (4.51 mg). Taken together seed yields and seed sizes indicate that the seeds from Tel Hadya were formed under least stress, those at Breda at intermediate stress, and at Salamieh at greatest stress.

In agreement with experiment 3.7 hardseededness was proportional to that measure of stress, the average of all species at Tel Hadya being 7.4% soft seeds on 20 October, 5.0% soft seeds at Breda, and 0.22% soft seeds at Salamieh. There was wide variation between species, M. scutellata and M. polymorpha 'Tah' having by far the greatest number of soft seeds (about 30% at Tel Hadya). However, at Salamieh, even M. scutellata was only 2.8% soft.

The results of this experiment indicate that there is a clear need to improve our understanding of the environmental factors leading to hardseededness and their interaction with genotype.

Experiment 3.8: commercial production of medic seed

Lack of facilities to produce medic seed remains one of the major constraints to adoption of the ley farming system, commercial quantities of seed being available only from Australia. Since the Australian cultivars are susceptible to frost (Cocks and Ehrman 1987), and have, in general, performed poorly in west Asia and the highland areas of north Africa, there is a need to develop sources of medics selected within the region. It is therefore necessary that ICARDA do all it can to promote seed production.

In 1986/87 this promotion took two courses: a training program was conducted in which weed control in medic seed crops was investigated, and ICARDA's own seed production was subjected to economic analysis.

For weed control a total of nine herbicides were tested. Five (Fluoredefen, Pronamid, Cyanazin, Codal and Trifluralin) were pre-emergent, and four (Fluazefolbutyl, Dinoseb-acetite, Bentazon, and 2,4 D-B) were post-emergent. Both broad-leafed and grassy weeds could be controlled by individual herbicides or mixtures as shown in Table 3.21. The pre-emergent herbicides were applied on 18 December and the post-emergent herbicides on 2 March, when medics were at the 3-4 leafed stage. The experiment was sown immediately after application of the pre-emergent herbicides.

The plots were sampled on 26 April to determine dry matter production of medics and weeds, and on 6 June to measure seed production. In Table 3.21 medic and weed yields are expressed relative to the un-weeded control: herbage yield of the medic control on 26 April was 2.1 t per ha and weed yield was 2.2 t per ha. The best results were obtained using Pronamid or a combination of Fluazefolbutyl and Dinoseb-acetite (treatment 13), neither of which yielded significantly less than the hand-weeded controls.

ICARDA produced about 3 t of medic seed in 1986/87. The various operations were carefully monitored, and the return from medic straw (assuming it had equal value to lentil straw) was calculated. The following operations were included in the economic analysis: initial cultivation, harrowing (twice), drilling seed, rolling after sowing, spraying to control weeds (twice), application of fertilizer, mowing and rolling the mature crop, baling straw, harrowing residues, and harvesting seed with a suction harvester. Depreciation, interest, fuel, lubrication and repair costs, calculated on the basis of the number of hours of each operation, were included. Total costs are shown in Table 3.22.

The average yield of seed was 200 kg per ha which means the cost of producing the seed was 30 SL per ha. This compares with the cost of imported seed of 16 SL per ha.

Table 3.21. The effect of various herbicides on the relative herbage yields of medic and weeds (control equals 100) and medic seed yield (kg per ha).

Herbicide	Rate (kg of active ingredient per ha)	Relative medic growth	Relative weed growth	Medic seed yield
1. Control (no weed control)	-	100	100	325
2. Control (hand-weeded)	-	222	0	750
3. Fluorodefen	1.0	94	38	443
4. Pronamid	0.5	182	27	605
5. Trifluralin	0.5	90	133	380
6. Cyanazine	0.5	78	64	261
7. Codal	1.5	53	104	208
8. Fluazefob-Butyl	0.5	117	105	408
9. Dinaseb-acetite	1.0	15	9	426
10. Bentazon	1.0	118	8	311
11. 2-4 DB	1.0	113	32	309
12. Mixture of 4,6	0.5, 0.5	112	37	470
13. Mixture 8,9	1.0, 0.5	153	21	640
14. Mixture 3,9	1.0, 1.0	91	14	504
15. Mixture 6,8	0.5, 0.5	117	107	475
16. Mixture 8,11	1.0, 0.5	103	34	236
LSD ($P < 0.05$)				183

Table 3.22. Summary of costs associated with producing medic seed at Tel Hadya.

	SL per ha
Total costs associated with machinery (including operating)	5711
Seed	310
Fertilizer	90
Herbicides	70
Other labour	730
	6911
Value of straw	984
Net cost	5927

The relatively high cost of ICARDA seed is brought about by the following factors:

- expensive machinery was used;
- the cost of cleaning the seed by hand was excessive because appropriate machinery was not available;
- the suction harvester was inefficient, harvesting only 50% of the seed;
- yields in some fields were low because of inadequate weed control; and
- only first year stands were harvested.

Future operations will be more efficient as operators get used to the suction harvester, land preparation improves, and seed is harvested from re-generating crops. Indeed the latter factor alone will reduce costs by almost 50% which, coupled with better use of the harvester, is expected to reduce costs to much less than that of imported seed. - **Ali Abd El Moneim and P.S. Cocks**

CHAPTER 4: IMPROVING THE GENETIC POTENTIAL OF PASTURE AND FORAGE LEGUMES

Producing improved cultivars of different pasture and forage species is the main goal of our breeding program. We deal with several species in order to develop a range of cultivars for different uses and environments. It is desirable to have widely adapted cultivars, at least to the extent that they can be recommended for particular ecological zones. Most of the selection is from ecotypes and landraces, about 15% of resources for plant breeding being allocated to hybridization.

The process of developing forage cultivars from wild species involves firstly germplasm evaluation, screening, and seed multiplication in nursery observation rows; secondly evaluation of selected genotypes in microplot field trials; thirdly, evaluation of promising genotypes in advanced yield trials; and finally multilocation (regional) testing of selected genotypes in different ecological zones. The reaction of selected genotypes to the major foliar diseases and nematodes under natural and artificial conditions takes place at all stages. Palatability and nutritive value of the herbage are also monitored.

A different approach is used for pasture legumes. As we discussed in Chapter 3 there are few selection criteria which reliably predict success in a cereal/pasture rotation. Therefore PFLP uses a process of natural selection, where large numbers of ecotypes are sown in mixtures to form the pasture year in a rotation. However, where selection criteria can more easily be set, as is the case with disease resistance, more conventional selection methods are used (experiment 4.8). The work on natural selection is not reported this year, although the data in Fig. 3.1. is taken from one of the sites at which we are working.

In 1986/87 germplasm of hairy and woolly-pod vetch (Vicia villosa ssp. villosa and ssp. dasycarpa respectively), Narbon vetch (V. narbonensis), and chicklings (Lathyrus sativus, L. ochrus and L. cicera) were evaluated in nursery observation rows. Promising genotypes of Narbon vetch and woolly-pod vetch were tested in microplots at two contrasting sites, Tel Hadya and Breda. One set of promising genotypes of chickling were tested in advanced yield trials at Tel Hadya, and a second set at Tel Hadya and Breda for the second cropping season, using sites and seasons as environmental factors. After crossing adapted common vetches with ecotypes whose pods do not shatter selection of adapted non-shattering lines continued into the F3 generation, and selection for resistance to root (especially nematodes) and leaf diseases among landraces and ecotypes of forage and pasture legumes was maintained. A study to investigate the potential of subterranean vetch (V. sativa ssp amphicarpa) was initiated. To develop more reliable selection criteria the growth and development of several forage legumes were studied.

Experiment 4.1: nursery row evaluation of annual forage legumes

During the last three seasons at Tel Hadya, attention has been paid to the collection and evaluation of native genotypes of forage legumes. Some showed good cold and drought tolerance as well as early spring growth, early flowering, and early maturity. Such genotypes could be of value for developing new cultivars to replace fallows with a productive forage legume.

During 1986/87, four experiments were conducted to assess 225 genotypes of Vicia villosa, 100 genotypes of V. narbonensis, 225 genotypes of Lathyrus sativus, 57 genotypes of L. cicera and 43 genotypes of L. ochrus. All genotypes were assessed in nursery rows in a simple lattice design with two replicates, plots having 3 rows per plot, 3 m long and 45 cm between rows.

The genotypes were scored on a 1-5 scale (1=good, 5=poor) for establishment, seedling vigour, winter and spring growth, cold effect, drought tolerance, growth habit, leafiness, pod shattering and leaf retention. The number of days to start of flowering, 50% flowering, 100% flowering and full maturity were recorded. The reactions against major diseases including broomrape (Orobanche crenata) were also monitored.

Hairy and woolly-pod vetch (V. villosa)

There was a wide range of variability in mean scores for all characters (Fig. 4.1 and Table 4.1). The most important finding was the identification of genotypes with a high proportion of leaf retention in late spring, an important attribute in forage legumes.

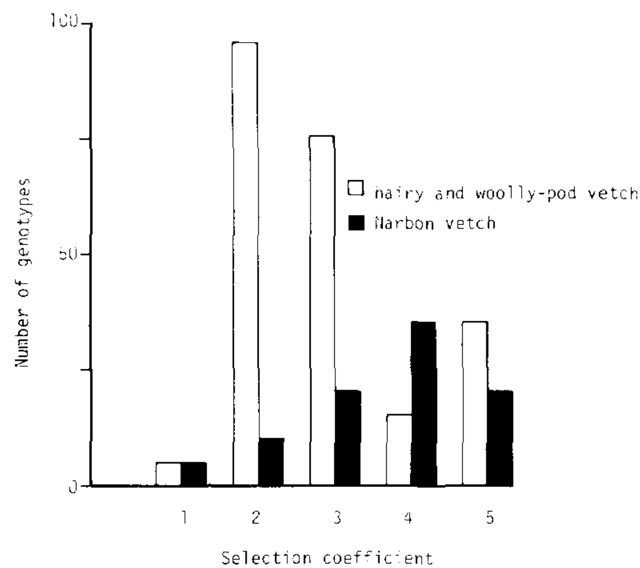


Fig. 4.1: Variability in the selection coefficient (1 = good, 5 = poor) of 225 accessions of hairy and woollypod vetches and 100 accessions of Narbon vetch in nursery rows at Tel Hadya.

Table 4.1. Range of variability of nine characters in collections of Narbon vetch and V. villosa in 1986/87.

Characters	Vicia villosa				Narbon vetch			
	Min.	Max.	Mean	S.E	Min.	Max.	Mean	S.E
Winter growth	0.90	4.00	1.577	0.0518	1.00	5.00	3.055	0.1113
Cold effect	0.89	4.00	1.451	0.0365	1.00	3.50	1.580	0.0685
Spring growth	0.62	5.00	3.425	0.0667	1.00	5.00	3.545	0.1358
Leafiness	1.00	5.00	3.138	0.0718	2.50	4.50	3.475	0.1148
Days to first flowering	114.00	156.00	134.859	0.6898	100.50	134.50	111.725	0.6445
Days to 50% flowering	120.50	162.00	142.938	0.6929	108.50	139.50	116.870	0.6429
Days to 100% flowering	128.00	168.60	150.520	0.6918	112.50	153.50	122.790	0.8390
Days to first podding	129.00	169.50	151.440	0.6935	113.50	154.50	123.790	0.8390
Days to maturity	162.00	196.00	180.718	0.5592	156.00	179.50	161.065	0.4886

The 36 genotypes with scores of 1 and 2 were selected for further evaluation in microplot trials.

Narbon vetch (V. narbonensis)

Narbon vetch shows good potential for dry areas (<300 mm rainfall). One of its most important attributes is resistance to bird damage in which it appears to be the most resistant of the vetches. Our observations also indicate that some genotypes flower before the attack of Orobanche, which will restrict its effect on seed yield. The 25 genotypes with scores of 1, 2 and 3 (Fig. 4.1), were selected for further evaluation under dry conditions at Breda.

Common chickling (Lathyrus sativus)

Great variability was found within the 225 genotypes of common chickling (Fig. 4.2 and Table 4.2). This variability enabled us to select the best 36 for further evaluation of dry matter and seed yield in microplot trials.

Table 4.2. Range of variability of seven characters in collections of L. ochrus, L. cicera and L. sativus in 1986/87.

Characters	L. sativus				L. ochrus and L. cicera			
	Min.	Max.	Mean	S.E.	Min.	Max.	Mean	S.E.
Cold effect	1.00	3.00	2.431	0.1024	1.00	3.00	1.820	0.0744
Winter growth	1.00	4.00	4.373	0.0990	1.00	4.00	3.670	0.1334
Spring growth	1.00	3.50	3.444	0.1113	1.00	3.50	3.200	0.1119
Vigor	1.00	3.50	3.644	0.1083	1.00	3.50	3.380	0.1108
Days to flowering	108.00	137.00	119.013	0.2310	108.50	126.00	112.535	0.3410
Days to podding	125.50	156.00	140.547	0.4319	114.50	133.50	119.485	0.3535
Days to maturity	153.00	181.00	168.200	0.3641	156.00	168.50	160.650	0.2366

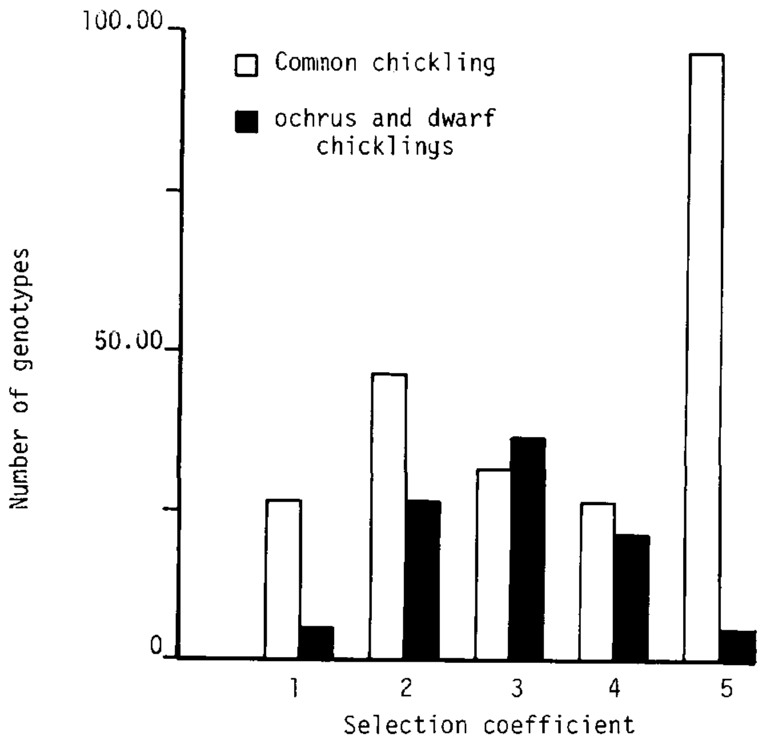


Fig. 4.2: Variability in the selection coefficient (1 = good, 5 = poor) of 225 accessions of common chickling and 100 accessions of ochrus chickling and dwarf chickling in nursery rows at Tel Hadya.

Ochrus chickling (*L. ochrus*)

Although the number of genotypes assessed was relatively low, a wide range of variability was found. One of the most important characteristics was the resistance of certain genotypes to *Orobanche*. Sixteen genotypes with selection scores of 1 and 2, were selected as basic material for a breeding program.

Dwarf chickling (*L. cicera*)

Genotypes of dwarf chickling were assessed along with other chicklings in a single experiment. This was due to the limited number available.

Sixteen genotypes showing desirable characters were selected for further evaluation in microplot field trials.

The finding of desirable attributes among forage legumes encourages us to assess a wide range of different species. Among them is subterranean vetch (*V. sativa* ssp. *amphicarpa*), which appears to merit special attention since it produces two kinds of seeds: the first above the ground while the second it buries below the ground. This attribute may offer considerable scope for developing a self re-seeding type of vetch. - **Ali Abd El Moneim Yawooz Adham (GRP)**

Experiment 4.2: evaluation in microplots, (Preschedule F20, F21)

A total of 25 genotypes of Narbon vetch and 25 of woolly-pod vetch were tested in microplot trials at two sites, Tel Hadya and Breda, where rainfall in 1986/87 was 358 mm and 245 mm, respectively.

Microplots of both Narbon and woolly-pod vetch were planted at Tel Hadya and Breda in 3.5 m^2 plots arranged in a triple lattice design with three replicates. For both crops the seeding rate was 80 kg per ha and P_2O_5 was applied at 40 kg per ha. The replicated microplots were duplicated: one was harvested at 100% flowering to measure herbage yield and the other at maturity for seed yield and other agronomic traits.

Results for Narbon vetch

Herbage and seed yields and flowering time were measured at both sites. There were significant differences between genotypes in total herbage and seed yields, as well as days to 100% flowering. A combined analysis of variance for the two sites revealed highly significant interactions between genotypes and sites. The genotypes which will advance to more advanced testing are therefore those which were highly productive at both sites in agreement with earlier results (Abd El Moneim and Cocks 1988). The results showed that herbage yield at 100% flowering varied from 2150 kg per ha for selection 2398 to 3760 kg per ha for accession 67 at Tel Hadya, whereas at Breda it varied from 950 kg per ha for selection 2392 to 1520 kg per ha for accession 67 (Table 4.3). Accession 67 produced the highest herbage and lowest seed yield at Tel Hadya while it produced the highest seed yield at Breda. Mean seed yields were 4100 and 940 kg per ha at Tel Hadya and Breda respectively, while herbage yields were 2910 and 1180 kg per ha at the two sites respectively. Regarding days to 100% flowering Narbon vetch reached 100% flowering at least one month earlier at Breda than at Tel Hadya (111 and 146 days respectively). Seed yield was negatively correlated ($r = -0.62$, $P<0.01$) with days to 100% flowering (Fig. 4.3). These results indicate a clear need to continue the search for early maturing genotypes of Narbon vetch, since it could be utilized as a dual purpose crop for grain and straw in dry areas.

Table 4.3. Herbage yield (kg per ha), seed yield (kg per ha) and number of days to 100% flowering for selected genotypes of Narbon vetch grown at Tel Hadya and Breda in 1986/87.

	Tel Hadya			Breda		
Selection	Herbage	Seed	Days to 100% flowering	Herbage	Seed	Days to 100% flowering
Acc. 67[+]	3763	2706	151	1520	1227	111
2391	3265	4942	144	1247	1003	110
2392	3037	4738	144	950	926	110
2387	3198	4676	143	1164	857	108
2388	3297	4629	146	1231	898	110
2380	2859	4609	142	1102	993	110
2390	3054	4273	145	1272	814	111
2393	3118	4202	145	1263	1098	113
2383	3248	4176	146	1367	1011	112
L.S.D.(P<0.05)	672	624	2.33	268	261	1.42

[+] Genotype which is sufficiently uniform to be tested as a complete accession.

Results for woolly-pod vetch

Twenty-five genotypes were tested in microplot trials at both Tel Hadya and Breda. There were large differences in herbage production, seed yield and days to 100% flowering between genotypes and sites. Nine genotypes, which combine high yields of both herbage and seed with early flowering were identified for advanced yield trials (Table 4.4).

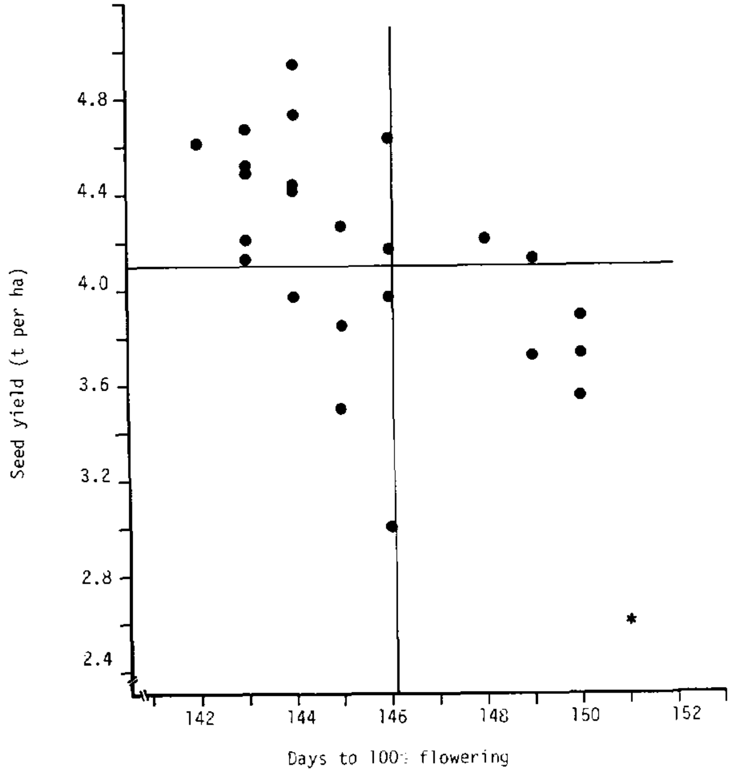


Fig. 4.3: Relationship between seed yield and days to 100% flowering in 25 genotypes of Narbon vetch at Tel Hadya in 1986/87. The asterisk (*) indicates yield and flowering time of accession 67 (control), and the vertical and horizontal lines indicate mean days to 100% flowering and mean seed yield, respectively.

At Tel Hadya, herbage yield varied from 4190 kg per ha for selection 2422 to 7470 kg per ha for selection 2417 and seed yield varied from 460 kg per ha for selection 2415 to 2460 kg per ha for accession 683. The high seed yield of accession 683 was associated with early flowering (Fig. 4.4). At Breda herbage yield varied from 1250 kg per ha for selection 2422 to 2090 kg per ha for selection 2407, and seed yield from 4 kg per ha for selections 2422 and 2423 to 560 kg per ha for selection 2421. Generally, seed production was significantly lower at Breda than Tel Hadya. Low seed production was probably due to the appearance of floral buds when bud development was inhibited by high temperature, with a consequent

Table 4.4. Herbage yield (kg per ha), seed yield (kg per ha) and number of days to 100% flowering for selected genotypes of woollypod vetch grown at Tel Hadya and Breda in 1986/87.

	Tel Hadya			Breda		
Selection	Herbage	Seed	Days to 100% flowering	Herbage	Seed	Days to 100% flowering
Acc. 683+	5791	2459	161	1777	441	119
2406	6373	2214	162	1769	640	118
2410	6364	2158	163	1717	335	119
2409	5932	2151	164	1763	316	120
2411	5939	2102	162	1788	420	121
2407	5229	2082	163	2090	442	121
2412	5852	1861	165	1711	313	120
2421	5658	1728	161	1755	561	118
2408	6525	1663	163	1586	347	122
L.S.D. ($P<0.05$)	1455	550	2.71	410	80	1.98

+ Genotype which is sufficienctly uniform to be tested as a complete accession.

high proportion of young buds dropping after fertilization. Seed yield was negatively correlated ($r= - 0.934$, $P<0.001$) with days to 100% flowering (Fig. 4.4), but there was no association ($r=0.108$) between herbage production and days to flowering (Fig. 4.5). Genotypes which gave high herbage production tended to produce less seed. - **Ali Abd El Moneim**

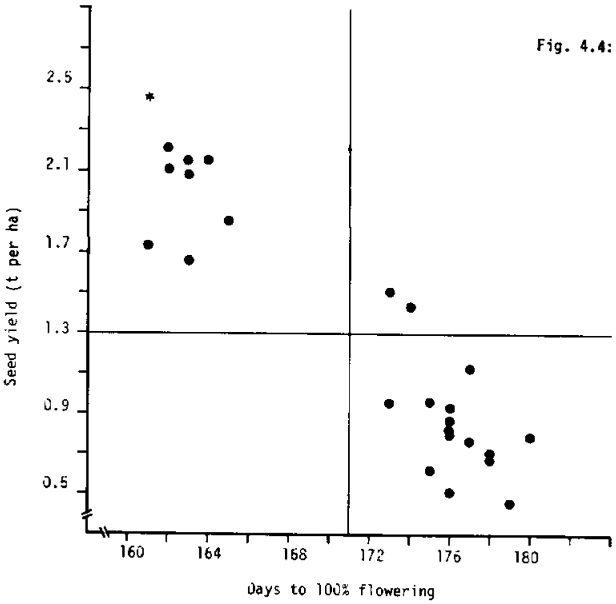


Fig. 4.4: Relationship between seed yield and days to 100% flowering in 25 genotypes of woollypod vetch at Tel Hadya in 1986/87. The asterisk (*) indicates yield and days to 100% flowering of accession 683 (control), and the vertical and horizontal lines indicate mean days to 100% flowering and mean seed yield, respectively.

