Introducing Ley Farming to the Mediterranean Basin

Proceedings of an International Workshop
26-30 June 1989, Perugia, Italy

Scott Christiansen
Luis Materon
Mario Falcinelli
Philip Cocks

editors

International Center for Agricultural Research in the Dry Areas

Established in 1977, the International Center for Agricultural Research in the Dry Areas (ICARDA) is governed by an independent Board of Trustees. Based at Aleppo, Syria, it is one of 18 centers supported by the Consultative Group on International Agricultural Research (CGIAR), which is an international group of representatives of donor agencies, eminent agricultural scientists, and institutional administrators from developed and developing countries who guide and support its work.

The CGIAR seeks to enhance and sustain food production and, at the same time, improve socioeconomic conditions of people, through strengthening national research systems in developing countries.

ICARDA focuses its research efforts on areas with a dry summer and where precipitation in winter ranges from 200 to 600 mm. The Center has a world responsibility for the improvement of barley, lentil, and faba bean, and a regional responsibility—in West Asia and North Africa—for the improvement of wheat, chickpea, and pasture and forage crops and the associated farming systems.

Much of ICARDA's research is carried out on a 948-hectare farm at its headquarters at Tel Hadya, about 35 km southwest of Aleppo. ICARDA also manages other sites where it tests material under a variety of agroecological conditions in Syria and Lebanon. However, the full scope of ICARDA's activities can be appreciated only when account is taken of the cooperative research carried out with many countries in West Asia and North Africa.

The results of research are transferred through ICARDA's cooperation with national and regional research institutions, with universities and ministries of agriculture, and through the technical assistance and training that the Center provides. A range of training programs are offered extending from residential courses for groups to advanced research opportunities for individuals. These efforts are supported by seminars, publications, and by specialized information services.

Introducing Ley Farming to the Mediterranean Basin

Proceedings of an International Workshop on
Introducing the Ley Farming System in the Mediterranean Basin

26-30 June 1989, Perugia, Italy

Editors

Scott Christiansen
Luis Materon

ICARDA, Aleppo, Syria

Mario Falcinelli

University of Perugia, Perugia, Italy

Philip Cocks

University of Western Australia, Nedlands, Australia

Sponsors

Government of Italy
International Plant Genetic Resources Institute, Rome, Italy
International Center for Agricultural Research in the Dry Areas

International Center for Agricultural Research in the Dry Areas
ICARDA
P. O. Box 5466, Aleppo, Syria

1993

Production Editor: Linda J. Sears

Typeset and printed at ICARDA

International Center for Agricultural Research in the Dry Areas (ICARDA)
P.O. Box 5466, Aleppo, Syria

1993

ISBN 92-9127-004-0

The views expressed in these proceedings are those of the authors and not necessarily of the sponsors. The mention of trade names does not imply endorsement of or discrimination against any product by the sponsors.

Contents

Foreword

It is with great pleasure that I welcome the publication of the proceedings of the Workshop to Introduce Ley Farming to the Mediterranean Region, held in Perugia, Italy in June 1989. The research and analyses reported upon in this volume represent an authoritative compendium on ley farming in the West Asia North Africa (WANA) region.

Work on introducing ley farming systems to WANA has been a collaborative undertaking. Between the 1950s and 1970s, efforts to introduce this technology met with limited success. A major cause was the location-specific nature of various components of the system and an approach based on its transfer, without adequate screening and testing of materials and practices, from developed to developing countries. The pattern was repeated in Algeria, Egypt, Iraq, Libya, Syria and Tunisia.

The fact that agricultural technology - including aspects of ley farming technology - is location specific suggests that the International Centers alone are not equipped to undertake the task in every region of WANA. A partnership of all concerned is a prerequisite for success. The workshop, and this proceedings, represent an important step in the process of fostering such a partnership and building on already existing cooperative foundations.

Nasrat Fadda
Director General

Acknowledgements

The editors wish to express their gratitude to several people who "saved" this proceedings. The secretaries of the Pasture, Forage and Livestock Program — Zuka Musatat, Sonia Noaman and especially Parvin Damania — all played their part. Tim Treacher gave his support while serving as Acting Program Leader. Finally, Surendra Varma and, most of all, Linda Sears of CODIS pushed this job through to completion. We also wish to thank the ICARDA Graphics Unit, the Print Shop and all the people who worked to organize the workshop in Perugia, Italy, including the University of Perugia and IBPGR, for their generous support.

Part 1. Ley Farming around the Region

Australian Attempts to Introduce the Ley Farming System to West Asia and North Africa

N.J. Halse

Department of Agriculture, Como, WA 6152, Australia

Abstract

This paper summarizes the ley farming connection that Australia has had over the years with countries in the West Asia and North Africa (WANA) regions. The stage is set with a history of ley farming as it took root in Australia and unfolds the logic associated with taking the ley farming system from Australia back to WANA. Australian work in the WANA region is reviewed and an assessment of the major problems encountered is presented.

Introduction

The title of this workshop concerns the Mediterranean basin. However, Australian attempts to introduce ley farming have been limited to countries in West Asia and North Africa (WANA). The one exception is a cooperative project carried out between Australia and Spain at Badajoz but this was more concerned with the use of subterranean clover (*Trifolium subterraneum* L.) for grazing systems than for ley farming systems.