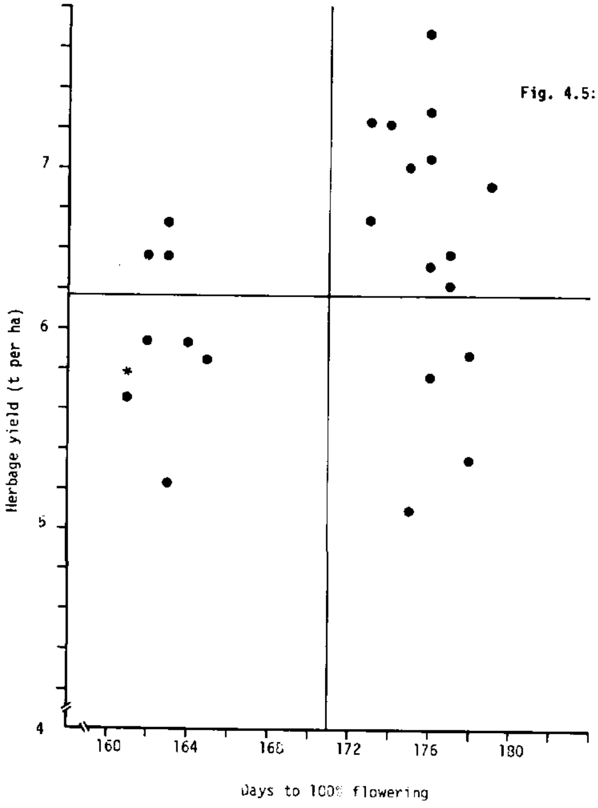


Fig. 4.5: Relationship between herbage yield and days to 100% flowering in 25 genotypes of woollypod vetch at Tel Hadya in 1986/87. The asterisk (*) indicates yield and days to 100% flowering of accession 683 (control), and the vertical and horizontal lines indicate mean days to 100% flowering and mean seed yield, respectively.

Experiment 4.3: chickling advanced yield trials (Preschedule F22)

Two experiments were carried out to evaluate promising genotypes of chicklings. In the first, sixteen genotypes of common chickling, promoted from microplots in 1985/86, were tested in advanced yield trials at Tel Hadya in 1986/87. In the second, sixteen promising genotypes of chickling (eleven *L. sativus*, four *L. ochrus*, and one *L. cicera*) were evaluated at two contrasting sites, Tel Hadya and Breda for the second season, using sites and seasons as separate environments. Both experiments were sown and managed in the same way as microplot field trials except that the plots were larger (28 m^2).

Results from the first experiment (Tel Hadya)

Days to 100% flowering varied from 114 to 124. Mean herbage yield was 2700 kg per ha, varying from 2050 kg per ha (selection 56) to 3250 kg per ha (selection 438), and mean seed yield was 1040 kg per ha, varying from 620 kg per ha (selection 484) to 1260 kg per ha (selection 479) (Table 4.5). The results indicate the clear need to collect and evaluate native genotypes of *L. sativus* which might show desirable attributes of cold and drought tolerance as well as early winter and spring growth.

Results from the second experiment (at Tel Hadya and Breda)

Yields were greater at Tel Hadya than at Breda, the means being 2730 and 1360 kg per ha for herbage and seed at Tel Hadya and 1060 and 390 kg per ha respectively at Breda (Table 4.6). The four genotypes of ochrus chickling produced higher seed yields than the other chicklings at both sites, due to early flowering and maturity which enabled plants to escape from severe attacks of broomrape

Table 4.5. Herbage (kg per ha) and seed (kg per ha) yields and number of days to 100% flowering for 16 promising lines of chickling (Lathyrus sativus) grown at Tel Hadya in 1986/87.

Selection	Herbage	Seed	Days to 100% flowering
461	3122	1000	121
451	3070	1002	124
464	2656	1231	116
54	2295	1150	124
479	3234	1261	124
481	2415	871	124
436	2817	842	123
460	2710	1619	121
438	3254	1003	123
440	2951	970	121
435	3833	949	123
456	2472	1116	121
434	2080	1140	119
56	2045	1238	118
484	2466	621	118
Acc. No.347+	2693	1111	114
Mean	2700	1037	120
L.S.D. (P<0.05)	685	306	3.15

+ Genotype which is sufficiently uniform to be tested as a complete accession.

(Orobanche crenata), and powdery mildew (Erisiphi pisi) both of which had a severe effect on the seed yield of late flowering genotypes.

Table 4.6. Mean herbage (kg per ha) and seed (kg per ha) yields for 16 selections of chickling grown in advanced yield trials at Tel Hadya and Breda 1986/87.

Selection[+]	Tel Hadya		Breda	
	Herbage	Seed	Herbage	Seed
439	3124	1163	1040	172
38	2494	977	942	322
463	2556	1033	1093	216
455	3240	945	1185	104
452	2552	1060	1040	176
471	2516	1122	953	280
459	3119	997	1035	160
29	3343	1163	1110	230
453	2876	919	1028	202
311	2963	1405	1195	544
Acc 347	2850	1550	1213	552
104	2155	1877	990	718
385	2063	2020	1147	756
384	2202	2167	1010	814
185	2710	2387	1100	768
476	2911	948	914	200
Mean	2727	1358	1062	388
L.S.D. (P<0.05)	587	385	265	62

[+] The first eleven selections are Lathyrus sativus, Four *L. ochrus*, and the last one is *L. cicera*.

The results of 1986/87 demonstrate the great variability which exists between genotypes at both sites, and also a highly significant site x genotype interaction. Including data from 1985/86 the combined analysis reveals that there was also a highly significant site x genotype x season interaction. The four ochrus chickling genotypes produced highest seed yield in both seasons.

This experiment will be continued for a third season to study the genotype x environment interactions more fully and to select genotypes adapted to dry areas.

The results with chickling are of special importance because chicklings play a role in dry areas as dual purpose crops for straw and grain production, and farmers prefer chickling for this reason. The results also encourage us to give more attention to the collection and evaluation of native genotypes of the three species in order to obtain the desirable attributes of cold and drought tolerance, early maturity, and disease resistance. - **Ali Abd El Moneim**

Experiment 4.4: Preliminary evaluation of subterranean vetch (*Vicia sativa* ssp. *amphicarpa*)

During the evaluation of new vetch germplasm in 1986/87 a few genotypes of *Vicia sativa* ssp. *amphicarpa* were discovered. These had been collected from dry areas in the central Anatolian region of Turkey, and from barley-growing areas in Syria where it sometimes grows as a weed.

Our preliminary observations revealed that seeds collected from aerial pods were smaller than those from subterranean pods, 25 mg vs 55 mg per seed respectively, and that 90% of aerial seeds germinated within 10-15 days compared with 15% of subterranean seeds. A small proportion of the remainder of the subterranean seeds germinated when in continuous contact with moisture for 60-90 days.

The possibility of using subterranean vetch as a self-regenerating annual legume in pastures and rangelands or to replace fallow in the traditional cereal/fallow rotation is being considered. Its ability to produce both aerial and subterranean seeds might enhance persistence under grazing, and its origin in central Anatolia indicates that it is likely to be winter-hardy.

Subterranean vetch is completely different from subterranean clover. The latter produces its flowers above ground but after pollination the developing fruits and seeds bury themselves in the soil by elongating the peduncles or primary flower stalks and reflexing the sterile calyces. In contrast subterranean vetch produces underground cleistogamous flowers that are never exposed to light. These flowers are sessile in the axils of minute, lobed leaves on subterranean rhizomes or stems. The flower bearing rhizomes develop from cotyledonary buds and buds situated at the basal nodes just above the root-collar. They are chloritic, delicate, rarely branched and consist of a few long internodes. The apex is recurved to protect the apical bud as it penetrates the soil. Subterranean and aerial flowers normally appear simultaneously, although occasionally the subterranean flowers develop after those above ground are completely matured. The underground flowers are more fertile than their exposed counterparts. The location of subterranean flowers probably protects them from environmental factors harmful to pollen formation and fertility and from grazing.

At present we are increasing seed stock of several genotypes and studying the effect of defoliation (grazing) on herbage and seed yield. - **Ali Abd El Moneim**

Experiment 4.5: early generation selection for non-shattering (seed retention) in six crosses of common vetch (*Vicia sativa*) (Preschedule F6)

A breeding program for seed retention in common vetch was initiated in 1984/85. Six crosses and their reciprocals were made between late maturing non-shattering 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 performance of F1 plants indicated that non-shattering is either completely or partially dominant over shattering.

In 1986/87 F2 plants were grown in the field as spaced plants to permit examination of individual plants. F2 plants were left in the field during July when the intense summer heat was more conducive to pod shattering. A visual score of pod shattering was given to individual plants using a scale from 1 indicating complete shattering to 5 indicating about 95% non-shattering.

The F2 plants, the first segregating generation, had an estimated segregation ratio suggesting that non-shattering is a simply inherited character controlled by one dominant gene. Selection was directed towards two types of plants: early, non-shattering, and late, non-shattering. The numbers of F2 plants tested varied from 813 to 2439 plants for each cross. In 1987/88, progeny rows with seeds harvested from selected F2 plants will be grown in the field as F3 families. Superior families with complete non-shattering and other desirable characters will be selected to compose F4 families which will be distributed to national programs for further testing under different ecological zones. - **Ali Abd El Moneim**

Experiment 4.6: screening for resistance to stem and leaf disease (Preschedule F17)

One of the most important selection criteria for developing productive forage legumes is resistance to major stem and leaf diseases. Screening for disease resistance takes place in both microplots and advanced yield trials. Promising genotypes are usually tested in disease nursery plots under artificial infection.

In 1986/87, sixteen promising genotypes of common vetch, and sixteen genotypes of chickling were screened for their reaction against major diseases.

Artificial infection with ascochyta leaf spot, stem blight and foot rot (*Ascochyta pisi*. and *Phoma medicaginis* var *pinodella*), powdery mildew (*Erysiphe pisi*), and downy mildew (*Peronospora viciae sativae*, Gaum) were used for common vetch, and ascochyta blight, (*Ascochyta pisi*), downy mildew, (*Peronospora trifoliorum*) powdery mildew, (*Erysiphe martii* f.sp. *Lathyri*) and bacterial blight (*Pseudomonas syringae PV. pisi*) were used for chickling.

Results revealed that there were four genotypes of common vetch resistant to ascochyta blight, downy mildew and powdery mildew. These are selections 2023, 2027, 1429 and 2065.

Results with chickling revealed that two genotypes, selections 479 and 438, are resistant to ascochyta blight. Seven genotypes were resistant or tolerant to both ascochyta blight and downy mildew. They are selections 54, 479, 436, 460, 438, 456 and 434. Symptoms of powdery mildew and bacterial blight did not appear.

These sources of resistance are available to national programs for use in their breeding programs. - **Ali Abd El Moneim**

Experiment 4.7: screening annual forages for resistance to root nematodes

Root-knot nematode (Meloidogyne artiella) and cyst nematode (Heteroders rosii), are important root-attacking nematodes which are a potential threat to all legumes crops (both food and forages legumes) as revealed in surveys of the last three years. Therefore a new objective in our breeding program is to search for resistance to root-knot nematode in common vetch and cyst nematode in chickling. In the last two years most of our vetches, peas, and chicklings have been screened for resistance, and sources of resistance have been identified. The screening program is on-going, since once new genotypes are developed and seeds become available for wider testing, it is necessary to assess their reaction against nematodes.

In 1986/87, sixteen promising chicklings were screened for resistance to cyst nematode in a highly infested field where the average number of cysts was 73 per 200 g soil, which was ideal for screening. In addition, under artificial infection in the plastic house, where the infection rate was 20,000 eggs per kg soil, seeds were sown in earthen pots, with six replicates of each genotype and three plants per pot.

The results revealed that selection 1440 was moderately tolerant, with the average number of cysts per g of roots being 256, whereas the average in the susceptible and highly susceptible genotypes varied from 324 to 490 cysts per g roots. None of the genotypes tested possessed resistance.

Common vetch: sixteen genotypes were screened for resistance to cyst and root-knot nematodes under artificial infection in the plastic house. The results revealed that none were susceptible to cyst nematodes, eleven were resistant and five were tolerant. To root knot nematodes it was found that five selections (713, 1429, 2003, 2023 and 2065) were tolerant. The average number of galls varied from 105 to 147 per g of root, whereas in highly susceptible genotypes it varied from 326 to 373 galls per g of roots. - **Ali Abd El Moneim**

Experiment 4.8: screening annual medics for nematode resistance.

During the 1986/87 cropping season, a screening program for resistance to nematodes in annual medics was initiated. One hundred genotypes comprising 11 species (51 accessions of Medicago rigidula, 15 M. rotata, 3 M. blancheana, 3 M. noeana, 6 M. polymorpha, 1 M. scutellata, 4 M. turbinata, 10 M. aculeata, 3 M. truncatula, 3 M. constricta and 1 M. murex) were screened in a heavily infested field at Tel Hadya. Nematode populations were monitored by taking soil samples before planting and during the growing season. For each sample, ten 1 kg lots of soil were collected at random, thoroughly mixed, and a 1 kg subsample removed for testing; one such sample was taken for each of the four replicates within the experiment.

Observations were made after germination and continued throughout the growing season. Random samples of plants were taken to isolate the nematodes and determine the degree of root infection. Root symptoms were diagnosed as root knots or root-galls, white cysts, excessive root branching and injured root tips. The reaction of each genotype against nematode infection was estimated using a 1-5 scale, where 1 was very resistant (VR): nematodes were not found or there were few on the roots, and 5 is very susceptible (VS): nematodes were found on the majority of plants, causing serious damage.

The same genotypes were screened under artificial conditions for resistance to root knot and cyst nematodes. Seeds were sown in 20 cm diameter earthen pots at the rate of six seeds per pot. Ten days after sowing thinning was done to keep three plants per pot, and another two weeks later freshly hatched second stage juveniles of root knot nematode were added around the roots of the plants at the rate of 20,000 per kg soil. The infection rate of cyst nematode was 20,000 eggs per kg soil. There were three replicates of each genotype for each kind of nematode. Observations on plant growth, symptoms on the shoots, and numbers of root galls or cysts per plant were counted two months after inoculation.

In the field mean numbers of cysts per 200 g soil and of root knot nematodes per 500 g soil are presented in Table 4.7. The soil was heavily infested by both nematodes and was thus ideal for screening. It was also observed that populations of both nematodes substantially increased during the growing period of the plants. Mature root knot females were observed in mid March, while white cysts appeared in mid April. By early May juveniles of root knot nematodes were absent on the roots, indicating that only one generation per growing season will occur under local conditions.

Preliminary observations indicated that the medics were severely attacked by root knot nematode, and slightly attacked by cyst nematode, under both natural and artificial conditions. Response to nematode varied considerably among the species, even among genotypes within the same species.

In the field the average number of root knots per g of root was 809, varying from 109 in *Medicago rigidula* selection 1856 to 1902 in *M. blancheana* selection 816. Under artificial infection the average was 1098 varying from 120 in *Medicago constricta* selection 1621 to 2903 in *M. blancheana* selection 816.

Table 4.7. Mean number of cyst (cyst per 200 g soil) and root knot (larvae per 500 g soil) nematodes present in soil of the experimental field on eight sampling occassions.

Sampling date	Cyst nematode	Root knot nematode
26.10.1986	59	1140
12.12.1986	56	1220
13.01.1987	43	804
15.02.1987	86	1302
14.03.1987	45	1080
15.04.1987	52	888
14.05.1987	69	1512
13.06.1987	109	2557
Mean	65	1313
L.S.D. ($P<0.05$)	12	386

In the greenhouse M. rigidula selections 1856, 1870, 1850, 1531, 977, 740, 1559, 1913, 1540, 1868, 734; M. noeana, selections 2124, 1940, SA15485; M. aculeata selections 918, 2001, 1837; M. rotata selections 1946, 2120, 1953; M. turbinata selection 2110; M. constricta selection 1621; and M. murex selection 1628 possessed resistance or tolerance to root-knot nematode under both field and artificial infection.

In the field, of the 51 genotypes of M. rigidula, two, *selections 1856 and 1870, were resistant, 9 were moderately* resistant, and 39 were moderately susceptible to root knot nematode (Fig. 4.6). In the greenhouse, selections 1856 and 1870 were moderately resistant and 16 strains were moderately susceptible (Fig. 4.6).

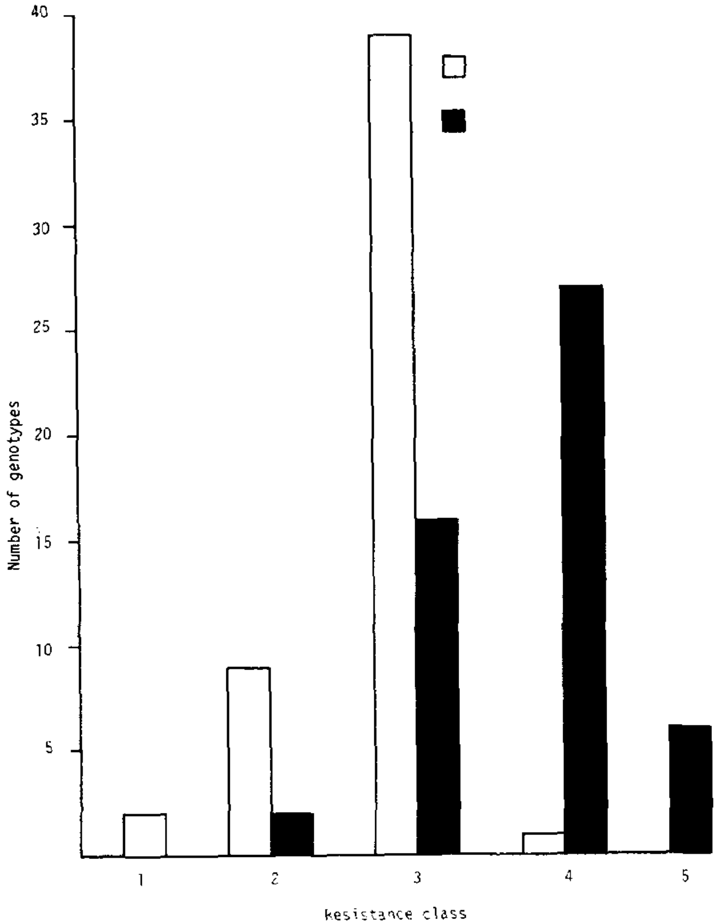


Fig. 4.6: *Variability in resistance to root-knot nematode among 51 ecotypes of* Medicago rigidula, based on the following score, 1 = resistant, no galls or very light galling; 2 = moderately resistant, with light galling; 3 = moderately susceptible, with moderate galling; 4 = susceptible, heavy galling; 5 = very susceptible.

In field screening for cyst nematodes the average number of cysts per g of roots was 40, varying from zero in most of the tested genotypes to 368 in M. rigidula selection 2012. In the greenhouse the average number of cysts per g of roots was 45, varying from zero in most of the genotypes to 202 in M. rotata selection 2118.

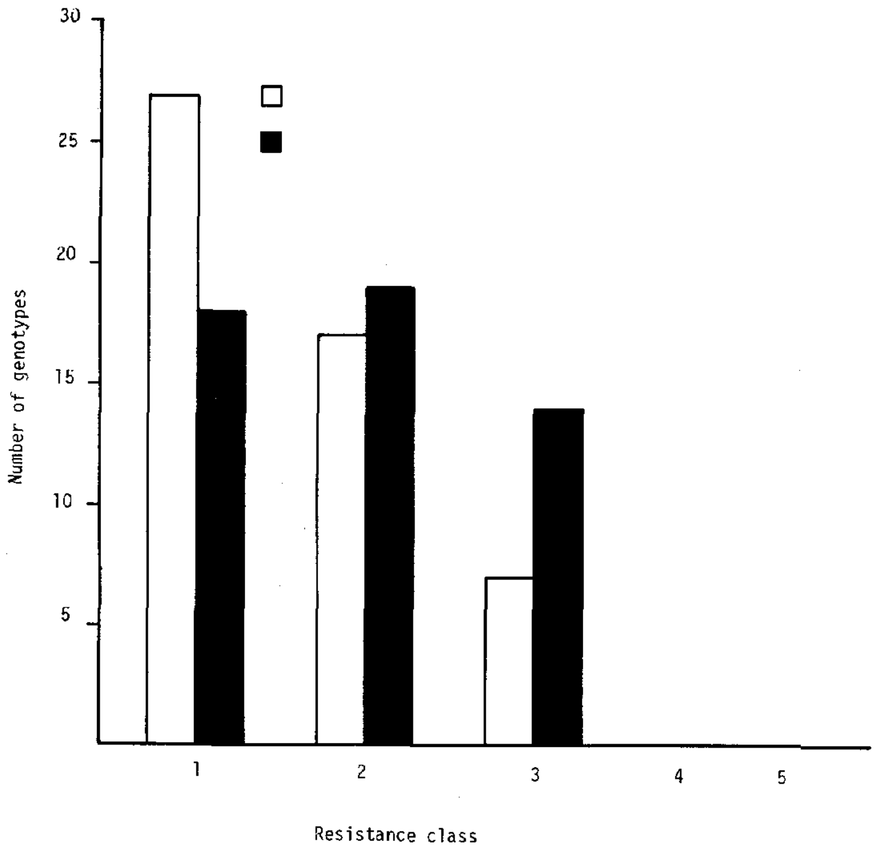


Fig. 4.7: Variability in resistance to cyst nematode among 51 ecotypes of Medicago rigidula at Tel Hadya, 1986/87. Scores as for Fig. 4.6.

Field and greenhouse screening revealed that 54 of the genotypes were classified as resistant to cyst nematode, 31 were tolerant, 14 were moderately tolerant and only one genotype, M. rotata selection 2118, was susceptible, the latter being also susceptible to root knot nematode.

The screening for cyst nematode revealed that 18 lines were resistant under both field and artificial conditions (Fig. 4.7). - **Ali Abd El Moneim, Gawdat Faddoul (Damascus University, Faculty of Agriculture), Yassin Swedan (ARC, Douma, Syria)**

Experiment 4.9: growth and seasonal quality of some vetch and chickling species (Preschedule F23)

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 have faced in assessing productivity of forage legumes is the correct time to measure herbage production and quality. The practice has been to harvest at the 100% flowering stage because this is the time normally recommended for hay cuts. This is clearly unsastisfactory as evidence gained in other experiments (eg experiment 2.6) has revealed that farmers are more interested in the grazing of forage crops, or harvesting them for straw. Furthermore harvesting at a particular phenological age can mean quite 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 extend that forage quality changes after flowering. Common chickling (selection 439), ochrus chickling (selection 104), Narbon vetch (accession 67), woolly-pod vetch (accession 683) and three genotypes of common vetch (selections 2541, 2020 and 2037), were used in the experiment.

The experiment was sown on 18 November 1986, at the seeding rate of 80 kg per ha, and 40 kg per ha of P_2O_5 was applied before sowing. A randomized block design was used with three replicates. In each block the entries were randomly allocated to 5 m x 5 m plots. Each plot was then sub-divided into several 0.5 m^2 subplots having adequate guard areas around the whole plot as well as between the sampling areas. At any one harvest, two 0.5 m^2 subplots were randomly harvested to make up a total of one square meter.

The first rain after sowing was on 18 December 1986, hence germination occurred around 25 December 1986. Six harvests were taken: on 2 March, 22 March, 6 April, 21 April, 5 May and 18 May 1987: 66, 87, 102, 118, 132, and 145 days after sowing. At each harvest, two 0.5 m^2 quadrats were harvested and the fresh weights were immediately recorded. Sub-samples were taken for oven drying at 80-90 ^oC for 24 hours for the determination of dry matter percent. Further sub-samples were taken and separated into stems and leaves, and on days 132 and 145 into stems, leaves and pods, for determination of leaf/shoot ratio on a dry weight basis. 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 and crop growth rate (C) was calculated according to the equation:

$$C = \frac{(W/2-W/1)}{(t2-t1)} \cdot \frac{1}{A}$$

Where W/2 and W/1, are yields at times 2 and 1 respectively, and A is the quadrat area.

At each harvest, samples from each genotype, including stems and leaves, were ground and analysed for CP, IVDDM, ash, NDF, and ADF.

Frosts occurred from before the first harvest until 22 March (day 87). The lack of significant differences between dry matter yields at day 66 (Table 4.8) indicates that early growth of the different genotypes was similar. Large differences were found between genotypes regarding time at which maximum dry matter was attained (Table 4.8). Narbon vetch, woolly-pod vetch, common vetch (selection 2541) and ochrus chickling (selection 104), attained their maximum yields at day 132, at phenological stages of 100% podding, 50% podding, 100% podding and 100% podding respectively. In contrast common chickling selection 439 and common vetch

Table 4.8. Mean herbage yield (t per ha) of the different genotypes of vetch and chickling for the different harvests.

	Day Date	66 2.III	87 22.III	102 6.IV	118 21.IV	132 5.v	145 18.V
Woolly-pod vetch							
acc. 683		0.33	0.99	2.08	4.01	4.34	3.69
Narbon vetch							
acc. 67		0.34	0.81	1.65	3.82	8.62	6.05
Ochrus chickling							
acc. 104		0.23	0.54	1.36	2.84	3.95	3.98
Common chickling							
acc. 439		0.19	0.56	1.16	2.64	3.93	4.49
Common vetch							
sel. 2541		0.30	0.75	1.38	3.47	4.81	4.74
sel. 2037		0.31	0.60	1.22	2.78	3.79	4.33
sel. 2020		0.22	0.60	0.90	2.18	3.41	3.61
L.S.D. ($P<0.05$)		0.132	0.179	0.404	0.653	1.735	1.68

selections 2037 and 2020 attained their maximum yield at day 145, at 100% podding for the first and at maturity for the other two genotypes. By the time each genotype attained maximum dry matter, a considerable portion of the dry matter was in the pods.

During the season significant differences were found between genotypes in respect to dry matter production (Table 4.8). At day 87 and 102 woolly-pod vetch had the highest dry matter followed by Narbon vetch and common vetch selection 2541, the latter two having comparable yields. At day 118 woolly-pod vetch, Narbon vetch and common vetch selection 2541 had the highest yields, while common vetch selections 2035, 2020, and common chickling selection 439 had the lowest yields. By day 132 all the entries except Narbon vetch had more or less similar yields: Narbon vetch however, doubled its yield between day 118 and day 132.

The LAI of all entries increased with time (Table 4.9). Except at day 132, woolly-pod vetch had the highest LAI: there were no significant differences between the other genotypes. The genotypes also differed in maximum LAI: 6.98 for woolly-pod vetch, the other genotypes ranging from 3.95 to 5.04. Growth rate (C) followed a similar pattern to that of LAI, all genotypes increasing linearly with time to day 118. Differences between entries with regard to C were less than for LAI.

Table 4.9. Mean leaf area indices of the different genotypes of vetch and chickling for the different harvests.

	Day	66	87	102	118	132
	Date	2.III	22.III	6.IV	21.V	5.V
Woolly-pod vetch						
acc. 683		0.96	3.02	5.69	6.98	2.83
Narbon vetch						
acc. 67		0.60	1.42	2.48	4.09	2.93
Ochrus chickling						
acc. 104		0.41	0.97	2.33	3.95	1.23
Common chickling						
acc. 439		0.37	1.06	2.44	4.49	3.20
Common vetch						
sel. 2541		0.56	1.34	2.44	5.04	2.21
sel. 2037		0.62	1.18	2.42	4.63	3.62
sel. 2020		0.43	1.12	1.98	4.07	3.42
L.S.D. ($P<0.05$)		0.21	0.37	0.957	1.278	1.388

All genotypes except Narbon vetch maintained their leaf/shoot ratio through to day 102, after which there was a sharp decline, the crops becoming very stemmy by day 132 (Table 4.10). Throughout the growing season Narbon vetch had the lowest leaf/shoot ratio and common vetch the highest. For the other genotypes there were only small, though significant, differences. Leaf/shoot ratios of all genotypes at day 132 were low compared to day 118.

Table 4.10. Straw and seed yields, straw quality (IVDDM and CP), and harvest index (HI) of the various genotypes of five forage legume species.

	Straw yield (t per ha)	Seed yield (t per ha)	IVDDM (%)	CP (%)	HI
Woolly pod vetch	3.69	1.29	29	13.1	0.26
Narbon vetch	6.05	3.45	60	10.1	0.36
Ochrus chickling	3.98	1.69	59	11.1	0.30
Common chickling	4.49	1.40	61	19.2	0.24
Common vetch					
selection 2541	4.74	2.31	58	13.1	0.33
selection 2037	4.33	0.98	57	13.2	0.18
selection 2020	3.61	1.18	61	15.9	0.25
L.S.D. (P<0.05)	1.68	0.68	46	3.02	

High early values of NDF, ADF, IVDDM and ash were maintained until day 102, beyond which NDF and ADF started to rise and IVDDM, CP and ash started to decline. Throughout the growing season Narbon vetch had the highest ADF and NDF, while differences between other genotypes were not significant. Eventually CP of all genotypes declined but total harvestable protein increased until day 118.

Increases between days 118 and 132, except for Narbon vetch, were small, and total harvestable protein of all genotypes at day 145 were either similar or lower than at day 132. Woolly-pod vetch had the highest protein yield until day 118, and common vetch selection 2020 the least. On day 132 Narbon vetch had the highest protein yield followed by common chickling selection 104. Maximum leaf protein was on day 118: at days 132 and 145 most of the nitrogen had been translocated from the leaves to the pods.

Seed and straw yields of Narbon vetch were far higher than the other forages, and harvest index of this species reached 0.36 (Table 4.10). Its straw quality (in terms of IVDMD) was also high indicating that this vetch may have considerable potential as a legume crop producing straw and grain to feed to livestock. As a grazing crop however, it is less palatable, and may not be so well suited.

As a result of this and other experiments (including on-farm experiments) the various forage crops may be of value as follows:

- common vetch - for high quality hay and grazing in areas receiving 300mm rainfall or more;

- woolly pod vetch - for hay and grazing with quality (due to lower palatability) rather less than common vetch; also of value in very cold areas;

- Narbon vetch - for grain and straw in areas receiving 250 - 350 mm of rainfall; and

- ochrus and common chickling - for grazing; grain and straw in areas receiving 250 - 300 mm rainfall. - **Ali Abd El Moneim, Mohamed A.M.** Khair (Visiting scientist, **ARC, Sudan)**

Experiment 4.10: distribution of pasture and forage seeds

Table 4.11 shows the distribution of seeds in 1986/87. By far the greatest amount was distributed within the ICARDA region, especially to north Africa. It was pleasing also that, for the second successive year, ICARDA was able to supply ACSAD with 100 kg of medic seed, mainly M. rigidula.

Table 4.11. Distribution of the seeds (kg) of ICARDA selections to institutions inside and outside of ICARDA's region.

	Species			
Country	Vetch	Chickling	Medics	Others
Algeria			40	
Australia	1			
Cyprus	15	15	9	
Egypt	2			29
France	13		85 (1)	
Jordan	100	55	170	
Kenya			2	
Lebanon				0.2
Morocco			105	
Pakistan	100	75		
Saudi Arabia	10			
Spain			1	
Syria			104 (2)	
Turkey	9			
United kingdom	2	1		
Total	252	146	515	29

(1) Collaborative project with France: most of the medics were sown in Algeria.

(2) Includes 100 kg to ACSAD: does not include ICARDA/SMAAR collaborative experiments.

Although a huge increase over previous years, we expect that the amount distributed in 1986/87 will be considerably exceeded in 1987/88. It should be noted that nearly 1t of medics, not included in Table 4.11, were used in ICARDA/SMAAR collaborative projects at Tah, Kamishly, Izraa, and other centres. ICARDA also collaborated in the production of 200 kg of M. rigidula seed at Kraim station, near Hama.

The amount of seed distributed is limited chiefly by ICARDA's ability to produce seed. - P.S.Cocks

CHAPTER 5: BIOLOGICAL NITROGEN FIXATION

Because problems associated with poor nodulation are more severe in pasture than in forage legumes, PFLP has given high priority to the former over the latter.

An essential component of a successful ley farming system is the effective and abundant nodulation of the medic plant. For various reasons, population levels of Rhizobium meliloti have declined from expected levels based on the fact that the Mediterranean basin is the center of origin of medics. It is therefore of importance to understand the reasons for this and the often complex interactions between the medic plant, rhizobia and environment. Even where R. meliloti is abundant there are often problems due to host-strain specificity and the poor competitive ability of effective strains.

Chapter 5 also deals with the important question of how to introduce effective rhizobia strains into the ecosystem. Experience has shown us that simple inoculation with peat-based inoculants often fails even though the strain is known to be effective. We believe that one of the reasons is the often harsh conditions at sowing time: because of other commitments and especially when the first autumn rains are late, farmers prefer to sow into dry soil. Under these conditions there is a high death rate of bacteria on the surface of the seeds and hence unsuccessful inoculation. This problem is examined in several experiments in Chapter 5 and is the basis of a developing link with the Boyce Thompson Institute in the United States.

Techniques of genetic engineering have probably been more successful in microbiology than in any other branch of biology. For this reason PFLP is developing linkages with other advanced institutions and these are also described.

Experiment 5.1: symbiotic response of medic species to indigenous rhizobia (Preschedule M18)

The objectives of experiment 5.1 are firstly to collect a wide diversity of R. meliloti, secondly to obtain information on their specificity with six medic species, and thirdly to clarify relationships between the strains and their native habitats.

As previously stated we have often observed that many soils in the region contain little or no rhizobia effective for particular medics. In order to know where inoculation is required, it is necessary to define the distribution of such soils. To find the answer, medic rhizobia were isolated from samples collected from arable and non-arable sites in Syria (91 samples), Jordan (18), Turkey (19) and Cyprus (6).

The isolates (strains) were grown in yeast mannitol broth and used to inoculate seedlings of M. rigidula, M. noeana, M. orbicularis, M. rotata, M. polymorpha cv Circle Valley and M. truncatula cv Jemalong. Aseptically-grown seedlings were transferred into test tubes containing a mixture of vermiculite and gravel, and allowed to grow for 6-7 weeks at which time symbiotic responses (plant mass, nodule number, colour, and vigour) were evaluated. Based on these parameters we have been able to rank the in-vitro response of each medic to each of the 134 isolates.

The results indicate that the indigenous rhizobia vary significantly in their ability to nodulate the various plant hosts. More than half of the strains produced abnormal plant-rhizobia relationships in at least some of the medics, most commonly M. obicularis and the Australian cultivars, i.e. no nodules or only ineffective nodules were formed (Table 5.1). M. rigidula nodulated effectively with many strains obtained from Syrian soils but often failed to nodulate when inoculated with strains from Jordan. These results are surprising as some of the species are widespread in the sites where the rhizobia were collected. However, it supports the hypothesis that many species and cultivars are poorly adapted to certain environments: in many instances, strains ineffective on one species were effective on others, indicating that considerable host specificity occurs with the indigenous populations.

Table 5.1. In-vitro nodulation performance of 134 indigenous R. meliloti straine on six annual medic species. The number of isolates (% in brackets) is given for each nodulation category.

Medic host	Effective nodules	Partially effective	Ineffective nodules	Nodules lacking
M. rigidula	38(28)	14(10)	34(25)	48(36)
M. noeana	26(19)	33(25)	33(25)	42(31)
M. rotata	40(30)	20(15)	42(31)	32(24)
M. orbicularis	25(19)	11(8)	36(27)	62(46)
M. polymorpha[1]	21(16)	16(12)	39(29)	58(43)
M. truncatula[2]	12(9)	38(28)	21(16)	63(47)

[1] Cultivar Circle Valley
[2] Cultivar Jemalong

Two conclusions can be drawn: firstly that in all medic species there is a chance of nodulation failure, even in uncultivated soils; and secondly, the diversity of rhizobia is such as to provide an opportunity to select competitive and persistent strains effective and compatible for all hosts. The strains which we found to give positive responses will be subjected to further and more vigorous

Table 5.2. Correlation coefficients for the relationships between paired varieties of M. rigidula in respect of their response to inoculation with 20 strains of R. meliloti.

Variety	cinerascens r	p	n	submitis r	p	n	rigidula r	p	n
agrestis	.771	<.001	20	.866	<.001	19	.178	ns	20
cinerascens	-			.826	<.001	19	-.072	ns	20
submitis	-			-			.083	ns	19

r = correlation coefficient; p = probability; n = number of comparisons; ns = not significant (P>0.05).

screening in plant-soil systems to evaluate their ability to survive and compete against ineffective native rhizobia.

Because of the taxonomic diversity of M. rigidula, which has four varieties, some attention was also given to the question of strain specificity within the species. From in-vitro experiments conducted in collaboration with Dr John Brockwell, (CSIRO, Australia), it was found that varieties agrestis, cinerascens and submitis were strongly inter-related when inoculated with rhizobia strains CC2601, CC2602, CC2603, CC2604, and ICARDA strains M1, M12, M17, M18, M23, M29, M34, M36, M37, M38, M44, M45, M90, M124, M140 and M144 (Table 5.2). In contrast there were no significant relationships involving variety rigidula, suggesting that it has specific requirements. However only single ecotypes of each variety were in the experiment so caution must be used in interpreting the results. Unfortunately, in field experiments conducted at Tel Hadya, it is not possible to detect these interactions because of a strong background of native rhizobia effective on M. rigidula. - **Luis A. Materon and John Brockwell** (CSIRO, Australia)

Experiment 5.2: status of the Rhizobium collection (Preschedule M19)

The objectives of experiment 5.2 are firstly, to establish a collection of rhizobia effective on medics, and other pasture and forage legumes, secondly, to provide rhizobia to and exchange with other scientists, and thirdly to encourage research on strain selection within west Asia and north Africa.

As in a plant breeding program, it is essential to base the improvement of rhizobia on an extensive collection of strains with origins as broadly-based as possible, geographically as well as taxonomically. To that end ICARDA commenced collecting rhizobia for pasture and forage species in 1985/86.

Most of the cultures of R. meliloti (forms nodules on medics), R. trifolii (forms nodules on clovers) and R. leguminosarum (forms nodules on vetches, chicklings, and lentils) have been isolated from soil samples collected from native pastures throughout Syria, Jordan, Turkey, and Cyprus during field trips, and from overseas germplasm collections. To confirm the nitrogen-fixing potential of R. meliloti, both M. rigidula and M. noeana have been used as 'trap species' as they seem to be the most promiscuous of the medic species so far studied. Seedlings are grown in a vermiculite and sand mixture containing a plant nutrient solution devoid of nitrogen. The soil sample (containing the rhizobia) is vigorously shaken with water and a small volume is used to inoculate the seedling. Rhizobia are then isolated from any nodule produced.

Currently the collection consists of 295 purified strains of R. meliloti, of which 35 are antibiotic-resistant mutants, 15 of R. trifolii and 42 of R. leguminosarum. In future, the collection will be enlarged with cultures from north African countries and elsewhere

Table 5.3. International requests and deliveries of peat-based rhizobia inoculant bags and cultures for pasture and forage legumes in 1986-87. In brackets: pure cultures on YMA slants.

Type of Legume	Number of inoculant bags[1]	Country[2]
Medics	49	Algeria
Medics	(15)	Australia
Medics	12	Cyprus
Vetches	9	Cyprus
Lathyrus	1	Cyprus
Medics	(10)	Egypt
Medics	2	Ethiopia
Clovers	(2)	Ethiopia
Medics	77(4)	France
Medics	8	Greece
Medics	105	Jordan
Medics	(4)	Italy
Medics	(1)	Lebanon
Medics	55	Morocco
Medics	2	Nepal
Medics	10	Pakistan
Vetches	5	Pakistan
Medics	5	Portugal
Medics	4(10)	Spain
Hedysarum	(2)	Spain
Medics	1(1)	Sweden
Medics	119	Syria
Vetches	8	Syria
Medics	2	Tunisia
Medics	10(4)	Turkey
Medics	(2)	U.K.
Medics	(4)	U.S.A.
Total	484(59)	

[1] Each inoculant bag weighs 90g and will inoculate approximately 3.5 kg of medic seed.

[2] Includes cooperative projects between ICARDA and Ministries of Agriculture

in west Asia, through cooperators from national institutions, IBPGR, MIRCEN, ICARDA's Genetic Resource Program and from researchers of other countries.

Up to now, rhizobia cultures have been maintained at $4^{o}C$ in bottles (20ml) containing yeast mannitol agar medium. However we have now initiated tests on the use of culture lyophilization, in which freeze-dried cultures can be stored in ampoules or small vials. This will result in longer preservation and minimize genetic variability.

Pure strains of rhizobia for pasture and forage species are available upon request. A catalogue containing information on ICARDA's collection will be prepared for the coming season.

There is a growing demand for inoculants for use in ICARDA projects in Syria and abroad, and for use by other organizations. The microbiology laboratory at Tel Hadya supplies all these requirements by preparing inoculants having peat-based carriers sterilized by gamma-irradiation. At maturity, the population density reaches approximately 10^{9} rhizobia per gram of peat inoculant.

In 1987 a total of 484 inoculant bags was distributed to cooperators, mostly from countries of the Mediterranean basin area (Table 5.3). Small amounts of peat-based inoculants are also prepared for interested researchers outside of the ICARDA region. - **Luis A. Materon**

Experiment 5.3: persistence of rhizobia strain WSM244 (Preschedule M20)

The objective of this experiment was to test the compatability, competitiveness and seasonal persistence of strain WSM244 a rhizobia used widely in west Asia and north Africa.

In the previous year it was found that, by using mutants resistant to a certain level of antibiotics, strain WSM244, previously used in Tel Hadya to inoculate M. rigidula, did not produce nodules on that host. The mutant used was resistant to high concentrations of streptomycin (150 micrograms per ml of streptomycin sulfate in yeast mannitol agar (YMA) medium) and had previously been shown to have unaltered nitrogen fixing capacity and symbiotic response. The mutant is present in a nodule if bacteria isolated from the nodule grow on the YMA medium supplemented with streptomycin. If the isolate will not grow on this medium it is assumed that the nodule was produced by native rhizobia.

The original experiment was sown in November 1985. It consisted of a split-plot design with three medic species (M. rigidula selection 716, M. truncatula cv Jemalong, and M. polymorpha cv Circle Valley) as main plots and three inoculation rates (1x, 5x, 10x the recommended rate of peat inoculant) as subplots. During the current year these treatments were ignored and the plots were kept only for studies of the seasonal persistence of WSM244.

Self-regenerating growth of seedlings was observed in the plots after the light rains in early December 1986. In mid-March 100 nodules from each species (distributed over all replicates) were collected and the isolated rhizobia transferred to YMA-antibiotic medium for identification. Five measurements on the nitrogenase activity were also conducted during the growing season. Total herbage yield was measured in late April.

Table 5.4. Proportion of nodules produced by inoculant strain WSM244 in self-regenerating medics during a second season in Tel Hadya (1986-87)

Species	%nodules produced by: WSM 244	native rhizobia	Mean number of nodule per plant	Mean nitrogenase activity*	Herbage yield kg/ha
M. rigidula	0	100	10.9	0.4	3135
M. polymorpha	94	6	3.3	0.3	4680
M. truncatula	96	4	6.5	0.2	2914
LSD (P<0.05)				1.3	

* Micromoles C_2H_4 per ml per plant per hr (acetylene reduction activity at the flowering stage)

The results showed that strain WSM244 was persistent in the soil and highly competitive with the native soil rhizobia for nodule sites in *M. polymorpha* and *M. truncatula*: the mutant strain produced 94 and 96%, respectively, of the nodules of these species (Table 5.4), whereas for *M. rigidula*, strain WSM244 was not detected. It therefore seems likely that WSM244, previously recommended, is a poor competitor for nodule sites on *M. rigidula*, a finding of practical importance for the future use of this species. On the other hand, it was found that, when a compatible host had previously been present, WSM244 persisted in the soil over the summer in the absence of medic plants (from May to November). This experiment will be continued. - Luis **A. Materon**

Experiment 5.4: techniques for inoculating medics (Preschedules M21 and M22)

The objectives of these experiments were firstly to determine whether coating seed after inoculation extends the life of seed-applied rhizobia, secondly to evaluate different adhesives used to stick rhizobia to seeds, and thirdly to measure the effect of the coating and adhesive treatments on plant growth.

Inoculating medic seed in semi-arid soils poses a problem of survival for the seed-applied rhizobia. The mortality rate is highest with shallow sowings, particularly when soil moisture is not adequate to ensure germination of the seeds. In west Asia and north Africa it is often necessary to sow medics before the onset of the first autumn rains and the rhizobia must survive on the seed coat sometimes for several weeks. Use of certain organic agents as adhesives to stick the inoculant to the seeds may extend survival of the rhizobia due to interactions of a physico-chemical nature. Covering the inoculated seed with a protective, non-toxic, finely ground coat will also provide extra protection.

To test a number of different adhesives an experiment in two parts was designed. In the first part, seeds of M. rigidula selection 716, M. rotata selection 1943, M. polymorpha cv Circle Valley, and M. truncatula cv Jemalong were inoculated with recommended ICARDA strains of R. meliloti, using a slurry made of peat and solutions (25% w/v) of the following adhesives: gum arabic, methyl (gum) cellulose, beet molasses, sucrose, and polyvinylpyrrolidone (PVP). Inoculation with water was included as a control where seeds were not inoculated with the slurry paste. Inoculant was added to provide approximately 10000 rhizobia per seed. The experiment had 3 replicates and was duplicated at Breda (280 mm) and Tel Hadya (330 mm average rainfall). Sowing took place on 23 December after a period of rain totalling 63 mm at both locations. A fertilizer dressing of 18 kg per ha of phosphorus was applied, and two herbage cuts were taken during the growing season.

Table 5.5 illustrates the main findings of the experiment. With the exception of M. rigidula, which formed nodules with native rhizobia, all species responded to inoculation. Gum arabic, gum cellulose and beet molasses performed generally better in M. rotata and the Australian cultivars, giving better nodulation and higher herbage yields.

The results indicate that using organic adhesives (compared with water) in the slurry paste results in greater viability of rhizobia, which are then able to colonize roots and produce more nodules. Unfortunately, gum arabic is expensive and not readily available to farmers. Gum cellulose and beet molasses are less expensive and are therefore recommended. Increasing the concentration of organic adhesives in the peat mixtures generates problems such as insect attacks on inoculated seed, clustering of seeds in the planter-box, and uneven sowing densities. Concentrations ranging from 15 to 25% (w/v) have been observed to be satisfactory to keep the peat inoculant uniformly attached to the seed.

The second part of the experiment was designed to test the seed coatings. Inoculated medic seeds were coated with finely ground calcium carbonate, sodium molybdate, activated organic charcoal, vermiculite or rock phosphate. The use of calcium carbonate to pellet or coat inoculated seed is a common practice in developed countries to ensure survival of seed-applied rhizobia in acid soils. However, we have previously observed that this material also affords protection to rhizobia in alkaline soils. The experimental design was similar to that in which the adhesives were tested. The adhesive used was gum arabic in solution (25% w/v). Sowing took place on 22 and 23 December at Tel Hadya and Breda, respectively.

Table 5.5. Yield of four medic species after inoculation with *R. meliloti* using 5 adhesives or a water control, compared with the absence of inoculation (harvested 5 to 7 April). Herbage yields are given for two locations, Tel Hadya and Breda.

	Herbage yield (kg per ha)							
Treatments	Tel Hadya	Breda	Tel Hadya	Breda	Tel Hadya	Breda	Tel Hadya	Breda
Adhesive agents	*M. polymorpha*		*M. truncatula*		*M. rotata*		*M. rigidula*	
Gum arabic	853	1274	927	2993	1829	3296	1864	2253
Gum cellulose	855	1331	943	2605	1466	2158	1896	2115
Sucrose	828	1133	524	3500	1620	1980	1984	2435
Beet molasses	992	1110	576	2996	1643	1843	2187	2067
PVP[1]	976	836	542	2953	1749	1905	1727	1921
Water	348	1168	362	2001	1229	1121	1809	2200
Uninoculated seed	249	450	183	681	568	1005	1864	2095
LSD ($P<0.05$)	305	563	387	716	895	1917	ns	ns
CV (%)	29	31	30	27	28	25	23	27

[1] Polyvynilpyrrolidone

The results are summarized in Table 5.6. At Tel Hadya and Breda, there were strong responses to inoculation with all medics except M. rigidula, which again was able to form nodules without being inoculated. Some further responses to coating agents were observed compared with non-coated treatment. For example, at Breda, herbage yield of M. truncatula was significantly better than both controls when calcium carbonate and vermiculite were used to treat the inoculated seed. Similarly, M. rotata responded positively to a charcoal coating on the seed. These findings confirm observations made and reported in the previous season.

Table 5.6. Response of medics to inoculation with rhizobia and the use of coating agents on inoculated seed sown in Tel Hadya and Breda in 1986-87 (Harvested 5 to 7 April).

	Herbage yields (kg per ha)							
Treatments	Tel Hadya	Breda	Tel Hadya	Breda	Tel Hadya	Breda	Tel Hadya	Breda
Coating agents	M. polymorpha		M. truncatula		M. rotata		M. rigidula	
Calcium Carbonate	1218	1599	1123	2403	1185	1641	1645	2053
Sodium molybdate	962	985	818	2265	1176	1362	1358	1005
Charcoal	907	1275	887	1967	1278	1965	1115	1167
Vermiculite	839	1118	753	2422	1407	1710	1411	1854
Rock phosphate	1027	957	788	1842	2266	1639	1406	2284
Uncoated	954	1149	1050	1461	1338	1630	1333	1777
Uninoculated seed	352	448	156	891	409	1203	1318	1386
LSD (P<0.05)	601	499	413	662	615	509	NS	NS
CV (%)	29	26	28	30	23	27	25	27

Even though the yield advantages over other treatments were not quite significant the use of finely ground calcium carbonate and rock phosphate will be encouraged to protect seed-applied rhizobia against adverse environmental conditions. These techniques will continue to be investigated at three locations in the coming season.
- **Luis A. Materon**

Experiment 5.5: selection of new strains of medic rhizobia (Preschedule M26)

The objective of experiment 5.5 was to evaluate rhizobia for compatability with their hosts to achieve maximum nitrogen fixation. Strains were selected on the basis of forming fully effective, N_2-fixing nodules on legume species in the presence of competing strains under the conditions of soil and climate in which they are grown.

Previous work has shown that there are strong host/strain interactions. In order to clarify these interactions we examined the nodulation of six species of annual medic with 30 rhizobia strains under field conditions. The species were: M. rigidula, M. noeana, M. rotata, M. orbicularis and the Australian cultivars Jemalong (M. truncatula) and Circle Valley (M. polymorpha). Two sites were chosen, Tel Hadya (358 mm in 1986/87) and Breda (245 mm). The experiments consisted of split-plot layouts with three replicates and were sown on 22 December (Breda) and 14 November (Tel Hadya); the plots were harvested on 29 April and 10 May, respectively.

Symbiotic response was measured by comparing the herbage yield of each medic with that of the uninoculated control. In Table 5.7 all increases shown were significant (non-significant increases have been omitted). At Tel Hadya the inoculated Australian cultivars produced from 3 to 10 times more herbage than the non-inoculated controls. At Breda, M. truncatula inoculated with strain ICARDA M57 tripled its yield and, in contrast to Tel Hadya, M. rigidula also responded positively to inoculation. Note that, in the absence of a strong competitor, WSM244 effectively nodulated M. rigidula at Breda, a result which contrasts with that at Tel Hadya where WSM244 failed to form nodules on this species (experiment 5.3). M. noeana,

Table 5.7. Magnitude of significant ($P<0.05$) responses in herbage yield to inoculation expressed as a ratio of the yields of plots sown with inoculated seed to those sown with uninoculated seed. Results are given for growth at Breda (B) and Tel Hadya (TH) in 1986/87. Blank spots indicate no response.

Medic host	Strain of *Rhizobium meliloti*					
	ICARDA M3	ICARDA M15	ICARDA M38	ICARDA M57	ICARDA M59	ICARDA M119
M. rigidula	B 1.7	B 2.0		B 1.7		B 1.9
M. polymorpha	TH 7.8	TH 8.9	TH 6.3		TH 9.9	
M. truncatula	B 2.2	B 1.8	B 1.9	B 1.8	B 2.7	B 2.0
	TH 5.8	TH 3.8	TH 3.1	TH 3.2	TH 3.9	
M. rotata	TH 2.3				TH 2.8	B 2.0
M. orbicularis	TH 3.6				B 2.5	
M. noeana			TH 1.4			

nodulated by ICARDA M38, increased its herbage yield by 1.4 fold at Breda. Profiles of responses for each strain and species are illustrated in Fig. 5.1.

The evaluation program needs to be continued until a group of elite strains are selected for each commercially important species of medic. However, the strains already isolated show considerable promise in overcoming what is seen to be one of the most important constraints (poor nodulation of medics) to the adoption of the ley farming system in west Asia and north Africa. - **Luis A. Materon**

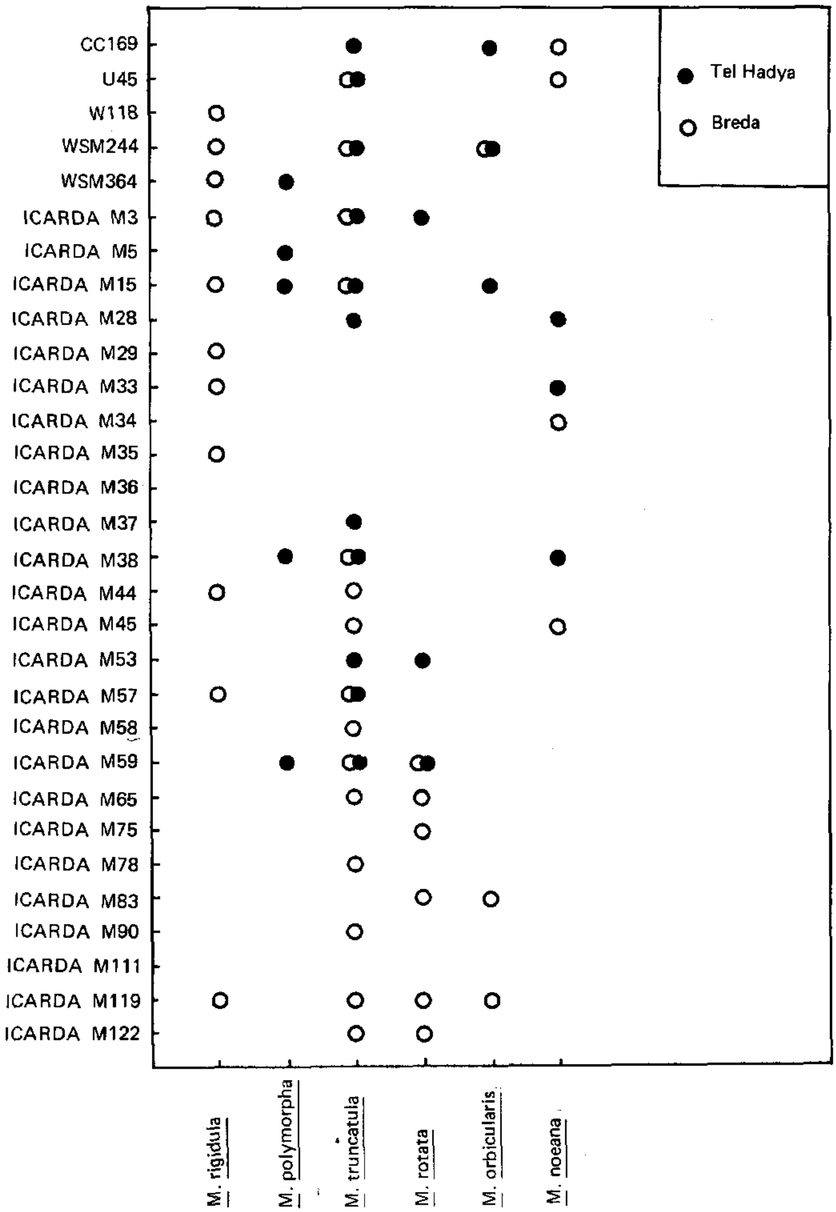


Fig. 5.1: Compatibility of 30 strains of rhizobia with six medic species at Tel Hadya (closed circles) and Breda (open circles). Presence of either closed or open circles indicates that the strain caused a significant increase in herbage yield over no inoculation: absence indicates no significant response.

Experiment 5.6: inoculation network trials

Several experiments to determine the need to inoculate pasture and forage legumes beyond north Syria were conducted with collaborators in Jordan, Syria, Turkey, Morocco, Tunisia, Italy, Australia, and Spain. Some used local plants and rhizobia as well as the material supplied by ICARDA. In addition to establishing the need to inoculate the objectives were to form close links with other institutions, to assist in solving other local problems regarding inoculation and strain/host specificities, and to evaluate some of our selected strains under different environmental conditions. The experiments are a means of disseminating information on how to conduct research on inoculation, nodulation, and related topics. We hope to expand the inoculation network trials in the coming years: those conducted during 1986-87 are listed in Table 5.8. Note that one experiment involved Hedysarum coronarium and another common vetch. These were included in response to specific requests from NARS.

It is not possible to present the results in this Report. However, all collaborations have returned results, which will be collated and presented in future Reports. - **Luis A. Materon**

Experiment 5.7: Mycorrhizae for medics

The objective of this experiment is, through using mycorrhizae, to improve nutrient uptake and nitrogen fixation. It is a collaboration with an advanced institute (the University of Granada), which will focus on developing techniques to inoculate soil with mycorrhizae.

Table 5.8. International network for inoculation of pasture and forage legumes..

Legume type	Collaborative institution	Country	Number of sites*
Medic	University of Jordan and SAGRIC International	Jordan	4
Medic	University Mohammed Ben Abdallah	Morocco	4
Hedysarum	Range Management Project	Tunisia	1
Vetch	Ministry of Agriculture	Syria	1
Medic	University of Tischreen	Syria	2
Medic	University of Cukurova	Turkey	1
Medic	CSIRO	Australia	(1)
Medic	University of Perugia	Italy	1(1)
Medic	Estacion Exp. El Zaidin	Spain	1

* Field trials and (in brackets) number of greenhouse trials.

In many semi-arid soils of west Asia and north Africa, scarcity of available phosphate is an important factor determining the growth of legumes: an adequate phosphate supply is necessary for satisfactory nodulation and symbiotic nitrogen fixation. Nodules often contain 2-3 times more phosphorus per unit of dry matter than the roots on which they are formed: the rate of fixation per gram of nodule can therefore be increased by fertilizer phosphorus. Various minor elements such as molybdenum, boron, zinc, iron, copper and sulphur are also required for satisfactory growth and nitrogen fixation.

Mycorrhizae can greatly 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 from soil beyond the root hairs, particularly for ions which diffuse slowly in the soil such as phosphate, zinc and molybdate.

A research team of the University of Granada is cooperating with ICARDA in isolating suitable strains of mycorrhizae for M. rigidula, M. rotata and M. polymorpha and are currently looking for the most productive medic-fungus combination. ICARDA's role will be to test these combinations in the field. The second phase will include evaluating techniques to infect roots with selected mycorrhizae and rhizobia.

Field experimentation will be initiated at an infertile site at Breda. - **Collaborative project with the University of Granada (Spain), Luis A. Materon**

Experiment 5.8: improvement of the energetic efficiency of medic rhizobia

In terms of its energy requirement biological nitrogen fixation is an expensive process for the legume. Hydrogen, which is a byproduct of nitrogen fixation, is lost as gas diffusing out of the nodules. However, some rhizobia species (not R. meliloti) have the capacity to recycle hydrogen, thus making nitrogen fixation process energetically less demanding.

Because it seems likely that this capacity to recycle hydrogen is a desirable characteristic in an efficient strain of rhizobia, and because the genes do not exist in medic rhizobia, we have started a cooperative project with the Polytechnical University of Madrid (Spain) in which the required genes will be genetically engineered into ICARDA strains M29 and M34. These strains have been chosen because of their proven compatability with M. rigidula, ICARDA's most promising medic.

The approach consists of transferring the genes P Sym-hup (coding for nitrogen fixation and hydrogen uptake) located in a portion of a plasmid carried by R. leguminosarum strain 128C53 into the genome of the two ICARDA strains. The plasmid has been marked by the transposon system (Tn5-mob) and transferred by bacterial conjugation into the receptors (strains M29 and M23). The strains so produced are currently being tested for genetic stability and to determine whether the alterations are due to the presence of the double genes coding for nitrogen fixation and hydrogen recycling. Once these parameters are defined and the organisms recommended for release, we will evaluate their symbiotic performance in association with the annual medics of interest to ICARDA.

ICARDA is aware that there are reservations about the release of genetically-engineered micro-organisms into the environment. While rhizobia are non-pathogenic and therefore do not represent any risk whatsoever, ICARDA will respect the views of organizations and countries and proceed with the release of genetically-engineered strains only when it is considered safe. - **Collaborative project with the Polytechnical University of Madrid, Spain; Luis A. Materon**

Experiment 5.9: freeze-dried oil-based inoculants

It has been demonstrated that inoculation of seeds with effective rhizobia is essential in many soils of west Asia and north Africa. However, survival of rhizobia is often impaired because of moisture stress after sowing, especially when sowing is shallow, necessary with small-seeded medics. To solve this problem we are looking for new systems of inoculation in which the rhizobia will have a better chance to withstand adverse environmental conditions. A new approach is to reconstitute rhizobia from a freeze-dried state and mix with mineral oil.

Freeze-dried inoculants have the advantage that they can be applied at higher rates (cells per seed) than peat based inoculants. This is especially important for small-seeded legumes and where populations of ineffective native rhizobia are high. Recently, some researchers have reported that oil-based inoculants extend the survival of rhizobia in dry soil.

Current work at the Boyce Thompson Institute (U.S.A.) includes the lyophilization of R. meliloti strains ICARDA M28 and M38, chosen because of their effectiveness with the most promising medic for north Africa (M. truncatula), and determination of their viability after freeze-drying and reconstituting in suspended mineral oil. These studies are being conducted in a sophisticated model-system condition simulator.

A small amount of this material will be available for inoculating medic in a small demonstration trial at Tel Hadya next season. - **Collaboration project with the Boyce Thompson Institute, U.S.A., Luis A. Materon**

CHAPTER 6: YIELD DECLINE IN CONTINUOUS CEREAL SYSTEMS

Chapter 6 describes a project, supported by the German Government and conducted by a German post-graduate student, which brings together scientists from three Programs: Cereals, PFLP and FRMP.

In the increasingly common continuous cropping system there is a distinct reduction in plant growth and a lower grain yield of cereal after cereal compared with cereal after fallow. This "decline" is thought to have many causes, including reduction of available plant nutrients, loss of soil fertility and structure, diseases and insect pests of the roots and stem bases, inhibition of the growth of cereals by phytotoxins arising from cereal residues (allelopathy), poor water-use due to changes in soil structure, and the build up of cereal weed populations.

The objective of the present project is to understand the causes of the decline under rainfed conditions. Four rotation experiments (of which two were used in 1986/87) were available to study the decline in the field, and additional experiments were set up under artificial conditions.

Studies such as this are basic to developing integrated cereal/livestock farming systems. As discussed elsewhere (Chapter 2) cereal yields in rotation with pasture and forages are often, but not always, equal to cereal after fallow. Where they are not, and Tel Hadya is an example, we need to develop an understanding of why this is so, to enable us to maximise returns from pastures and forages. The work reported in Chapter 6 is an attempt to do this.

Of the possible causes of decline in yield, the work this year was concentrated on nitrogen supply, plant density, soil microorganisms and crop residues.

Experiment 6.1: monitoring barley and wheat in rotation experiments (Preschedule M32 and M33)

Investigations were continued on two of the four experiments reported in the 1985/86 Program Report (Experiments A and C in 1985/86). In experiment A, which began at Breda in 1981, continuous barley is compared with barley/fallow and barley/vetch, and in experiment C, which began at Tel Hadya in 1983, continuous durum wheat is compared with six other rotations, including wheat/fallow and wheat/medic. Both experiments contain treatments comparing additional nitrogen with no nitrogen. The results in this section pertain only to the investigation of continuous cereal yield decline. Both experiments are under the supervision of FRMP.

Barley yield (Experiment A)

The objective of the work in this section was to study the components of yield in the three rotations under study.

Low plant and spike density (the number per m^2) were not important factors causing low barley yields in 1986/87, a result which agrees with observations in the year before. However, differences in plant height, spike length, plant size, and the number of kernels per head were marked ($P < 0.05$), even greater than in the previous season, barley after barley giving lower values than after fallow or common vetch (Table 6.1).

The reduction in growth of unfertilized continuous barley started to be measureable at the tillering stage (March 1987), and even earlier (February 1987) in fertilized barley (20 kg $_N$, 60 kg P_2O_5). The relationship between plant height and spike length (Fig 6.1) in continuous barley differed from that in barley/vetch and

Table 6.1. Morphological and yield characteristics of barley (cv. Beecher) grown in three rotations at Breda.

Rotation	Plant height(cm)	Spike length(cm)	Plant mass (g)	Kernels per head
Barley/barley	31.2	3.12	51.3	13.7
Barley/fallow	37.7	3.72	84.3	18.9
Barley/vetch	38.3	3.71	87.6	20.8
L.S.D.	5.8	0.60	14.9	3.0

barley/fallow rotations. The relative increase of spike length with increased plant height was lower in continuous barley compared with barley in the other rotations ($P < 0.05$).

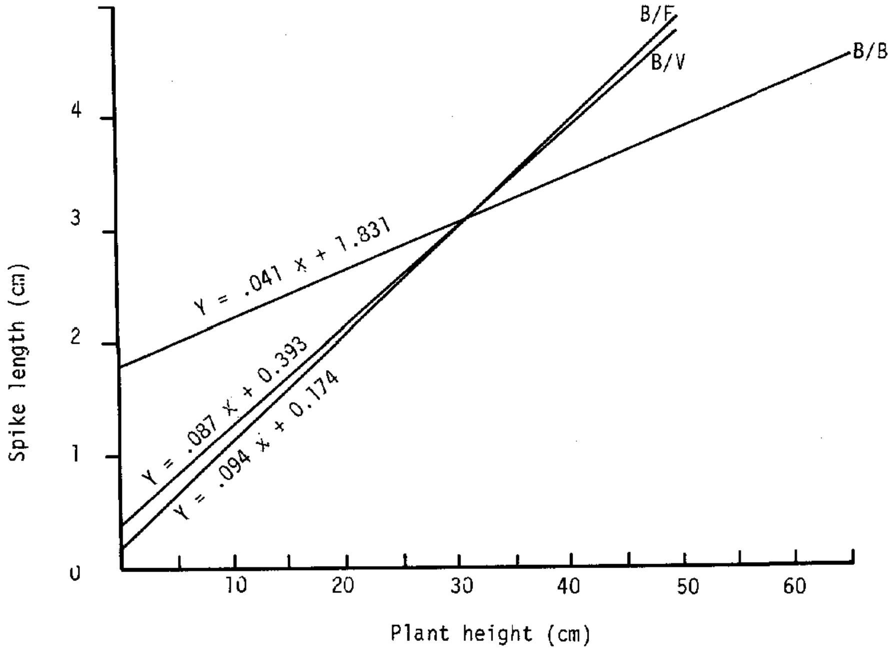


Fig. 6.1. Linear regession of spike length on plant height in barley after barley (B/B), barley after vetch (B/V) and barley after fallow, at Breda 1987.

Wheat yield (Experiment C)

The objective of this aspect of the work was to determine how far the decline in wheat yield is related to nitrogen supply when *phosphate is not a limiting factor.*

A comparison of the growth of wheat (durum wheat cv. Sham 1) after wheat (W/W) with wheat after fallow (W/F) or medic pasture (W/M) showed that adding 90 kg per ha nitrogen produced a large compensatory effect, over a wide a range of characters (Table 6.2),

Table 6.2. Effect of using nitrogen fertilizer in wheat/wheat (W/W), wheat fallow (W/F) and wheat/medic (W/M) rotations on the agronomic characters of durum wheat (cv. Sham 1) at Tel Hadya. The data is expressed in relative terms where W/F = 100.

Character	Nitrogen (kg)	W/W	W/F	W/M	L.S.D.
Dry mass	0	40	100	91	21
on 18 Mar.	90	79	100	106	17
Plant height	0	62	100	87	9
on 22 May	90	89	100	93	8
Plant number	0	56	100	56	18
on 22 April	90	76	100	94	18
Tiller number	0	64	100	93	17
	90	81	100	96	14
Seeds per head	0	51	100	85	27
	90	78	100	83	25
1000 grain mass	0	88	100	77	7
	90	98	100	86	8
Grain yield	0	41	100	59	23
	90	59	100	62	19

most interactions being significant. Results for spike length (P< 0.05) and the length of the leaf immediately below the flag leaf (P< 0.001) are illustrated in Figs 6.2 and 6.3 respectively. The ratio of length and width was significantly higher in continuous wheat (Fig 6.3). This shows that a narrowing of the leaf is a symptom of the continuous cropping syndrome in wheat, confirming results reported last year.

These results indicate the involvement of nitrogen supply.

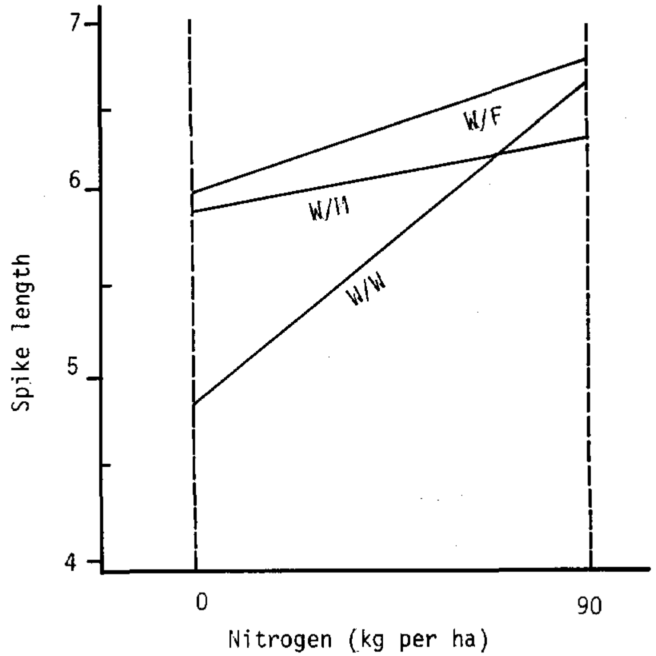


Fig. 6.2. Spike length at two rates of nitrogen (0 and 90 kg per ha) in three rotations at Tel Hadya: wheat after fallow (W/F), wheat after medic (W/M), and wheat after wheat (W/W).

Crop establishment (Experiment C)

It was shown in 1985/86 that there was a reduced emergence in continuous wheat compared with the other rotations. It is important to study the whole process from germination to emergence, and to discover whether germination occurs even though the seedlings fail

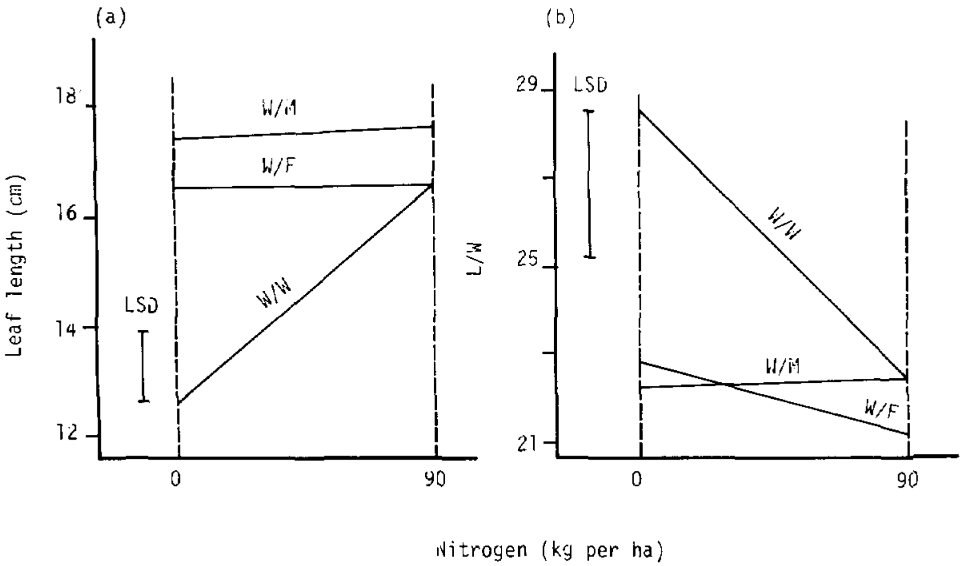


Fig. 6.3. (a) Leaf length and (b) length/width ratio of the last leaf below the flag leaf for three rotations at Tel Hadya: wheat after medic (W/M), wheat after fallow (W/F) and wheat after wheat (W/W).

to emerge above the soil surface. Another aspect of crop establishment is the change in seedling density: studies of seedling populations have also been conducted.

A "handsowing experiment" was established within the durum wheat rotation experiment, in which 100 seeds were sown in 5 rows to a depth of 8 cm precisely. Its objective was to monitor establishment and growth from a known number of seeds sown in the same conditions in the three rotations under study. About one month after sowing, samples of emerged seedlings and un-germinated seed were taken. It was found that there were more ungerminated seeds and more unemerged seedlings in W/W than in W/F or W/M. From their general appearance it could be easily seen that the whole plant development was slower at all stages of growth. Changes in plant density are shown in Fig 6.4: from the beginning to the end of the season the population density for continuous wheat was lower.

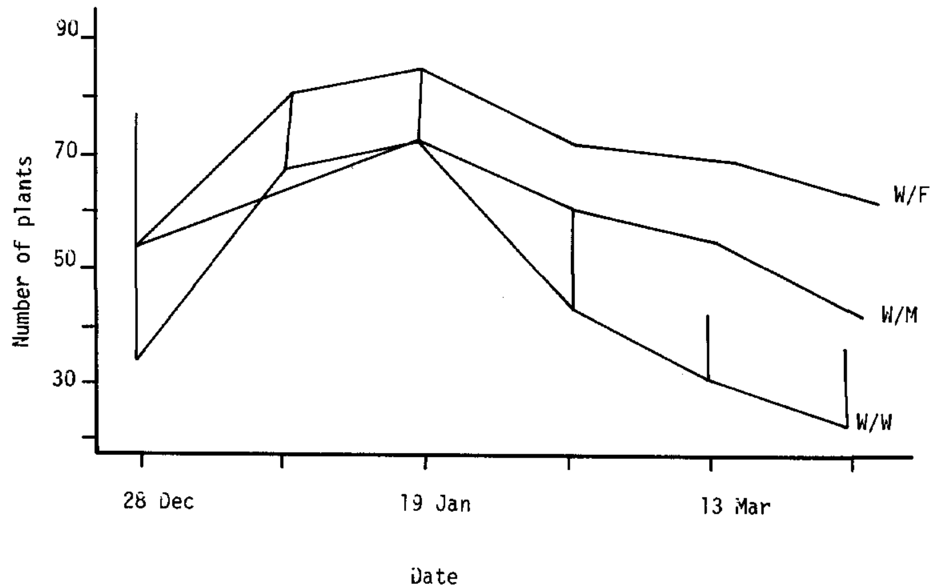


Fig. 6.4. Plant number, after sowing 100 seeds, present at six times in three rotations at Tel Hadya: wheat after fallow (W/F), wheat after medic (W/M) and wheat after wheat (W/W). The bars represent L.S.D. ($P < 0.05$) at each sampling time.

Plant pathology (Experiments A and C)

Investigation of the possible role of "foot" and "root" diseases in causing the decline were continued from last year. This year fungal diseases appeared at a low (wheat) to moderate (barley) severity, but there were no significant differences in root browning between crops in the various rotations.

A new finding is that a violet coloured organism can often be isolated from ungerminated and germinated seeds in continuous wheat rotations (Experiment C). The organism was first sampled in January 1987, and in February was also found on the roots and hypocotyl of wheat growing in all rotations, but most frequently in W/W. When germination of wheat was tested on plates inoculated with this organism germination was inhibited and there were pathogenic effects on the seedlings. Root growth was also almost completely inhibited, and shoot growth was reduced (P< 0.05) in both barley and durum wheat. It is therefore possible that presence of this organism is a previously unknown factor causing reduced growth and low seedling emergence in continuous wheat systems.

In the experiment with barley (Experiment A) the barley stripe disease, caused by Pyrenophora graminea, often occured, but did not appear to be affecting the lower stem of the plants.

Soil microbiology (Experiment C)

Work has been continued to compare the total microbial activity in soil of the W/W, W/M, and W/F rotations and to find whether certain organisms have a role in producing differences between continuous wheat and wheat after fallow. Colonies of bacteria, actinomycetes, and fungi were counted in soil dilution plates, there were three sampling dates for durum wheat, and soil was sampled at 5-7 cm and 25-27 cm depths. Only total population size has been analysed to date. Important results are summarised in Table 6.3.

There were fewer bacteria in W/W than in W/F or W/M soil at both 5 cm (P< 0.10) and 25 cm (P< 0.05) depths, and fewer actinomycetes in W/W samples taken at 5 cm (P< 0.05), but not at 25 cm. There was a significant increase in the ratio of the number of actinomycetes to the number of bacteria in soil down to 5 cm in W/F compared with W/M and W/W. The highest bacterial count (to 5 cm) occured in W/M, probably due to a higher amount of organic matter. A possible conclusion is that yield decline in continuous wheat is due to reduced microbial activity causing a lower rate of release of available nitrogen for the plants. This is despite the soil having the same amount of organic matter in W/W and W/F (measured at the same time).

Table 6.3. Number of individuals[1] (millions per g soil) of bacteria and actinomycetes at two depths in three rotations in February.

Rotation	Depth(cm)	Bacteria	Actinomycetes	Ac/Ba
Wheat/Wheat	5	42.1[a(2)]	5.6[a]	0.13[a]
Wheat/Fallow	5	57.7[a]	10.3[b]	0.18[b]
Wheat/Medics	5	75.3[b]	9.6[b]	0.13[a]
Wheat/Wheat	25	22.0[a]	7.5[a]	0.07[a]
Wheat/Fallow	25	30.2[b]	10.1[a]	0.12[a]
Wheat/Medics	25	32.6[b]	9.4[a]	0.10[a]

(1) Based on serial dilution counts assuming that one individual cell produces one colony in a plate test.

(2) In any group of three, numbers with different superscripts differ significantly ($P < 0.05$).

Crop residues

Cereal growth in patches of undecomposed straw residues often appear to be poorer than in surrounding areas. Therefore, to test whether cereal residues are toxic to cereal seedlings, a green house experiment on the effect of residues or of residue extracts was conducted. The following hypothesis was tested: during decomposition toxins are released which inhibit root development, or inhibit certain microbes essential to well-being of the plant.

The experiment had 12 treatments and 6 replicates in a randomized complete block design.

The treatments were:

1. Rotations (2): soil from the wheat/wheat (W/W) and wheat/fallow (W/F) treatments of Experiment C
2. Residues (3): + cereal residues, + an extract from cereal residues (watered in daily); and a control with no residues or extract
3. Sterilisation (2): autoclaved and not autoclaved soil

Plant establishment: Seedlings in W/W emerged slower than in W/F ($P < 0.005$) as also occurs in the field. The residue extract had a positive effect on yield in unsterilized soil, and one that was greater in W/W soil than in W/F soil (Fig 6.5). However in sterilized soil the effect of adding the extract on yield was reversed: yields were lower, but the negative effect was greater in W/W than in W/F, as the positive effect was in unsterilized soil (Fig 6.5). In W/W this interaction was highly significant ($P < 0.005$) but it was not so in W/F. It is possible that the high content of nutrients in the extract caused the positive effect in unsterilized soil while in sterilized soil there were deleterious products of sterilisation, and fewer microorganisms to inactivate toxins which could be responsible for the adverse effects on germination.

Without incorporating straw and root residues into the soil the coleoptile length of seedlings were smaller in W/W than in W/F (Fig 6.6). Adding the residues eliminated this difference. The addition of straw and root residues could have improved soil structure in W/W, or absorbed toxins. The microorganism population may also have been affected by toxins produced in previous seasons.

Chlorophyll content: Leaves of some plants in the crop residue experiments appeared brighter than of others. Plants were harvested at 4.5 weeks and from a standard leaf area chlorophyll was extracted by dimethyl sulfoxide, and light absorption in the extract measured

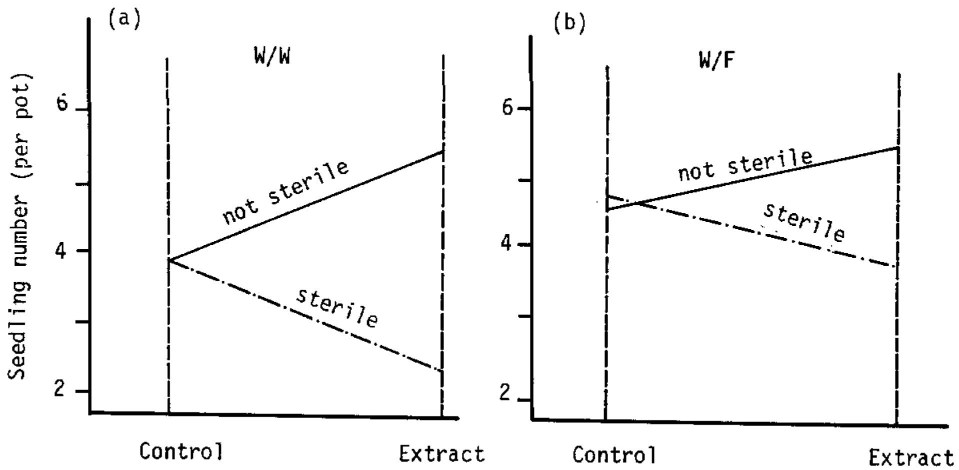


Fig. 6.5. Effect of a cereal residue extract on wheat emergence eight days after sowing in sterilized and un-sterilized soil of two rotations: (a) wheat after wheat and (b) wheat after fallow.

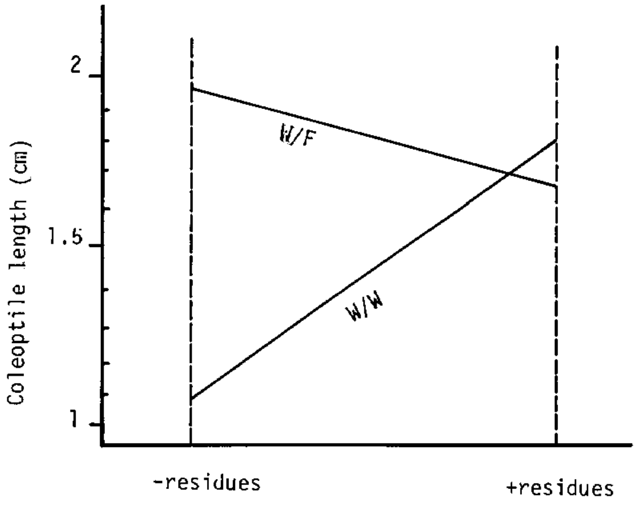


Fig. 6.6. Effect of cereal residues on the seedling size of wheat eight days after sowing in soils of two rotations: wheat after fallow (W/F), and wheat after wheat (W/W).

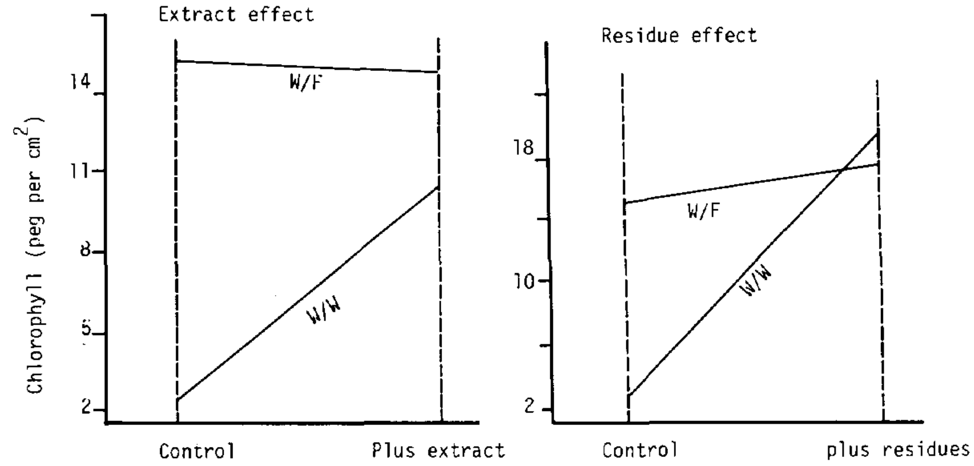


Fig. 6.7. Effect of cereal residues or their extracts on the chlorophyll content of wheat leaves growing in soil from two rotations: wheat after fallow (W/F), and wheat after wheat (W/W).

at 645 and 663 nm in a spectrophotometer. Results for chlorophyll a + b were measured in ug per cm^2. In W/F there was seven times more chlorophyll than in W/W (P< 0.001) (Fig 6.7). By adding a residue extract to the soil the amount of chlorophyll significantly increased (P<0.05) in W/W, but remained the same in W/F. These findings are again most easily explained by the release of nutrients in the extract, which stimulated wheat growth in the nutrient-poor W/W soil, but not in the more fertile soil after fallow.

By incorporating natural residues into sterilised soil the toxin effect increased in W/W soil, but not in W/F. This interaction is close to the significance level (P< 0.06). If this is correct it could indicate that the toxic effect is stronger in W/W, because there was a greater quantity of cereal residues present and there could be no amelioration of the toxicity by the microbial population. - **S. Krause, H. Weltzien (University of Bonn), O. Mamluk (Cereal Program)** and P.S. Cocks

CHAPTER 7: ECOLOGY AND AGRONOMY OF PASTURES

Pastures are complex mixtures of species, based, in our research, on legumes. In native pastures, species diversity is immense (see Table 2.1), but even in sown pastures there is a mixture of the sown and various volunteer species, all of which provide feed for grazing animals. The animals themselves interact with the plant population, grazing favouring some species at the expense of others. The study of the inter-relationships between species, climate, soil, and grazing animals is called pasture ecology, and is essential to develop our understanding of pasture-based farming systems.

The term pasture agronomy is limited to problems associated with the sowing and management of pastures in the first year of establishment. In Chapter 7 both ecology and agronomy are discussed together. The Chapter includes results of research on both sown and native pastures.

Experiment 7.1: establishment of medic pastures (Preschedule M30)

The objective of experiment 7.1 was, through the use of several currently available seeding machines, to compare the emergence and establishment of medic seedlings sown at a wide range of depths.

The first year of a medic pasture is critical. Once it is successfully established the pasture should be capable of self-regeneration indefinitely. Shallow sowing has been used successfully by ICARDA for a number of years. However, different methods and implements have been used and the distribution of seed in the soil was not determined, although year to year variation in seedling density was observed. For years when there is reduced establishment, detailed information is needed on which component of the seed population has failed.

A preliminary study, reported last year (1986 Annual Report), showed that germination improved with increasing depth from the surface to a depth of 3.5 cm. More comprehensive experiments were conducted in 1987.

Nominal sowing depths

Many types of sowing methods were used in experiment 7.1. Seed was broadcast, precision sown at 2, 4, 6, 8 and 10 cm, and sown deeper by incorporating seed (which had been broadcast) by cultivation with a ducksfoot cultivator at its maximum working depth of about 20cm.

On the first sowing date (21 October 1986), 24 establishment methods (Table 7.1) were compared, 16 of these being compared again in a later series of sowings (11 December). The first date encountered the hazard of a 6-week drought; emergence varied between 16 and 83% among treatments, the mean value being 53%. The second sowing date produced a mean emergence rate of 51%, varying from 22 to 77% among treatments.

All methods produced a medic stand, for which seedling number, herbage yield, and seed yield were measured. There were no total failures, stands varying from excellent to moderate or poor.

In the first sowings, the results were excellent at nominal depths of from 0 to 6 cm, with a conspicuous reduction in yield at 10cm. For the second sowing, the results were good for nominal depths from 2 to 10cm, with a reduction in yield when seeds were broadcast.

The best sowing depth was 4cm (for both sowing dates).

Table 7.1. A list of sowing methods used in experiment 7.1.

Code	SOWING
0	Drilled, Normal Oyjord
	Drilled, Special Oyjord
02	Depth 2 cm
04	4 cm
06	6 cm
08	8 cm
010	10 cm
B	Broadcast
Code	**COVERING**
N	Nil
R	Rolling
T	Tabban
H	Spike-toothed harrow (5 cm)
D	Ducksfoot cultivator (10cm)
Rake	Use of a rake
	SPECIAL EFFECTS
I	Inoculated with rhizobia
Rock	Sown on shallow soil over rock

Table 7.1. continues on the next page.

Table 7.1. Continued.

TREATMENT COMBINATIONS (PLOT TYPES)
AND ACTUAL DEPTH OF SOWING

TREATMENT	DEPTH	TREATMENT	DEPTH
ON	Intermediate	BN*	Shallow
OR	Intermediate	BR	Shallow
OT	Intermediate	BT	Shallow
OH*	Deep	BH	Deep
OD*	Deep	BD	Deep
ODT*	Deep	BDT	Deep
02	Intermediate	BI	Shallow
04	Intermediate	02I	Intermediate
06	Deep	04I	Intermediate
08	Deep	06I	Deep
010	Deep	08I	Deep
B. Rake*	Shallow	B. Rock*	Shallow

Note

Treatments marked * are not sensible practical methods, but they were included in the design as extras or to give all combinations necessary for interpretation of results if something unexpected happened. For example, if there were a delay (due to breakdowns or weather) between sowing and covering, it might be difficult to determine the reason for differences between treatments ON and BH: establishment would be affected not only by the deeper position in BH than in ON, but also by the immediate protection at sowing afforded by ON in contrast to BH. The relative performance of the treatments could vary with the weather pattern. Thus the inclusion of the extra treatments OH and BN was considered desirable.

Excavation of seeds

Observations on the recovery of seed after sowing were made for the early sowing date. They showed that a high population of seeds went deeper than the nominal sowing depth, due probably to falling down cracks, and some seeds were nearer to the surface than expected, presumably due to the soil settling and compacting. The sowing rate of 30 kg per ha gave an expected 530 seeds per m^2. Excavation of soil was made only from the most likely depths (to reduce labour costs). Nevertheless this resulted in a high rate of recovery, a mean of 440 seeds (83% of seed sown) per quadrat being found (mean for all treatments).

They were distributed at depths from 1 to 21 cm (the lowest sampling depth).

Actual sowing depths

Although many interesting comparisons may be made of the 24 methods, it is more useful to relate the actual sowing depths achieved to subsequent establishment and pasture productivity. Nominal sowing depths, even where "precision" sowing was employed, are less useful than actual depths, determined directly.

Using the results of the seed excavation studies (since most of the seed sown was recovered), the treatments could be classified in three categories:

Shallow: 1-3cm, within which 78% of seed was recovered.
Intermediate: 4 to 7cm (74% of seed).
Deep: 6 to 11cm (86% of seed).

The classification of sowing methods is given in Table 7.1. Table 7.2 summarizes the results for the three depths, and shows that the intermediate category was superior to the other two under the prevailing weather conditions.

Table 7.2: Twenty four methods of sowing medic (termed "treatments") involving different machines, nominal depths and ways of covering the seed, have been classified according to the actual seed depth achieved. The influence of actual depth on seedling emergence and pasture yield is given for sowing on 21 October. Sixteen treatments were tested again on 11 December.

Depth	Number of Treatments	Seedling Emergence (%)	Dry-Matter Yield (kg/ha)	Pod Yield (kg/ha)
	Early Sowing Date (21 October)			
Shallow	6	50	4429	1793
Intermediate	7	63	4072	1564
Deep	11	45	3261	1473
	Late Sowing Date (11 December)			
Shallow	3	37	1983	*
Intermediate	7	58	2634	*
Deep	6	50	2300	*

* data not yet available.

Seed germination

The average number of seedlings which emerged was 300 per m^2 (57% of total seeds sown). When the emergence rate was assessed for each seed depth, the evidence for 14 treatments suggests that many seedlings emerged from depths down to 6-7cm while in 4 treatments emergence from between 8 and 11cm is implied. In two broadcast treatments, most of the seed occurred at 1-3cm and suffered a 50% death rate.

Inevitably the quadrats used for excavation were not the ones used for counts of seedling emergence and so the above evidence is indirect because of variability in the distribution of seed. Direct measurements of hypocotyl length were therefore made. Mean length varied from 4.4 to 6.9cm, values compatible with known seed depths. Roots reached a mean depth of 10.5cm, a value which was fairly constant among treatments.

Table 7.3. A comparison of rainfall with soil moisture levels at various depths during a subsequent drought, and the distribution of roots of medic seedlings which survived the drought.

Rainfall. Total rain received by 8 November, before the drought	65 mm
Soil Moisture Present in the profile to a depth of 21 cm at mid December during the drought (expressed as mm of rain)	27 mm
Distribution of Moisture in the soil in mid December	
Depth 0-7 cm	18 mm (65%)
Depth 7-14 cm	6 mm (23%)
Depth 14-21 cm	3 mm (12%)
Total	27 mm
Distribution of Roots of seedlings which germinated on 5 November and survived the drought. Measurement made mid December.	Hypocoty[1] length 4.6 cm Roots from 4.6 - 10.5 cm

Soil moisture

In the early sowing, measurements of soil moisture were related to hypocotyl length and root distribution. The observations were made in mid December, a month after most of the seedlings had emerged (5 November).

Results are given in Table 7.3 and show that the lower layers of *soil were fairly dry and that seedlings had their roots in the* moister layers of soil. Since the soil below 10cm was dry it is presumed that the deeper sowings were at a disadvantage in a rainfall pattern which failed to maintain moist soil at the position where some of the deeper seedlings had their roots.

To simulate good and bad seasons it is planned to test the present findings under ambient rainfall, and to use shelters and irrigation. A survey of medic sowing experience under different weather patterns is currently being conducted, and from preliminary results it seems that the minimum requirement for emergence is probably 45 ± 5 mm from recent rainfall of which 10 ± 5 occurs soon after sowing. It is hoped to test this hypothesis. - **A. Smith, N. Nersoyan**, and **M.** Touma

Experiment 7.2: effect of frequency and severity of defoliation in first year medic pasture (Preschedule L35)

The objectives of experiment 7.2 were firstly to measure the effect of severe and light defoliations on first year medic pasture, and secondly to compare recovery of medics with that of other legumes.

Plant species respond in different ways to the stress imposed by defoliation under grazing. A project was conducted in which various pastures were subjected to contrasting harvesting regimes during a two-month growing period. The influence of these on herbage production was examined, and used as a prediction of the reaction of species to grazing. Because it is easier, harvest was by hand rather than involving grazing animals.

Four treatments were obtained by combining two frequencies (weekly and every 2-4 weeks) and two severities (10-20% removed and 50-60% removed) of defoliation: hereinafter termed often and seldom, and mild and hard, respectively.

An extract of the results is given in Fig. 7.1 which shows that herbage productivity declined with increased frequency of simulated grazing, and that mild grazing was less damaging to the pasture than hard grazing. It is interesting to see that medic (M. rigidula selection 716), a pasture species, responded better to grazing than common vetch, traditionally a forage species.

"Yield" in this experiment was the total of the herbage removed and that finally remaining. Inevitably the proportion 'grazed' varied with the regime, and although higher yields were obtained with little or no grazing, there would be serious consequences in terms of animal production if conserved herbage were not available for that type of management.

For comparative purposes, crops which are not adapted to grazing were included in the experiment. It was not surprising that herbage yield of wheat and lentil declined rapidly with defoliation intensity. - **A. Smith and participants in the residential training course**

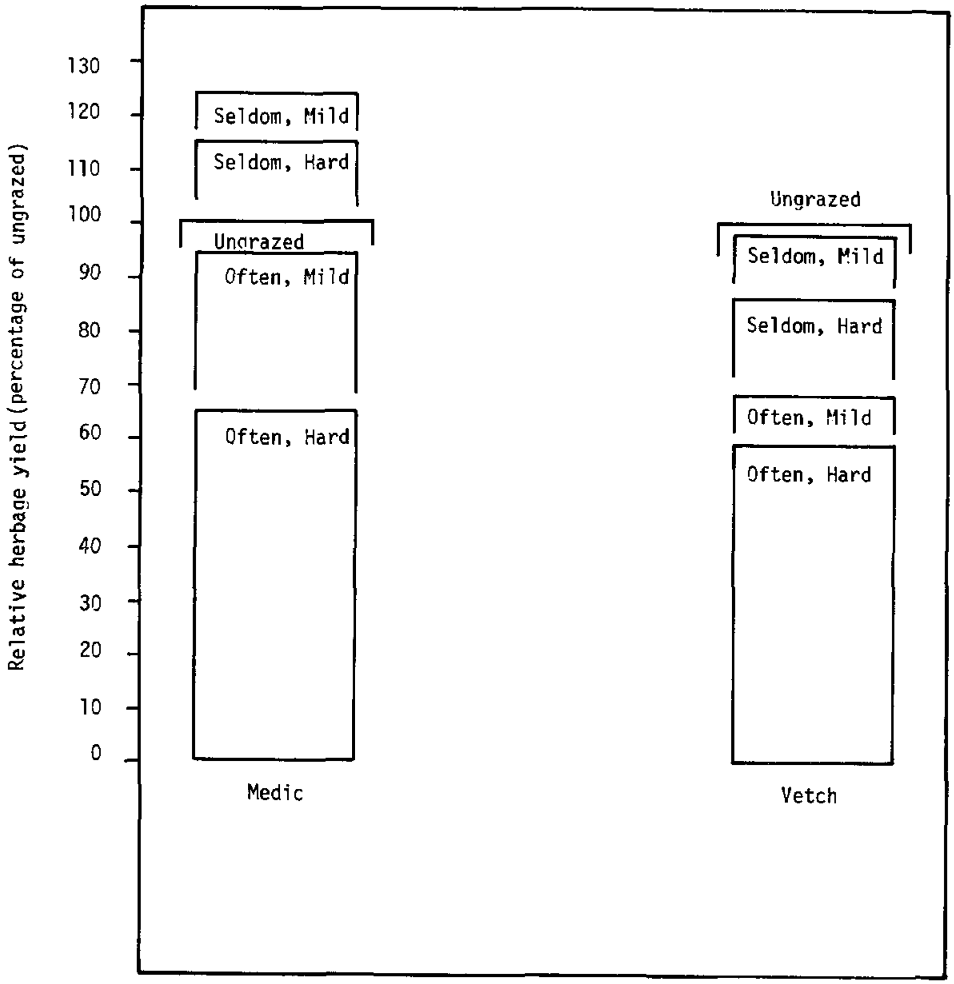


Fig. 7.1: Influence of the frequency and severity of defoliation under simulated grazing on the cumulative yield of medic and vetch between March and May. Two frequencies and two severities, when combined, gave four defoliation treatments, the yields for which are shown relative to the standing biomass from an ungrazed control (defined as 100% for each diagram).

Experiment 7.3: selection by grazing sheep among medic/weed populations (Preschedule L29)

The objectives of experiment 7.3 were firstly to compare the influence of severe with lenient grazing on seed production of first year medic pasture and secondly to quantify the influence of grazing severity on the balance between medic and weeds in first year pasture.

For medic pastures, the first (establishment) year is critical for seed production. It will be necessary to advise farmers on how to deal with a poor establishment dominated by weeds: when to start grazing in spring and how to manage livestock.

A project was therefore conducted to throw more light on this subject. "Good" and "poor" medic (M. rigidula selection 716) pastures were produced by varying the seed rate. These pastures were then grazed by sheep at three grazing pressures:

HARD (to destroy the weeds);
MILD (to allow the medic plants to grow well);
or at an INTERMEDIATE pressure.

Grazing was on two occasions, in February and in March. Continuous grazing would have been difficult to achieve and so rotational grazing of small plots using a large number of sheep for a short time (less than one week) was employed.

A summary of the treatments used is given in Table 7.4. They produced large differences in pasture productivity measured as the quantity of herbage produced by medic and weeds, and the quantities of seed finally remaining. The range of variation is given in Table 7.5, and varied from x2 to x18.

Table 7.4. Summary of grazing management treatments in experiment 7.3.

		Main Effects
	Date of grazing	
E	Early	Grazing in February and March
L	Late	Grazing in March only
	Quality of pasture	
G	Good	High proportion of medic in pasture
P	Poor	Low proportion of medic
	Grazing pressure	
H	Hard	Weeds (and, incidentally, medic) almost completely eaten
I	Intermediate	
M	Mild	Little grazing of medic (or, incidentally, of weeds)
		Grazing Management Treatments
EPH	Early,	Hard grazing of poor pasture
EPI	Early,	Intermediate grazing of poor pasture
EPM	Early,	Mild grazing of poor pasture
EGH	Early,	Hard grazing of good pasture
EGI	Early,	Intermediate grazing of good pasture
EGM	Early,	Mild grazing of good pasture
LPH	Late,	Hard grazing of poor pasture
LPI	Late,	Intermediate grazing of poor pasture
LPM	Late,	Mild grazing of poor pasture
LGH	Late,	Hard grazing of good pasture
LGI	Late,	Intermediate grazing of good pasture
LGM	Late,	Mild grazing of good pasture

Stocking rate had little influence on the quantity of medic seed produced (Fig. 7.2), but early grazing resulted in a substantially greater output of weed seeds. In terms of kg per ha of seed, medic and weed seed productions were similer. However, seed size of weeds varied from 0.02mg (Silene sp) to 20mg (Scorpiurus sp) among the 17 or so species present, a range of x1000, in comparison with medic which had seeds of mass 5.5mg (varying with the season of growth). There was a preponderance of small-seeded weeds so that in terms of seed number the advantage was in favour of weeds.

However, this was in a situation where there was no grazing while the medic pods were developing in April and May. During that time there was rapid weed growth, even in plots where hitherto there had been little evidence of weeds. The results indicate the need for a further experiment in which grazing is continued during April and May. To avoid medic pods from being removed at that time it is also proposed to use goats, which often prefer to eat plants other than legumes. - **A. Smith, N. Nersoyan, and M. Touma**

Experiment 7.4: the grazing of plant parts by sheep (Preschedule L36)

The objectives of experiment 7.4 were twofold: to compare the effects of 'grazing' different parts of the plant on herbage and seed yield, and to predict ways of controlling grazing to increase yield.

It has already been shown (Chapter 2) that sheep may select among different parts of a plant, and that, in the case of medics, they may differentiate between leaves, apical areas and other parts. It is important to learn whether this choice has implications to productivity, and if so whether appropriate agronomic or grazing management options may be open to us.

Table 7.5. Range of influence of the twelve grazing management treatments (in brackets) listed in Table 7.4 on actual and potential herbage dry matter production, sheep grazing days, and on the quantity of seeds produced, for medic and weeds growing in a mixed pasture. Rounded minimum and maximum values are quoted for treatment means, the range expressed as a factor calculated on accurate values as the ratio of the maxima and minima.

	Minimum	Maximum	Factor
Actual Herbage Production (t per ha)			
Medic Eaten	0.2	1.5	X8.4
	(EPM)	(LGH)	
Weeds Eaten	0.2	1.4	X6.2
	(EGI)	(LPH)	
Sheep grazing days (12 hrs)			
per hectare	103	1812	X17.5
	(EPM)	(LGH)	
Potential Herbage Production (t per ha)			
Palatable	2.0	5.7	X2.9
(medic+weeds eaten	(EPH)	(EGM)	
and medic remaining)			
Total	5.1	8.6	X1.7
(above plus all	(LGH)	(EPH)	
mature weeds remaining)			
Seed Production (kg per ha)			
Medic	247	537	X2.2
	(LPH)	(EPI)	
Weeds	180	680	X3.8
	(LPH)	(EPM)	
Seed Production (number, millions per ha)			
Medic	44	97	X2.2
	(LPH)	(EPI)	
Weeds	273	805	X3.0
	(LPH)	(EPH)	

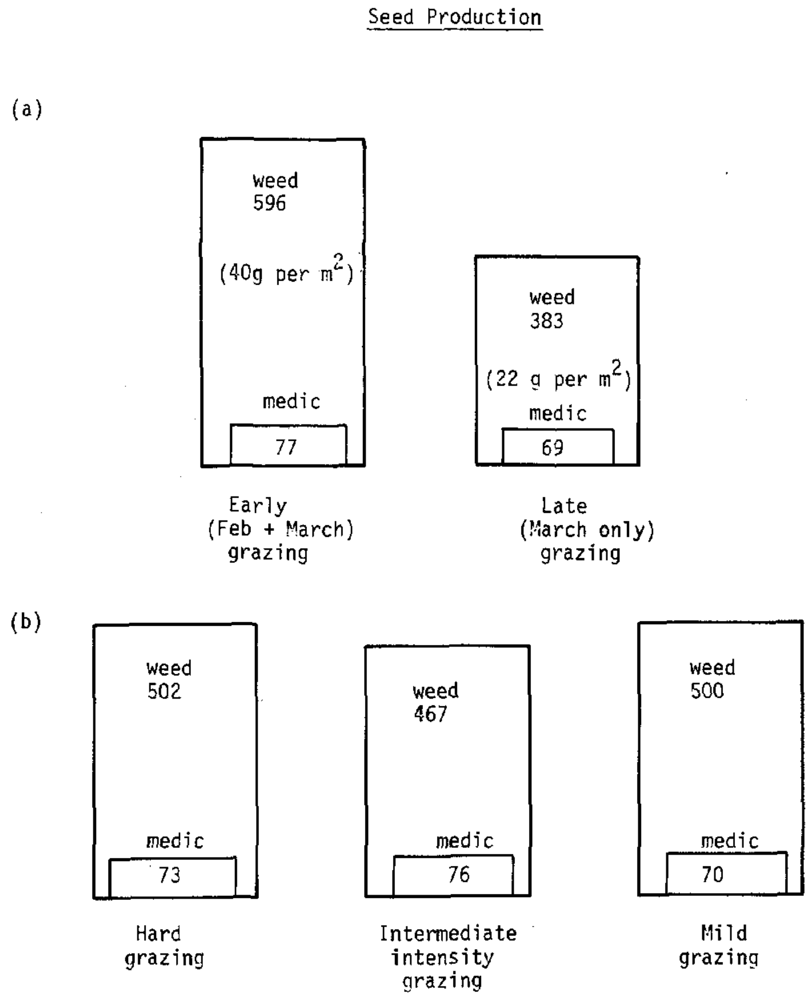


Fig. 7.2: Influence of (a) early grazing compared with late-season grazing on the number of weed seeds produced in a medic-weed mixed pasture, contrasted with (b) the lack of influence of grazing pressure on either the number of weed or of medic seeds (numbers in millions per hectare).

Initial investigations, made last year, strongly suggested that the removal of shoot apices (together with leaves and stems) caused a serious reduction of herbage yield and pod production, whereas the removal of leaves (but not shoot apices) did not seem to be damaging.

A shoot is defined here as part (but not all) of the aerial part of a plant, consisting of a stem with attached leaves, flowers, fruits, and smaller lateral branches. The primordia consist of the main (terminal) apex of that shoot, and lateral apices. Each apex may be vegetative or reproductive. A shoot could also be termed 'a branch' of the plant, with lateral or secondary branches.

Results in 1987 confirmed the previous observations. A highly significant difference in herbage yield and pod number occurred: the removal of leaves only resulted in higher production than the removal of complete shoots including (at later dates) flowers and pods, or the removal of only the tips of shoots. In experiments conducted in both years, the severity of shoot excision has varied between the removal of the shoot tip only, half shoots, and complete shoots. In all cases, the fundamental common effect has been the removal of the main apex system, a factor which seems to have the major influence on productivity, while the length of each portion of shoot removed seemed to have only a secondary effect.

In experiment 7.4 the harvesting of leaves gave 15% more dry-matter yield (including pods) and 80% more pods, when measured during the period 26 March to 4 May, and compared with shoot harvesting. However, when pod yield was measured (on 25 May, by which time pods were fully matured and dry) the removal of leaves gave an advantage of 24% in pod number, and a 35% advantage in seed number compared with the removal of shoots (two treatments meaned).

Results are summarised in Fig. 7.3. In future it is hoped to relate these findings to the activities of sheep and goats, in order to design improved grazing systems. It should also be possible to manipulate pasture by the use of agronomic practices (e.g. changing the seed-rate) to alter the positions of leaves and flowers (through the effect of density).

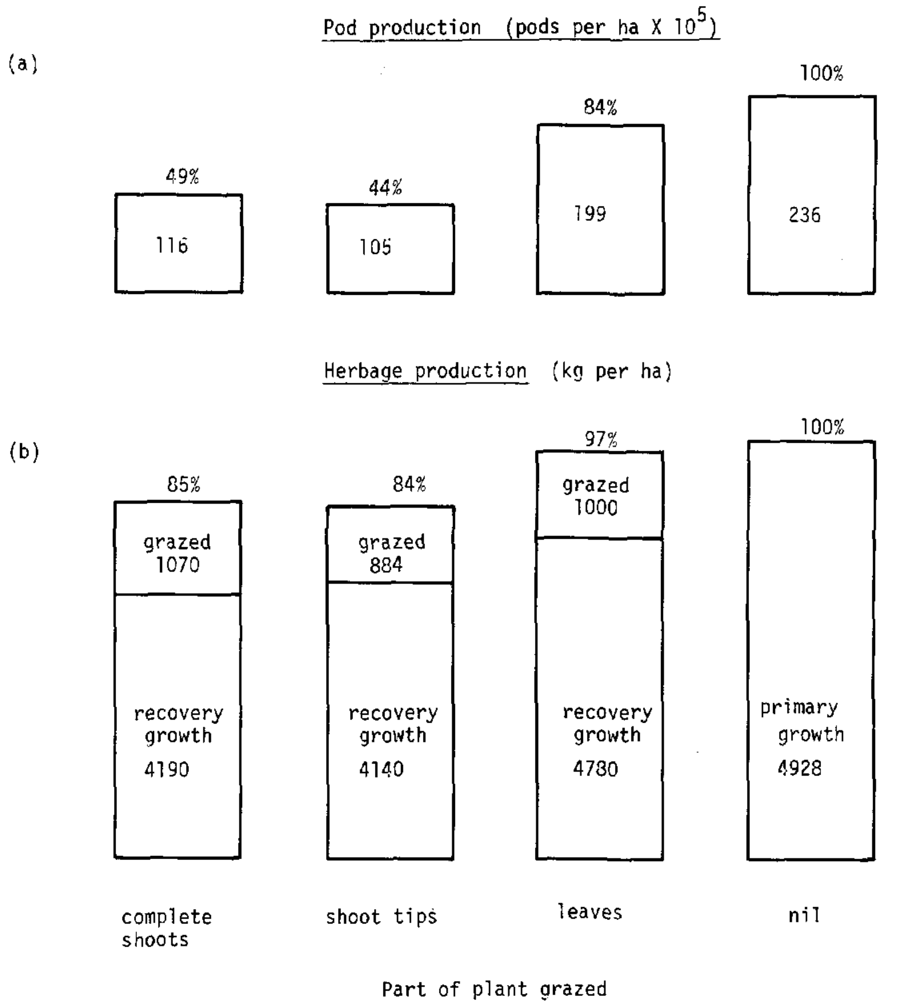


Fig. 7.3: Plant morphology and grazing. The effect of harvesting only leaves, or complete shoots, or only the tips of shoots by simulated grazing on (a) seed production and (b) herbage by a weed-free medic pasture.

Another factor to be considered later is date of starting shoot apex removal. It is probable that, if this occurs very early in the year, the results will be different from removal later due to the changing balance of dominance and suppression among apices, and the dates of initiation of reproductive apices.

It is also worthwhile to screen medic species and genotypes for the presence of genotypes with an appropriate morphology, that being genotypes with prostrate stems, pods close to the ground on short peduncles, leafy, and the leaf laminae elevated on long petioles. It is then possible that under grazing, the leaves will tend to be removed first and the pods tend to remain on the plants - an ideotype rather like subterranean clover (*T. subterraneum*).

In 1987/88 it is proposed to screen medics for the presence of suitable characters which will be tested for yield in comparison with normal phenotypes. These are expected to produce more pods under close cutting, and ultimately under grazing for which purpose they are being evaluated. Promising selections will form the progenitors of lines which could lead to a new variety. - **A. Smith and participants of the residential training course**

Experiment 7.5: the response of pasture legumes to application of phosphorus (Preschedule ML6)

The objective of experiment 7.5 was to establish the shape of the phosphorus response curve of several annual legumes.

In understanding the ecology of marginal land it is necessary to know what happens to components of plant communities. In doing this it is very important to study the response of individual species to phosphorus to determine if variation exists. The investigation of the factors which affect phosphate response of legumes in marginal land (see Chapter 2) has shown that details are needed of the shape of response curves for the most common species in various locations.

In this experiment five species (M. polymorpha variety Tah, M. rigidula selection 716, M. noeana selection 2124, M. rotata selection 1943, and Astragalus hamosus) were sown at nine rates of phosphorus (0, 4, 8, 16, 24, 32, 40, 60 and 80 kg per ha), the rates having been chosen to give response curves. The experiment was conducted at ICARDA's out station near Jinderis (annual rainfall 470 mm, rainfall in 1986/87 601 mm, available P less than 2.5 ppm). The species were chosen on the basis of their being widespread and abundant native plants of Syria.

The treatments were arranged in a randomized complete block with three replicates. Prior to sowing the soil was sampled from 0-10cm for available P.

The Oyjord experimental drill was used to apply the treatments. After inoculating the seed with appropriate rhizobia the plots were sown on 20 November at 40 kg per ha. Herbage was harvested on two occasions, winter and spring: at each harvest plants were cut to ground level in 1m x 2m quadrats. The samples have been stored for chemical analysis.

Seed yield was measured in June, in 1m x 1.5m quadrats. Pods were separated from the soil and other residues, threshed, and weighed.

Herbage production

The data in Table 7.6 show the average response in herbage yield of the five legumes in winter. Astragalus hamosus did not show any significant response to phosphorus, there were small (but insignificant) increases in M. noeana and M. polymorpha, while M. rigidula and M. rotata showed highly significant winter responses. In spring, M. rigidula and M. polymorpha reached maximum herbage yield at 60 kg per ha of P, after which yield started to decrease (significantly so at P80 for M. rigidula): in M. rotata and M. noeana herbage yield was still increasing up to the highest P rate.

Table 7.6. Effect of phosphorus rate (kg P per ha) on herbage yield (kg per ha) (a) in winter and (b) in spring of five pasture legumes.

P rate	*M. rigidula*	*M. noeana*	*M. rotata*	*M. polymorpha*	*A. hamosus*	Mean
(a) Winter yield						
0	256	135	216	136	64	162
4	316	134	216	146	62	175
8	323	136	212	174	65	182
16	348	144	251	179	68	198
24	422	158	254	184	70	218
32	502	170	283	187	67	242
40	523	172	323	184	67	254
60	539	187	364	188	74	270
80	550	195	399	200	62	281
Mean	420	159	280	175	67	
LSD (P<0.05)	80	80	80	80	80	36

The response to phosphorus in spring is best illustrated by a model often used for describing fertilizer response, the Mitscherlich response function which is most simply written

$$Y = a\,[\,1-e^{-b(x+c)}\,],$$

where **a** represents the asymptotic level of yield, **b** the rate at which yield tends to its asymptotic level, and **c** the amount of phosphorus already available in the soil. By applying this equation to the spring data the response curves for the five species were drawn (Fig. 7.4).

The legumes responded differently to phosphorus. *M. rigidula* and *M. rotata* produced the most herbage at all levels of P and responded the most, while *Astragalus hamosus* produced least and showed the least response. The species with the highest percentage

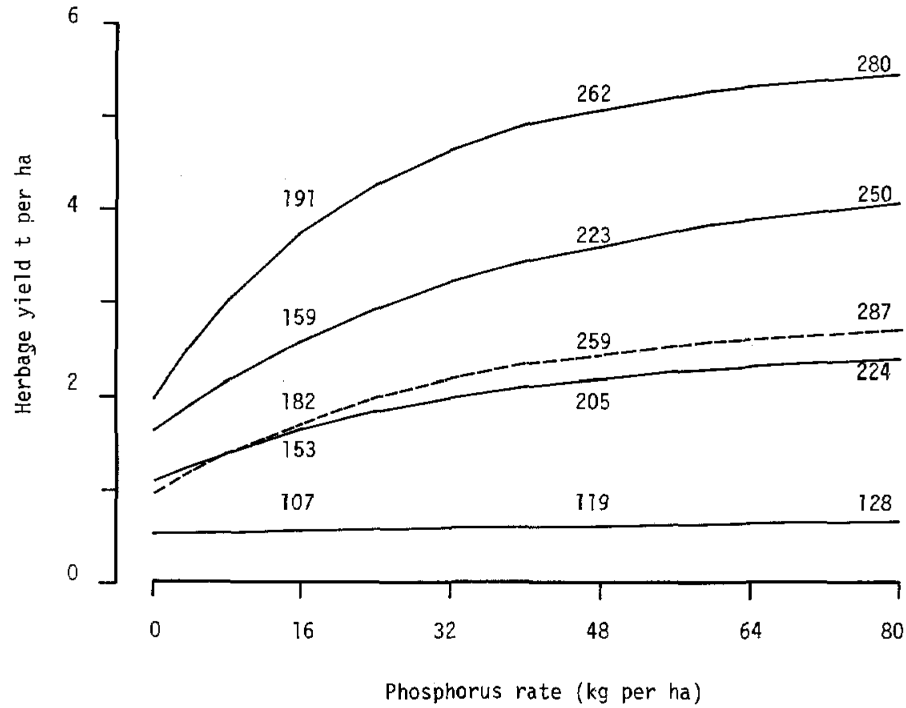


Fig. 7.4: The response in herbage production (t per ha) of (from top to bottom) Medicago rigidula, M. rotata, M. noeana (broken line), M. polymorpha, and Astragalus hamosus to phosphorus. The numbers are relative yields (base 100 at zero phosphorus) calculated on the basis that a Mitscherlich response curve fits the original data.

increases in dry matter were M. noeana and M. rigidula. Note that the reduction in yield of M. rigidula and M. polymorpha, previously mentioned, is not shown in Fig. 7.4 because the Mitscherbich equation assumes no such reduction.

Applications of slightly less than 20, 24 and 36 kg per ha of P were enough to double the spring herbage yield of M. rigidula, M. noeana and M. rotata, respectively, while for M. polymorpha a similar response was obtained at 44 kg per ha of P. For Astragalus hamosus, even by application of the highest rate of P, herbage yield could not be doubled.

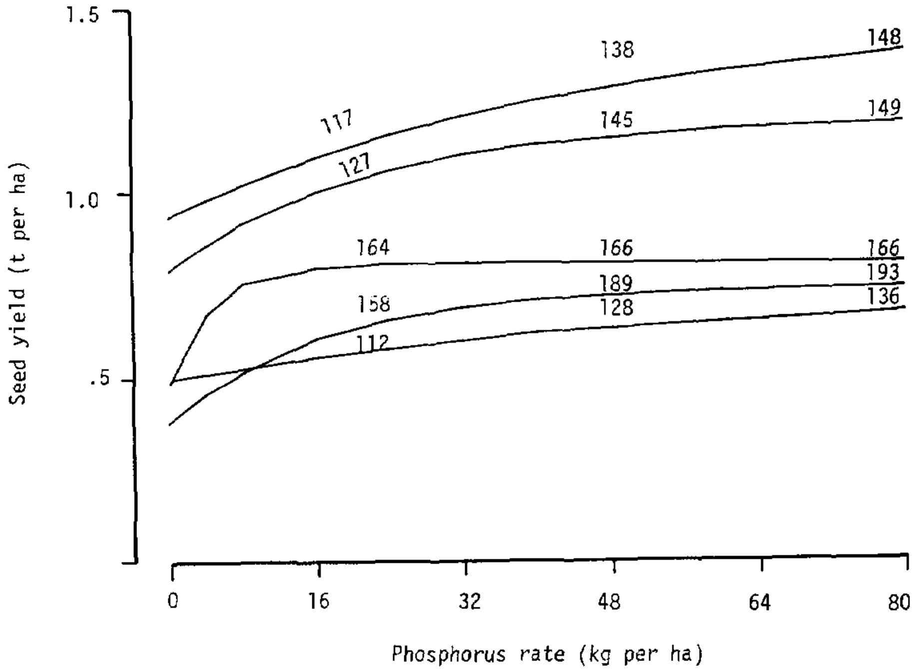


Fig. 7.5: The response in seed production of (from top to bottom) Medicago rotata, M. rigidula, M. noeana, M. polymorpha, and Astragalus hamosus. *The numbers are relative yields* (base 100 at zero phosphorus) and the position of the lines calculated using a Mitscherlich response curve.

Seed production

The effect of phosphorus on seed yield of the five legumes is shown in Fig. 7.5. As with herbage M. rotata and M. rigidula produced the highest seed yields at all P levels. The fitted curves reveal that M. polymorpha and M. noeana were the most responsive. Although there were some increases in seed yield of Astragalus hamosus these increases were not significant, and this species must be regarded as unresponsive.

The results confirmed previous findings that seed yield is less responsive to phosphorus than herbage yield. After chemical analysis the results of this experiment will help to assess the responsiveness of previously un-fertilized native pasture. - **M.A. Turk, Prof. A.J. Willis, and (University of Sheffield) P.S. Cocks**

CHAPTER 8: PARASITES IN AWASSI SHEEP

Increasingly, aspects of animal health are seen as constraints to the adoption of new livestock-producing farming systems. In the previous two Program Reports (ICARDA 1985, page 130, and PFLP 1986, page 4) there have been brief descriptions of work sponsored by JICA which has monitored the incidence of gastro-intestinal parasites, especially in experiment 2.1. In the course of this work the prevalence of nematodes in the lungs of Awassi sheep has been observed to be the most important chronic health condition suffered by the sheep. This year the work has been expanded to study the effect of drenching village sheep with anthelmintics to control these lungworms.

Experiment 8.1: monitoring helminth parasites in the sheep of experiment 2.1 (Preschedule ML2)

Especially at high rates of set-stocking an important factor in new grazing systems is the health of livestock. In particular the risk of internal parasites is significant and presents to farmers a problem which may not exist in traditional systems. While it was not the aim of experiment 2.1 to study internal parasites - indeed the sheep are drenched as a matter of routine - it seemed a good opportunity to monitor internal parasites, especially lungworms, and see if there was any indication of a build-up in numbers at high rates of stocking.

Preliminary work in 1984/85 (Thomson and Orita 1988) had already indicated that lungworms are a greater threat to sheep than the gastro-intestinal helminths. Of the lungworms, *Dictyocaulus* filaria, a species living freely in the lung passages, is less common than the parenchyma dwelling parasites of the Protostrongylidae.

Faeces were taken at monthly intervals from November 1986 to November 1987 from two of the five sheep in each treatment of experiment 2.1, selected randomly. Helminth eggs were counted using the McMaster technique and lungworm larvae counted after extraction from faeces using a modified Baerman apparatus. All sheep were drenched with GH27 (Levamisol) on 29 December 1986 and Ivomec(ivermectin)/GH27 on 10 March 1987 to control all helminth parasites.

The percentage of ewes infected with lungworms and strongylid (gastro-intestinal) helminths each month are shown in Fig. 8.1. The seasonal cycle of reproductive activity of the parasites are apparent, the highest levels of infection being in autumn and winter when temperatures are low, humidity is high, and when egg laying by the parasites takes place.

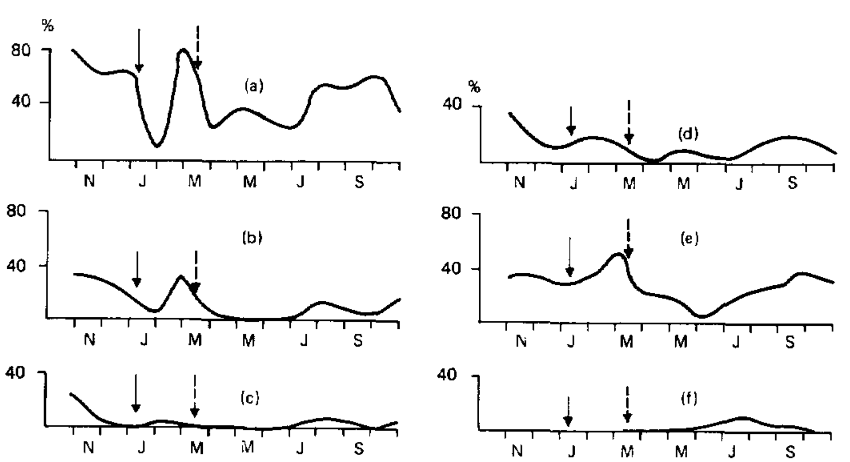


Fig. 8.1: Percentage of ewes infected with (a) strongylid (gastro-intestinal helminths, (b) Dictyocaulus falaria, (c) Protostrongylus spp., (d) Muellarius spp., (e) Cystocaulus spp. and (f) Neostrongylus spp. from October 1986 to October 1987. Sheep were treated with Levamisol (——→) on December 29, 1986 and Ivomec-GH27 (- - -→) on March 10, 1987.

Above 60% of ewes were infected with Strongylid helminths in winter and spring, but this level decreased to 25% in June increasing again in autumn. Up to one third of the ewes were infected with D. filaria in autumn but burdens were only moderate. Of the Protostrongylids, infections with Cystocaulus and, to a lesser extent, with Muellarius, appeared to be the only ones of any significance. Variation in the infection rate with season of Cystocaulus appeared to be less pronounced than with other genera, but infection rates exceeded 25% of the ewes from August to March. Ewes appeared to pass larvae of Neostrongylus during the hot summer period, which is contrary to expectations, but overall infection was very low. Whether this is a peculiarity of the genus, or an artefact associated with the low infection rate, is not known.

Noteworthy is the contrasting effects of the anthelmintics on the gastro-intestinal and lung helminths. Treatment against the gastro-intestinal parasites (and also D. filaria) was effective, with a pronounced fall in the number of ewes affected after treatment. But the parenchyma-dwelling Muellarius and Cystocaulus were little affected, although there was some suggestion that the egg-laying of Cystocaulus was inhibited after the March treatment.

Even in the second year of the study, no effect of stocking rate on the infection of ewes was detected. It is possible that at the stocking rates being imposed (the highest is only 1.6 ewes per ha), and because of the routine treatment of ewes with anthelmintics, parasite burdens will remain low. The closed nature of sheep management at Tel Hadya, which prevents the sheep becoming reinfected from flocks outside, is probably another contributory factor. Routine monitoring of ewes will continue in 1987/88, but the main focus of research on helminth parasites will shift to on-farm monitoring (experiment 8.2). However, at least an early hypothesis of the research, that infection rates by Protostrongylids tend to be higher than Dictyocaulus in adult sheep (Thomson and Orita, 1988), seems to have been confirmed in this study. - **E.F. Thomson and G. Orita (consultant from JICA)**

Experiment 8.2: influence of lungworms on the productivity of village flocks (Preschedule L33)

The objective of experiment 8.2 was to study the effects of controlling Protostrongylids on liveweight, body condition and fertility of ewes, and on the mortality of lambs and their pre-weaning growth rate.

The lungs of Awassi sheep are parasitized by lungworms located either in the bronchii and bronchioles, or in the parenchyma. Examples of the latter are the Protostrongylid genera (Protostrongylus, Muellerius, Cystocaulus and Neostrongylus) which infect sheep after passage through an intermediate host, usually several species of snails. Another genus of lungworm, Dictyocaulus, is transmitted via faeces without requiring an intermediate host. Very little work has been done on infections of Awassi sheep with Dictyocaulus, and no on-farm studies are known. In experiment 8.2 the opportunity was also taken to monitor the seasonal prevalence of Dictyocaulus and various Protostrongylids in village sheep.

Preliminary studies

In February 1987 approximately 370 ewes were taken from eight flocks at three locations: Al Bab, Al Tah, and Gammari (all in north Syria). Each flock was subdivided into three treatment groups: Fenbendazole (10 mg per kg liveweight), Morantel citrate, (8 mg per kg) and a placebo control (Maalox). Morantel citrate is an anthelmintic effective only against gastro-intestinal parasites while Fenbendazole is effective against both gastro-intestinal worms and lungworms.

Seven ewes from each treatment in several flock were slaughtered and autopsied in early April. All helminth parasites were collected from lung tissue and the gastro-intestinal tract. The lungs were examined for macroscopic lesions and sections were taken for microscopic evaluation. The autopsies have provided information on the genera of parasites present, the kind and degree of pathology of the lungs (whether worm - related or otherwise) and background information on the state of health in the flocks.

Data on levels of lungworm infections are given in Table 8.1. Cystocaulus and Muellerius were the predominant genera in all samples prior to treatment. Dictyocaulus was also present, surprising in these 4 year old ewes, since Dictyocaulus is considered to infect young lambs and yearlings. It remains to be seen just how much Dictyocaulus and the Protostrongylids contribute individually or synergistically to lung pathology and respiratory distress in sheep.

Table 8.1. Number of lungworm larvae (mean number per g of faeces) in autopsied ewes, before and after treatment with Fenbendazole, Morantel or a placebo.

Treatment	Number of ewes	Before treatment (larvae per g)				After treatment (larvae per g)			
		Cysto-caulus	Muell-arius	Proto-strongylus	Dictyo-caulus	Cysto-caulus	Muell-arius	Proto-stongylus	Dictyo-caulus
Fenbendazole	7	113	60	4	7	23	4	0	<2
Morantel	6	126	12	0	14	97	49	0	2
Placebo	7	170	9	0	8	123[1]	6[1]	0[1]	7[1]

Notes: Treatment on 23 February and 2 April 1987. Autopsy on 6-8 April 1987.

Table 8.1 also gives the number of larvae per gram of faeces after treatment. As expected, the Fenbendazole group had fewer larvae, the few present being primarily due to Cystocaulus infection in two of the ewes. Results for Morantel and the placebo show that lungworms were not affected by those treatments. The decline in larvae is typical in April, when the autopsies were conducted.

Table 8.2 shows the number of adult worms recovered at autopsy. The adult Protrostongylids are delicate and therefore difficult to separate from lung tissue; consequently, the total number of these worms is probably under-estimated. The primary genus present was *Cystocaulus*, ascertained from the shape of the bursa and spicula in stage II male larvae. One ewe, more than 5 years old, was heavily infected with *Cystocaulus* species, the adults of which were abundant in the lower lobes. In another the presence of a large number of fourth stage larvae was indicative of a "spring rise" - type increase in parasite numbers.

Table 8.2. Number of adult Protostrongylids and *Dictyocaulus* at autopsy for ewes treated with Fenbendazole, Morantel and a placebo. Values are per g of lung tissue.

Treatment	*Cystocaulus*	*Muellarius*	*Protostrongylus*	*Dictyocaulus*
Fenbendazole	4	0	0	1
Morantel	2	<1	0	10
Placebo	2[1]	0	0	5

Histological sections demonstrated lungworm lesions of varying severity in the lower lobes of all lungs. Most sheep were also infected with *Echinococcus* (hydatid cyst) which had destroyed large portions of lung tissue. Additional work is in progress to characterize these lesions.

In future it will be interesting to note if the *Marshallagia*/*Ostertagia* group is predominant in the gastro-intestinal tract of sheep grazed in or near steppe land. The contribution of these parasites to respiratory disease in winter and their effect on productivity remains to be investigated.

Results on the recovery of gastro-intestinal parasites are presented in Table 8.3. From the number of worms present it would appear that Fenbendazole and Morantel were both effective in removing small-intestinal parasites but not in removing abomasal worms. This is surprising because the dose of Fenbendazol was higher than that recommended for treatment of these worms.

Table 8.3. Counts (per g faeces) of adult and immature gastro-intestinal helminths from autopsied sheep treated with Fenbendazole, Morantel or a placebo.

	Abomasum		Small intestine		Large Intestine
Treatment	Adults	Immature	Adults	Immature	Adults
Fenbendazole (n=7)	12	244	<1	6	<1
Morantel (n=6)	35	948	<1	10	4
Placebo (n=7)	155	455	30	68	6

Another surprise was the large number of immature larvae in the abomasa of the ewes (samples included abomasal contents, scrapings and digested mucosa). These were predominantly late stage IV larvae of Ostertagia. The fact that they appeared so rapidly after treatment may indicate that they were present in the mucosa of the abomasum and that inhibited-type ostertagiasis could be an important contributor to sheep parasitism in Syria.

The worms present in the greatest number in the abomasum were Marshallagia spp., at present not identified to species level. Other species present in the abomasum included Ostertagia circumcincta and O. trifurcata. Nematodirus fillicopis, Trichostrongylus capricola and T. vitrinus were present in the small intestine. These are species that would be expected in sheep raised in these areas of Syria and under prevailing management systems. However, the large number of Marshallagia and Ostertagia in the abomasum may indicate that most of the effect of gastro-intestinal parasites is due to these worms. This is an additional area of investigation in planning strategic anthelmintic treatment.

Present Studies

Monitoring of flocks on each farm will continue. Flock management and inventory data (birth, deaths, sales, feeding, etc.) are being collected on a monthly basis. Ewes and lambs are weighed and their condition scored regularly, while at least 10% of ewes are sampled for parasites.

Liveweight changes have been analyzed for each flock on each farm. There are significant differences between farms ($P<0.05$), probably attributable to differences in management practices. There are no significant differences between treatment groups at this early stage. However, after three treatments, the Fenbendazole groups had a higher average liveweight gain than either of the other groups. It is noteworthy to consider that this increase was not apparent between February and July 1987. The chronic nature of parasitism requires that liveweight be followed for much longer periods to identify the effects of the worms. Ewes at all farms will therefore be weighed, sampled and treated for the coming three to four years, and their lambs will be weighed from birth. The results will indicate the expected productivity loss due to lungworms.

The data are also indicating that differing geographical locations and management practices have resulted in different kinds of parasite problems. For example, the Protostrongylid producing the greatest number of larvae at Al-Bab was Cystocaulus, whereas at Al-Tah it was Muellerius. Future data collection and analysis should indicate the factors accounting for these epizootiological differences between locations. - **C. Rhodes (private consultant), E.F. Thomson, G. Orita (consultant from JICA), and F.A. Bahhady**

CHAPTER 9: TRAINING

Training is an essential part of the Program's activities. In PFLP it is designed to (a) enhance the research capacity of NARS in the field of pasture, forage and livestock improvement as defined by the needs of national programs within west Asia and north Africa, (b) build a viable network of agricultural researchers who work closely with ICARDA on pasture, forage and livestock research, (c) meet the needs of selected individuals in national programs who require detailed training in specific problem areas of research relevant to PFLP research activities, and (d) assist in the academic training of agricultural colleges of the region by providing opportunities for field oriented thesis research to be conducted with assistance and supervision of PFLP senior scientists.

Six types of training were offered in 1986/87:

Residential course

From 1 March - 18 June, 1987, the residential course took place at Tel Hadya where nine trainees from nine countries (South Yemen, U.A.E., Syria, Sudan, Nepal, Ethiopia, Egypt, China and Algeria) participated. A relatively large volume of resources and senior scientists' time were devoted to the course of which the major objectives were to provide middle level research personnel from national programs with the knowledge and skills necessary to conduct field research into improving the production and utilization of feeds for sheep.

The period of training (March - June) coincides with our most important research activities. The syllabus focused on field and laboratory techniques for annual forage breeding, agronomy and utilization of forages, the ley farming system, biological nitrogen fixation, improving livestock nutrition, marginal land improvement, and grazing management. Every trainee was closely associated with a concerned senior scientist, and, depending on his interest or national program requirements, assumed responsibility for his/her own project, becoming an integral part of the research team as a whole. This gave the trainee experience in planning, conducting, analysing and reporting experimental work, details of which are given in Table 9.1.

Table 9.1. Projects assigned to participants in the 1987 residential course.

Name	Country	Title of the project	Supervisor
Mansour Saeed Khan	S-Yemen	Medic seed production	Ali Abd El Moneim
Imad Momammed Tarakji	Syria	Screening annual medics for nematodes	Ali Abd El Moneim
Gerbremedhin Hagos	Ethiopia	Forage-germplasm evaluation and utilization	Ali Abd El Moneim
He Yong Song	China	Selection Criteria for Forage Crops	Ali Abd El Moneim
Hemadach Abd El Majid	Algeria	Effect of seeding rates, row spacing and weed control on agronomic characteristics of woollypod vetch	Ali Abd El Moneim
Ali Ahmed Al Mohrizi	U.A.E	Lamb fattening and pea palatability	Euan Thomson
Atif Abd El Malik	Sudan	Lamb fattening and pea palatability	Euan Thomson
Sudarshan Regmi	Nepal	Grazing management of medics	Alan Smith
Ibrahim Mohammed Ahmed	Egypt	Quality assessment of forages	Safouh Rihawi

Field training was supported by a series of lectures and discussions dealing with practical and theoretical subjects. Educational aids, including manuals detailing important areas of improvement of pastures, forages and livestock, were provided.

Evaluation and follow up is considered to be an important aspect of the course. The trainees were asked to evaluate various subject areas of the course throughout the training period, and their comments and discussion have been taken into account in designing future courses. When the trainees return to their home countries, continued and close contact is maintained through visits by senior staff.

Short Term Training

This activity provides concise, problem-oriented training on a specific aspect of the Program activities. It comprises field work, laboratory work, lectures and discussions.

Field techniques in biological nitrogen fixation: A two-week training course was given from 22 February to 5 March. Seven participants from six countries of the ICARDA region attended the course. Its aim was to transfer technological information to persons considered essential to the development of legume/rhizobia research in national programs.

The course covered the following topics: 1) an overview of the legume/rhizobia system, 2) manipulation of cultures, 3) assessment of naturalized soil populations of rhizobia, 4) agronomic aspects and field experimentation, 5) measurement of nitrogen fixation, 6) effects of crop management, and 7) inoculum production and use.

This type of training activity is expected to continue and an increase in the number of participants and lecturers is anticipated.

Medic planting and harvesting: A short training course on establishing medic seed crops was conducted at Salamieh Research Station (near Hama, Syria), in November 1986. Five trainees participated in the course, which focused on seed bed preparation and sowing. The same participants and two others from Algeria spent one week at Salamieh during harvest. They were trained in the use of mowers to remove excess herbage, baling of the herbage, and using the suction harvester.

Medicago and Trifolium identification and classification: Two trainees from the Steppe and Range Directorate, Syria, were trained on identification and classification of medics and clovers from 1-15 April, 1987. The course was designed to help them to make collections from the native Syrian flora.

From 14 March to 14 April a trainee from the Steppe and Range Directorate, Syria was trained on the carrying capacity of native pasture.

One trainee from Tchreen University (Lattakia) visited ICARDA from 14 June to 2 July to learn about quality assessment of pasture and forage plants.

Long Term Training

This type of highly specialized training involves junior scientists from countries of the region working with PFLP at ICARDA. The participants are involved in research of particular interest to ICARDA and their national programs and become fully involved in that aspect of the Program's work.

Medic seed production: One of the major constraints restricting the use of annual medics is lack of experience in seed production. Therefore, a training course from November 1986 to July 1987, focused on practical aspects of medic seed production, including the effect of grazing, and use of the suction harvester. Trainees were responsible for medic seed production in their national programs, which is particularly important, since PFLP hopes to release medic cultivars in the near future.

On farm research training: New technology developed by PFLP is only useable when transferred to farmers' fields. From January to July 1987 two trainees studied the methodology of forage-livestock on farm trials. They were involved in the on-farm research at Breda and El Bab.

Different aspects of Sheep husbandry and nutrition for 9 months were the subject of another course (November 1986 - July 1987). Training focused on management of experimental flocks (milking, weighing, feeding, keeping records, and analysis and reporting of feeding experiments).

Senior research fellow

A senior research fellow from Sudan spent 4 months (March to June 1987) with PFLP. He conducted an experiment on seasonal changes in herbage and quality of promising lines of *Vicia spp* and *Lathyrus spp* (see Chapter 4). He will return during the same period in 1988 to complete his research.

Training of Trainers

So far, little attention has been given to improving the quality and relevance of the training being conducted by national programs themselves. Since they are beginning to increase their own in-country training activities the funds received from UNDP for a 'training of trainers' project are timely. Through the UNDP project PFLP selected a Syrian, to be trained in training, for a period of two years. The training focuses on subjects related to strengthening such areas as needs assessment, curriculum, and evaluation and management of training courses.

Graduate degree training

There is a need in north Africa and west Asia for scientific staff to plan and conduct research in the field of pasture, forage and livestock improvement. PFLP can work jointly with Universities to select and help supervise graduate students. This cooperation establishes a link between scientists at the Universities and ICARDA, and at the same time helps to advance graduate studies, with the overall objective of improving academic standards. PFLP has provided four places for graduate degree training in the last two years. - **Ali M. Abdel El Moneim**

APPENDIX 1: REPORT OF THE QUINQUENNIAL REVIEW (QQR) IN 1983 AND IMPLEMENTATION OF ITS RECOMMENDATIONS

The QQR took place in spring 1983. At that time the Pasture and Forage Improvement Program (now PFLP). comprised four projects: further collection of germplasm (5% of the budget), annual forage to replace fallow (33%), annual pasture to replace fallow (32%), and rejuvenation of marginal lands (13%), the remaining resources (17%) being used for training and administration. There were two senior (international) scientists and a Q2 level (regional) training scientist.

Since the QQR, and partly as a result of it, livestock and microbiology research have been, respectively, completely and partly transferred from the Farming Systems program (now Farm Resource Management Program) to PFLP. The recommendations of the QQR in respect to these subjects are therefore included in the discussion.

A summary of the recommendations and suggestions, and the PFLP responses, are listed below.

1. Because there is a need to link the work on pastures and forages more closely to grazing-animal production the QQR <u>recommended</u> transfer of ICARDA's livestock work from FRMP to PFLP.

   The transfer occurred early in 1984 and has resulted in close co-operation between plant and animal scientists. Indeed the livestock group conducts research in all existing projects.

2. The QQR <u>recommended</u> that a transfer of effort from 'annual forage to replace fallow' to 'rejuvenation of marginal

lands' should take place and that the latter should concentrate on pasture improvement of common land within the cereal zone and low rainfall land just outside the cereal zone, using adapted annual medics or other pasture species.

Resources to marginal lands increased by 50% relative to total resources between 1984 and 1987. In line with the QQR this was achieved mainly at the expense of the annual forage project, although in 1987, as a result of some exciting new work, the latter's budget was partly restored. The remaining part of the re-allocation was from annual pastures, achieved by combining ecological surveys of rangelands with collecting pasture germplasm. Resource allocation since 1984 is shown in Table A.1.

Table A.1. Allocation of resources to the 4 research projects and to training and administration within the Pasture, Forage and Livestock Program.

	1984	1985	1986	1987
Project				
Annual pastures	30	25	23	23
Annual forages	20	15	15	17
marginal land	14	20	23	22
Livestock management	16	20	24	23
Training ano auministration	20	20	15	15

Although the QQR recommended that the main thrust of research into marginal lands should be use of adapted medics and other species, it has been considered necessary to first study the ecology of existing pastures (preschedule ML 1), constraints imposed by soil fertility, and manipulation of pastures by grazing management (preschedule ML 2).

3. The QQR recommended that the project on 'annual pastures to replace fallow' should be carried out as a joint project with the FRMP to obtain input from soil scientists and crop agronomists.

   The two-course rotation experiment at Tel Hadya is conducted jointly by FRMP, PFLP, and the Food Legume Improvement Program (FLIP). In this experiment FRMP has overall responsibility including all aspects of crop agronomy, while PFLP conducts detailed work in the medic/wheat rotation, and manages livestock activities in the medic/wheat and vetch/wheat rotations. In other work FRMP contributes to on-farm experiments, although their contribution is mainly limited to socio-economic matters.

   Indeed, in spite of its emphasis on the barley/livestock system, FRMP has allocated very few of its resources to work on annual pastures. However PFLP itself has developed a systems approach to its annual pasture work, the lack of which, we believe, was the main criticism of the QQR. For example the on-farm research on medics (preschedule M 6) includes studies of soil fertility, the effect of phosphorus application, the importance of herbicides, and interactions between nitrogen fertilizer and rotations.

4. The QQR recommended that in order to accelerate the rate at which adapted pasture medics become available for a wider range of environments, special efforts should be made to obtain evaluation data, and, where possible, bulk seed supplies, from other projects and organizations active in similar work in the region.

The Program actively co-operates with the ADAB-sponsored project in Jordan, and GTZ and USAID projects in Morocco. It also maintains contact with the South and Western Australian Departments of Agriculture, the two organizations who have wide experience of medics in Iraq, Libya and Algeria. It is a collaborator with the French Government's (INRA) project on medics in Algeria.

However these projects depend on using Australian medic cultivars. Since they have become aware of ICARDA's work all have commenced some screening of local ecotypes, including ICARDA germplasm. No bulk supplies of seed are available from these projects: indeed the projects themselves are becoming dependent on bulk supplies of seed from ICARDA, rather than the reverse. ICARDA takes great pride that, in the years since the QQR, it has become a clear leader amongst national and international institutes in developing locally-adapted medics.

Multiplication of seed under contract in South Australia was attempted in 1985 and 1986. However harvest of seed in Australia takes place after sowing time in west Asia, and so at least 6 months is lost compared with seed multiplication at Tel Hadya. Furthermore, seed yields of M. rigidula, the species multiplied in Australia, have been disappointing.

5. The QQR recommended that the appointment of a grazing management scientist to assist the work on grazed annual medic pastures and to increase the total input into research in livestock systems should be given highest priority in staffing.

Dr Alan Smith was appointed to the Program in 1985. He has established stocking rate experiments on medics grown in rotation with wheat (preschedule L 13), and is studying the interactions between grazing, weed population, and medic seed production in first year pasture (preschedule L 29).

6. The QQR recommended that in making further appointment to PFLP, ICARDA should firstly consider the high priority for microbiological support to ensure the availability of effective symbionts for all legumes strains, and secondly the need for a scientist with experience in grazed pastures in a Mediterranean environment (pasture ecologist). On the other hand it considered that there was a reduced need for plant disease studies.

   As a result of studies in 1983/4 it became clear that lack of inoculation was indeed one of the major problems with medics. The appointment of a microbiologist was accelerated and Dr Luis Materon commenced duties in 1984. He has worked on selecting rhizobia strains suitable for *M. rigidula*, *M. noeana*, *M. rotata*, and *M. polymorpha*, (for example preschedule M 18) and on developing appropriate inoculation procedures (preschedule M 20).

   It has not been possible to appoint a pasture ecologist. However Dr Ahmed Osman, who had previously been working on the agronomy of forage legumes, is now working on the productivity and ecology of marginal lands. The Program Leader, Dr Philip Cocks, is responsible for the ecology of medic pastures.

   The Plant Pathologist, Dr Omar Mamluk, was transferred to the Cereal Program in 1983.

7. The QQR recommended inclusion of socio-economic expertise with the livestock work in PFLP.

Since the socio-economists in FRMP collaborate closely with scientists in PFLP, especially in on-farm research and surveys of farming practice, it was not considered necessary or desirable to split the small economics section of FRMP. The present situation in regard to collaboration with FRMP is most satisfactory, however PFLP views with some concern the lack of numbers in the socio-economic group and believes that there is a need for more farm-management economists.

8. The QQR suggested that, as resources permit, further survey work on livestock should be carried out on livestock systems beyond Syria, and especially in Tunisia. It suggested that emphasis should be placed on the role of livestock as stabilizing agents for economic survival in farming environments with highly variable rainfall.

In response to this suggestion the FRMP project in Tunisia has used Tunisian livestock scientists - apart from an advisory role PFLP has not been extensively involved. In other work the emphasis on livestock as a stabilizing factor is given very high priority, especially the integration of livestock with cereal production, biological nitrogen fixation through the use of legumes, and the economic importance of livestock in generating cash flow.

9. The QQR suggested that the production potential of local sheep be examined under a range of nutritional conditions, especially the interaction between nutrition, time of mating, frequency of lambing, time of weaning, and lactation period.

Three flocks were maintained at low, medium, and high planes of nutrition (preschedule L 1). Most of the factors mentioned were studied, and the Program is now gradually phasing out this work to replace it with on-farm experiments using pastures and livestock, and the development of grazing management and rotation studies at Tel Hadya.

10. In emphasizing the importance of grazing management studies the QQR believed that such studies are required throughout the region.

Resources have not permitted the extension of grazing management studies beyond Syria. However, within Syria, an experiment using medic pastures was commenced in 1986/87 at Kamishly, in collaboration with the Livestock Research Directorate of the Ministry of Agriculture and Agrarian Reform (preschedule L 34). It is proposed to establish an experiment on grazing management of edible shrubs on marginal land with the Steppe and Range Directorate (preschedule ML 12).

This work is best extended beyond Syria by exposing the Syrian work to regional scientists during training courses, workshops, and seminars. Grazing management will be extensively discussed during the PFLP/FLIP workshop on the place of legumes in farming systems, to be held in 1988.

11. The QQR suggested that regular veterinary screening for external and internal parasites be introduced through arrangements with relevant national agencies.

The secondment of Dr Giro Orita through the Japanese International Cooperation Agency (JICA) made it possible to commence a study on the incidence and frequency of gastro-intestinal parasites (preschedule L 5). This work has recently extended from Tel Hadya to village work at Tah (south of Aleppo) and El Bab (north-east of Aleppo).

12. The QQR suggested that it might be useful to test locally-developed genetically improved Awassi sheep on pastures and forages.

It has not been possible to respond to this suggestion. However PFLP believes that it is important that both health and genetic constraints to productivity are considered when developing pasture and forage based farming systems (see Chapter 1). To this end it is proposed to develop and strengthen animal health and genetic studies in relation to improved nutrition.

13. The QQR believed that ICARDA should not become involved in research into goats or draught animals.

To date there has been no research into either of these subjects. However, since most flocks are in fact mixtures of sheep and goats, it is desirable that, in determining grazing management strategies, mixtures of goats with sheep be included. There is still no intention to work with draught animals.

APPENDIX 2: RECOMMENDATIONS OF A WORKSHOP TO DISCUSS FUTURE PRIORITIES FOR ICARDA RESEARCH ON SMALL RUMINANTS IN MEDITERRANEAN AREAS

In making its recommendations to CGIAR the TAC Priorities Review noted that 'small ruminants are very important in the production systems of farmers with few resources, and have received little attention in the past; the national systems are weak; and the demand projections for sheep and goat products up to the year 2000 indicate that the gap between production and consumption is increasing faster than for other food commodities'. The Review went on to identify small ruminant research in north Africa and west Asia as a priority area.

ICARDA responded to the CGIAR study by consulting with NARS and outside experts at a Workshop held in Aleppo from 30 November to 3 December, 1987. The Workshop considered three main areas of research - ruminant nutrition, animal genetics, and animal health - and developed a series of recommendations for each. It was not specifically asked to discuss the work on pastures and forages, but to concentrate on the livestock disciplines instead. The Proceedings will be published by Kluwer Academic Publishers and should appear early in 1989.

Experts from Australia, Cyprus, Egypt, Ethiopia, France, Germany, Jordan, Morocco, The Netherlands, Syria, Turkey, the United Kingdom, and the United States of America attended the meeting, which also included representatives from ILCA and ACSAD.

Recommendations of the Workshop (in order of priority) are presented under three headings: ruminant nutrition, small ruminant genetics, and animal health. The Workshop recognized that ICARDA would need additional resources to conduct most of this work.

Ruminant nutrition

Crop residues: the present emphasis was highly commended and it was felt that ICARDA was already a leader in this field. The priorities for the future were seen as follows:

- completion of research on degradability and intake of cereal straws;
- development of methodologies to assist cereal breeders screen large numbers of genotypes;
- use of new techniques (eg infrared spectroscopy) to include measurement of fibre and lignin; and
- effect of mineral and protein content of straws on voluntary intake.

Annual medics: the work on medics to replace fallows was considered to have enormous implications for the region, and, although not in their terms of reference, the Workshop urged ICARDA to focus on management methods.

Feed resource/genotype interactions: the Workshop considered this to be a complex area and urged preliminary work on 'improved' and unimproved' genotypes as follows:

- voluntary intake of the different genotypes;
- rate of flow of different feedstuffs through the digestive tract of improved and unimproved genotypes; and
- selection of extreme animals to relate performance with feed intake.

Supplementary feeding: strategies to improve the utilization of stubbles, rangelands, and native pastures need to be developed. Recommendation were to:

- consider the role of urea and sulphur molasses blocks to improve utilization of low-protein feeds;

- develop methods of administering anthelmintics, trace elements and vitamins through blocks; and

- determine the optimum strategy for feeding other supplements such as bran and barley.

Palatability of forage legumes: research is needed to study anti-quality factors, especially in forage peas, but also in other forage legumes where appropriate.

Grazing behaviour: this was seen to be an important topic in mixed flocks of sheep and goats, and in particular a need was seen to:

- determine the actual nutrients consumed by cannulated sheep and goats in various grazing situations; and

- find out the optimum ratio of sheep and goats for weed control in pastures, most efficient utilization of pastures, and maximum farm profitability.

Adaptation to the environment: the Awassi sheep are adapted to an environment with fluctuating nutrient supply. Research was recommended to:

- find out how best to utilize body fat reserves;

- relate use of fat reserves to time of lambing;

- relate fat utilization with protein intake and the role of undegraded dietary protein; and

- determine how to reduce rumen degradability of locally available sources of protein.

Water metabolism: the effect of saline water on production, and the reasons for different performance between genotypes and species drinking saline water need to be determined to formulate the best strategies for livestock production where supplies of fresh water are limited.

Collaboration with advanced institutions: a number of institutions expressed willingness to collaborate with ICARDA. Amongst these were Cornell University, the Rowett Institute, and Wye College, all of whom were prepared to act as consultants, and, with ICARDA, co-supervise post-graduate studies in which field work would be conducted at Tel Hadya or in other WANA institutes.

Small ruminant genetics

Efficiency of feed utilization: objectives should include:

- comparison of the efficiency of different sheep genotypes in utilizing straw, other crop byproducts, pastures, and forages; and

- determination of the best way of managing improved sheep genotypes in extensive and intensive farming systems.

Survey of sheep and goat breeds: information needs to be collected and collated on the existing genetic wealth of sheep and goats and its utilization in livestock-producing farming systems.

Development of methodologies to evaluate improved livestock: objectives should be to:

- develop methods of screening populations for specific characters (eg milk production, disease resistance);

- analyse genotype X environment interactions, especially in relation to existing stocking rate experiments;

- determine the effect of breeding season on reproduction and other traits; and

- compare improved and unimproved genotypes on farmers' fields, including the effect of releasing 'improved sires' on flock productivity.

Evaluation of breeding objectives: in relation to existing farming systems and the economic situation of farmers this should include:

- an assessment of the Awassi in relation to use of more frequent breeding systems;

- economic assessment (including allowance for the provision of adequate feed) of increasing the twinning rate of Awassi sheep;

- evaluation of the significance of improving wool quality and quantity; and

- assistance in the formation of networks to develop and evaluate national breeding schemes.

Animal health

Parasitology: the present studies at ICARDA headquarters and on farmers' fields should be maintained and broadened to obtain a more general picture of disease constraints using existing and improved feeding systems.

Adaptation of technology to control diseases: it was believed that many of the technologies to control diseases appropriate in the developed world are inappropriate to developing countries. It was recommended that:

- social and economic constraints to utilization of modern disease control techniques be determined;

- on-farm research to develop appropriate technologies be commenced with an initial emphasis on control of external and internal parasites; and

- the role of genetic control of diseases should be investigated.

Flock management: concern was expressed that the health of ICARDA's own flock may be at risk. It was emphasized that ICARDA's priority is rightly the provision of improved feeding systems, and to ensure that livestock play their proper part in such research ICARDA should:

- include a comprehensive flock health program in its management strategy;

- quarantine new sheep and goat introductions until vaccinations take effect;

- maintain enzootic stability against endemic diseases by continued contact with local sheep through grazing of the same pastures in succession, while at the same time avoiding direct contact; and

- develop an ability to diagnose and treat diseases as they occur.

PUBLICATIONS

Refereed journals

Abd El Moneim, A.M. and Cocks, P.S. Yield stability of selected forage vetches (Vicia spp) under rainfed conditions in west Asia. Journal of Agricultural Science, (Cambridge), in press.

Capper, B.S., Rihawi, S., and Nagi, I. Genetic and environmental effects on barley straw quality. Animal Production, 44, 480.

Cocks, P.S. Seed production and seed survival under grazing of *annual medics (Medicago spp) in north Syria. Journal of* Agricultural Science, (Cambridge), in press.

Cocks, P.S., and Ehrman, T.A.M. The geographic origin of frost tolerance in Syrian pasture legumes. Journal of Applied Ecology, 24, 673-683.

Falistocco, E., Piccirilli, M., and Falcinelli, M. The basic karyotype of Trifolium subterraneum subsp. brachycalycinum. Annali di Botanica, 44, 171-174.

Rihawi, S., Capper, B.S., Osman, A.E., and Thomson, E.F. Effects of crop maturity, weather conditions, and cutting height on yield, harvesting losses, and nutritive value of cereal-legume mixtures grown for hay production. Experimental Agriculture, 23, 451-459.

Thomson, E.F., and Termanini, A. Voluntary intake and liveweight changes of Awassi sheep fed barley straw and cottonseed meal. Egyptian Journal of Animal Production, in press.

Thomson, E.F., and Orita, G. Seasonal prevalence of lungworms of Awassi sheep in north west Syria. Tropical Animal Health and Production, in press.

Other publications

Capper, B.S., Thomson, E.F., and Herbert, F. Genetic variation in the feeding value of barley and wheat straw, in 'Proceedings of a Workshop on Plant Breeding and the Nutritive Value of Crop Residues', ILCA, Addis Ababa.

Cocks, P.S. The need for seed production of pasture and forage species. in 'Seed Production in and for Mediterranean Countries', eds A.J.G. van Gastel and J.D. Hopkins, EEC and ICARDA, Aleppo, pages 143-153.

Cocks, P.S., and Abd El Moneim, A.M. A systems approach to evaluation of pasture and forage legumes in west Asia. In 'Proceedings of a Workshop on Genetic Resources of Cool-Season Pasture, Forage and Food Legumes', Cairo, in press.

Cocks, P.S., and Thomson, E.F. Increasing feed resources for small ruminants in the Mediterranean basin. In ' Proc. of Workshop on Small Ruminant Research in the Mediterranean Basin', ICARDA, Aleppo, Syria.

Materon, L.A. Maximising biological nitrogen fixation by forage and pasture legumes in semi-dry areas. In, 'Nitrogen Fixation in Mediterranean Areas', eds, D. Beck and L.A. Materon, Martinus Nyjhof, Dordrecht, The Netherlands, in press.

Smith, A. Grazing management for food production. An introduction for scientists and technologists in developing countries. ICARDA Technical Manual 15, November 1987, Aleppo.

Regmi, S. and Smith A. A study of the productivity of medic pastures under grazing. PFLP Internal Report, May 1987, Aleppo.

Thomson, E.F. Feeding systems and sheep husbandry in the barley belt of Syria. ICARDA-106 En, Aleppo.

Thomson, E.F. Forage crops and pastures for intensifying sheep production in northern Syria. Entwicklung und Laendliche Raum, 21, 8-10.

Thomson, E.F., Cocks, P.S., and Bahhady, F. Improving feed resources: a key step towards expanding ruminant production in semiarid north Africa and west Asia. In, 'New Techniques *in Sheep Production', eds I. Fayez, M. Marai, and J.B.* Owen, Chapter 18, Butterworths, London, pages 197-203.

REFERENCES

Abd El Moneim, A.M., and Cocks, P.S. (1986). Adaptation of Medicago rigidula to a cereal pasture rotation in north-west Syria. Journal of Agricultural Science (Cambridge), 107, 179-186.

Abd El Moneim, A.M., Cocks, P.S. and Swedan, Y. (1988). Yield stability of forage vetches under rainfed conditions in west Asia. Journal of Agricultural Science (Cambridge), in press.

Bolland, M.D.A., and Collins, W.J. (1987). Persistence of seed produced from single seed crops of subterranean clover on sandy soils near Esperance, Western Australia. Australian Journal of Experimental Agriculture, 27, 81-85.

Carter, E.D. (1980). The survival of medic seeds following ingestion of intact pods by sheep. Australian Agronomy Conference, Lawes Queensland, Australia, page 178.

Cocks, P.S. (1988). Seed production and seed survival under grazing of annual medics (Medicago spp) in north Syria. Journal of Agricultural Science (Cambridge), in press.

Cocks, P.S., and Ehrman, T.A.M. (1987). The geographic origin of frost tolerance in Syrian pasture legumes. Journal of Applied Ecology, 24, 678-683.

Collins, W.J., Francis, C.M., and Quinlivan, B.J. (1976). The interrelation of burr burial, seed yield and dormancy in strains of subterranean clove. Australian Journal of Agricultural Research, 27, 787-797.

Crawford, E.J. (1983). Selecting cultivars from naturally occurring genotypes: evaluating annual Medicago species, in 'Genetic

Resources of Forage Plants' eds J.G. McIvor and R.A. Bray, CSIRO, Melbourne, Australia, pages 203-216.

Donald, C.M. (1954). Competition among pasture plants II. The influence of density on flowering and seed production in annual pasture plants. Australian Journal of Agricultural Research, 5, 585-597.

Donald, C.M. (1959). The production and life span of seed of subterranean clover (T. subterraneum L.). Australian Journal of Agricultural Research, 10, 77-87.

Donald, C.M. (1970). Temperate pasture species, in 'Australian Grasslands', ed. R.M. Moore, A.N.U., Canberra, Australia, pages 303-320.

Engelman, L., and Hartigan, J.A. (1985). K-Means Clustering, in 'BMDP Statistical Software Manual' eds W.J. Dixon, L. Engelman,, J.W. Frane, M.A. Hill, R.I. Jennrich, and J.D. Toporek, University of California Press, Berkely, U.S.A., pages 464-478.

Gates, P., Smith, M.L., White, Gretel, and Boulter, D. (1983). Reproductive physiology and yield stability in Vicia faba L. in 'Temperate Legumes: Physiology, Genetics and Nodulation' eds D.G. Jones and D.R. Davies, Pitman Advanced Publishing Program, Boston, U.S.A., pages 43-54.

Hovell, F.D.D., Ngambi, J.W.W., Barber, W.P., and Kyle, D.J. (1986). The voluntary intake of hay by sheep in relation to its degradability in the rumen as measured with nylon bags. Animal Production, 42, 111-118.

Hyde, E.O.C. (1954). The function of the hilum in some Papilionaceae in relation to the ripening of the seed and the permeability of the testa. Annals of Botany (London), 18, 241-256.

Maerts, U. (1987). Methods to simulate distributions of crop yields based on farmer interviews. ICARDA-117En, Aleppo, Syria.

Orskov, E.R., Hovell, F.D.D., and Mould, F. (1980). The use of the nylon bag technique for the evaluation of feedstuffs. Tropical Animal Production, 5, 195-213.

Orskov, E.R., and McDonald, J. (1979). The estimation of protein degradability in the rumen for incubation measurements weighted according to rate of passage. Journal of Agricultural Science, 92, 449-503.

Puckridge, D.W., and French, R.J. (1983). The annual legume pasture in cereal-ley farming systems of southern Australia: a review. Agriculture, Ecosystems, and Environment, 9, 229-267.

Quinlivan, B.J. (1965). The influence of the growing season and the following dry season on the hardseededness of subterranean clover in different environments. Australian Journal of Agricultural Research, 16, 277-291.

Quinlivan, B.J. (1968). Seed coat impermeability in the common annual legume pasture species of Western Australia. Australian Journal of Experimental Agriculture and Animal Husbandry, 8, 695-700.

Quinlivan, B.J. (1971). Seed coat impermeability in legumes. Journal of the Australian Institute of Agricultural Science, 37, 283-295.

Taylor, G.B., Rossiter, R.C., and Palmer, M.J. 91984). Long term patterns of seed softening and seedling establishment from single seed crops of subterrenean clover. Australian Journal of Experimental Agriculture and Animal Husbandry, 24, 200-212.

Thomson, E.F. (1984). First experiences with joint managed forage and grazing trials, in 'Proceedings of the Third Farming Systems Symposium' ed. C. Butler-Flora, Kansas State University, Manhattan, U.S.A., pages 234-250.

Thomson, E.F., Jaubert, R., and Oglah, M. (1985). On farm comparisons of milk yield of Awassi ewes grazing introduced forages and communal village lands in the barley zone of NW Syria, in 'Proceedings of the First International Conference on Animal Production in Arid Zones', ed. O. Awa, ACSAD, Damascus, Syria, in press.

Thomson, E.F., and Orita, G. (1988). Seasonal prevalence of lungworms of Awassi sheep in northwest Syria. Tropical Animal Health and Production, in press.

Thomson, E.F. and Termanini, A. (1988). Voluntary intake and liveweight changes of Awassi sheep fed barley straw and cottonseed meal. Egyptian Journal of Animal Production, in press.

Tully, D., Thomson, E.F., Jaubert, R., and Nordblom, T.L. (1985). On-farm trials in north-western Syria: testing the feasibility of annual forage legumes as grazing and as conserved feed, in 'Proceedings of the IDRC/ICARDA Workshop on Livestock On-farm Trials', eds T.L. Nordblom, A.K. Ahmed, and G.R. Potts, pages 209-236.

Van Soest, P.J. (1984). Nutritional Ecology of the Ruminant, O and B Books, Corvallis, U.S.A., pages 282-285.

Yasue, T., and Ota, K. (1985). Studies on the hard seed of milk vetch (Astragalus sinicus L.). Proceedings of the Crop Science Society of Japan, 27, 289-292.

REFERENCES

Abd El Moneim, A.M., and Cocks, P.S. (1986). Adaptation of Medicago rigidula to a cereal pasture rotation in north-west Syria. Journal of Agricultural Science (Cambridge), 107, 179-186.

Abd El Moneim, A.M., Cocks, P.S. and Swedan, Y. (1988). Yield stability of forage vetches under rainfed conditions in west Asia. Journal of Agricultural Science (Cambridge), in press.

Bolland, M.D.A., and Collins, W.J. (1987). Persistence of seed produced from single seed crops of subterranean clover on sandy soils near Esperance, Western Australia. Australian Journal of Experimental Agriculture, 27, 81-85.

Carter, E.D. (1980). The survival of medic seeds following ingestion of intact pods by sheep. Australian Agronomy Conference, Lawes Queensland, Australia, page 178.

Cocks, P.S. (1988). Seed production and seed survival under grazing of annual medics (Medicago spp) in north Syria. Journal of Agricultural Science (Cambridge), in press.

Cocks, P.S., and Ehrman, T.A.M. (1987). The geographic origin of frost tolerance in Syrian pasture legumes. Journal of Applied Ecology, 24, 678-683.

Collins, W.J., Francis, C.M., and Quinlivan, B.J. (1976). The interrelation of burr burial, seed yield and dormancy in strains of subterranean clove. Australian Journal of Agricultural Research, 27, 787-797.

Crawford, E.J. (1983). Selecting cultivars from naturally occurring genotypes: evaluating annual Medicago species, in 'Genetic

Resources of Forage Plants' eds J.G. McIvor and R.A. Bray, CSIRO, Melbourne, Australia, pages 203-216.

Donald, C.M. (1954). Competition among pasture plants II. The influence of density on flowering and seed production in annual pasture plants. Australian Journal of Agricultural Research, 5, 585-597.

Donald, C.M. (1959). The production and life span of seed of subterranean clover (T. subterraneum L.). Australian Journal of Agricultural Research, 10, 77-87.

Donald, C.M. (1970). Temperate pasture species, in 'Australian Grasslands', ed. R.M. Moore, A.N.U., Canberra, Australia, pages 303-320.

Engelman, L., and Hartigan, J.A. (1985). K-Means Clustering, in 'BMDP Statistical Software Manual' eds W.J. Dixon, L. Engelman,, J.W. Frane, M.A. Hill, R.I. Jennrich, and J.D. Toporek, University of California Press, Berkely, U.S.A., pages 464-478.

Gates, P., Smith, M.L., White, Gretel, and Boulter, D. (1983). Reproductive physiology and yield stability in Vicia faba L. in 'Temperate Legumes: Physiology, Genetics and Nodulation' eds D.G. Jones and D.R. Davies, Pitman Advanced Publishing Program, Boston, U.S.A., pages 43-54.

Hovell, F.D.D., Ngambi, J.W.W., Barber, W.P., and Kyle, D.J. (1986). The voluntary intake of hay by sheep in relation to its degradability in the rumen as measured with nylon bags. Animal Production, 42, 111-118.

Hyde, E.O.C. (1954). The function of the hilum in some Papilionaceae in relation to the ripening of the seed and the permeability of the testa. Annals of Botany (London), 18, 241-256.

Maerts, U. (1987). Methods to simulate distributions of crop yields based on farmer interviews. ICARDA-117En, Aleppo, Syria.

Orskov, E.R., Hovell, F.D.D., and Mould, F. (1980). The use of the nylon bag technique for the evaluation of feedstuffs. Tropical Animal Production, 5, 195-213.

Orskov, E.R., and McDonald, J. (1979). The estimation of protein degradability in the rumen for incubation measurements weighted according to rate of passage. Journal of Agricultural Science, 92, 449-503.

Puckridge, D.W., and French, R.J. (1983). The annual legume pasture in cereal-ley farming systems of southern Australia: a review. Agriculture, Ecosystems, and Environment, 9, 229-267.

Quinlivan, B.J. (1965). The influence of the growing season and the following dry season on the hardseededness of subterranean clover in different environments. Australian Journal of Agricultural Research, 16, 277-291.

Quinlivan, B.J. (1968). Seed coat impermeability in the common annual legume pasture species of Western Australia. Australian Journal of Experimental Agriculture and Animal Husbandry, 8, 695-700.

Quinlivan, B.J. (1971). Seed coat impermeability in legumes. Journal of the Australian Institute of Agricultural Science, 37, 283-295.

Taylor, G.B., Rossiter, R.C., and Palmer, M.J. 91984). Long term patterns of seed softening and seedling establishment from single seed crops of subterrenean clover. Australian Journal of Experimental Agriculture and Animal Husbandry, 24, 200-212.

Thomson, E.F. (1984). First experiences with joint managed forage and grazing trials, in 'Proceedings of the Third Farming Systems Symposium' ed. C. Butler-Flora, Kansas State University, Manhattan, U.S.A., pages 234-250.

Thomson, E.F., Jaubert, R., and Oglah, M. (1985). On farm comparisons of milk yield of Awassi ewes grazing introduced forages and communal village lands in the barley zone of NW Syria, in 'Proceedings of the First International Conference on Animal Production in Arid Zones', ed. O. Awa, ACSAD, Damascus, Syria, in press.

Thomson, E.F., and Orita, G. (1988). Seasonal prevalence of lungworms of Awassi sheep in northwest Syria. Tropical Animal Health and Production, in press.

Thomson, E.F. and Termanini, A. (1988). Voluntary intake and liveweight changes of Awassi sheep fed barley straw and cottonseed meal. Egyptian Journal of Animal Production, in press.

Tully, D., Thomson, E.F., Jaubert, R., and Nordblom, T.L. (1985). On-farm trials in north-western Syria: testing the feasibility of annual forage legumes as grazing and as conserved feed, in 'Proceedings of the IDRC/ICARDA Workshop on Livestock On-farm Trials', eds T.L. Nordblom, A.K. Ahmed, and G.R. Potts, pages 209-236.

Van Soest, P.J. (1984). Nutritional Ecology of the Ruminant, O and B Books, Corvallis, U.S.A., pages 282-285.

Yasue, T., and Ota, K. (1985). Studies on the hard seed of milk vetch (Astragalus sinicus L.). Proceedings of the Crop Science Society of Japan, 27, 289-292.

Staff at 31/12/1987

Program Leader: P.S. Cocks
Livestock Scientist: E.F. Thomson
Pasture Ecologist: A.E. Osman
Microbiologist: L.A. Materon
Senior Training Scientist and Forage Breeder: A.M. Abd El Moneim
Grazing Management Scientist: A. Smith
Pasture Scientist (North Africa) P. Beale

Research Associates

F. Bahhady (Assistant Livestock Scientist)
N. Nersoyan
S. Rihawi
H. Sawmy
M. Turk
M. Zaklouta
L. Russi
M. Pagnotta

Research Assistants

M. Jabboulieh
A. Khatib Salkini
M. Bellar
A. Termanini
F. Ghassaly
M. Touma
A.K. Ferdawi
E. Khoudary
A.H. Antar
I. Saeed
B. Abu Dan
G. Zakko
S. Filo
S. Nour

Senior Technicians

W. Bou Moughlabay
A. Semaan
A. Nassar

Technicians

F. Ahmed
S. Sabouni
S. Bittar
H. Hreitani
M. Hailani
A. Badenjki
R. Abu Nakad
K. Kaddah
W. Hamo
G. Basmadji

Secretaries

Z. Ablo
A. Battikha
Z. Mousattat

Consultants

Dr G. Orita
Dr C. Rhodes

المركز الدولي للبحوث الزراعية في المناطق الجافة
ايكاردا
ص. ب. 5466 ، حلب ، سورية

INTERNATIONAL CENTER FOR AGRICULTURAL
RESEARCH IN THE DRY AREAS
Box 5466, Aleppo, Syria

1988