In the text I specifically refer to Syria, Iraq, Jordan, Libya, Tunisia, Algeria and Morocco. Climatic comparisons are also made with Turkey and Iran. I have mentioned the Australian projects of which I am aware, but will base my paper on projects with which I am personally familiar.

Reasons for Australian Involvement

Australian interest and involvement in the Mediterranean basin arose from a series of factors: the development of farming systems that seemed appropriate; similarity of climate; common origin of crops and pastures; a need to improve productivity of agriculture in WANA, and the political and technical acceptability of Australian scientists.

Australia, like North America, never had a subsistence agriculture and most of its land has been farmed for less than 100 years. For this reason, its agriculture started in a post-industrial revolution era in a commercial mode. It was mechanized, with access to capital and virtually unlimited land, and was oriented to the production of export commodities for cash income. In a well-educated community with good flows of information, farmers and scientists together developed new methodologies adapted to the rather difficult environment. It has been only natural that Australians have wanted to try these methods in other countries.

The climate of the southern part of the Australian mainland is similar to that of WANA. The main similarity is in the incidence of winter rainfall, the principal characteristic of the Mediterranean climate. Although this is more marked in most of WANA it can be seen from Table 1 that there is a little overlap: Erzurum in particular receives high summer rainfall. Both regions have substantial areas receiving 200-400 mm of winter rainfall (Table 1). Another factor of agricultural significance is winter temperature. Certainly there are much colder areas in the WANA region than in Australia but Table 2 shows that there is again an overlap in the distribution of winter temperatures in the two regions, particularly between eastern Australia and north Africa. Overall climates are most similar between western Australia and lowland Morocco.

Southern Australia's crops, pasture plants and weeds largely originated in the WANA area. They were introduced with European settlement of Australia when ships brought seeds, some deliberately and some accidentally, to Australia from the western Mediterranean region. Many of these introductions were probably staged through England (Cocks 1980) and some were first naturalized in southern Africa and then subsequently brought to Australia by ships carrying animal fodder from southern Africa. As Australian agricultural scientists appreciated the value of these introductions, deliberate plant-collecting missions from Australia to WANA were carried out by many scientists (Neal-Smith, Bailey, Crawford, Francis, Collins and many others). This led to the proposal that Australian farming systems—medic rotations in particular—could be of value to WANA.

Over the last 40 years, there has been an intensified effort to improve productivity in WANA to meet the needs for better food supplies and to increase the income levels of poor farmers. This has been led by international agencies such as FAO, Ford Foundation, and of course the CGIAR. It has derived much of its impetus from the direct efforts of the various countries themselves and of their own agencies such as the Arab Centre for Studies of Arid Zones and Dry Areas (ACSAD).

A fifth factor is less easy to define, but is also relevant. Australian agriculture is still young and cereal/pasture rotations have been elaborated only in the last 50 years (Halse and Wolfe 1985). As a result, many of the Australian scientists who helped establish these systems are still active. Australian scientists are practical and used to working in the field under difficult conditions. Together with the low political profile of a small, remote country like Australia these attributes have combined to make Australian scientists both appropriate and acceptable.

Table 1. Comparison of winter rainfall incidence in WANA countries and Australia.

	Rainfall (mm)		
	Annual	Wettest in 7 mo	Percent in 7 mo†
WANA			
Amman	416	411	99
Aleppo	371	360	97
Mosul	385	376‡	98
Azzizia	215	201	93
Settat	391	358	92
Tabriz	282	238‡	84
Sidi Bel Abbes	395	326	83
Tunis	420	350	83
Australia			
Merredin	305	233§	76
Cleve	398	288§	72
Horsham	446	311§	70
Batna	346	236	68
Wagga Wagga	544	345§	63
Erzurum	513	322‡	62

† Usually October to April.
‡ Usually November to May.
§ Usually April to October.

Development of Ley Farming in Australia

The deliberate use of pasture legumes commenced in 1890 (Gladstones and Collins 1983) with limited sowings of subterranean clover in areas of more than 600 mm of annual rainfall. Diffusion was slow and limited to word-of-mouth. The first formal proposal for ley farming in cereal-growing areas was made by Dunne and Shier (1934) only 55 years ago in western Australia.

Early experiments showing the benefit of medic pastures on cereal yields in Victoria were recorded years later (Tuohey *et al.* 1972; Tuohey and Robson 1980). In these experiments a fallow was still used prior to the cereal crop. In western Australia the practice of fallow was abandoned in the period 1950 to 1965. On heavier soils the fallowing was a benefit to crop yield in drier areas, but, overall, farmers and research

Table 2. Monthly mean of coldest winter months in WANA countries and Australia (Australia, July; WANA, January).

Country	Site	Temperature (°C)
Mild		
Morocco	Settat	10.2
Tunisia	Tunis	10.3
Libya	Azzizia	11.5
Australia (West)	Merredin	10.0
Australia (South)	Cleve	10.9
Cool		
Algeria	Sidi Bel Abbes	8.0
Syria	Aleppo	6.2
Iraq	Mosul	7.1
Jordan	Amman	8.2
Australia (Victoria)	Horsham	8.6
Australia (NSW)	Wagga Wagga	8.6
Cold		
Algeria	Batna	4.6
Iran	Tabriz	-2.7
Turkey	Erzurum	-8.9

workers considered that the value of pasture was worth more than the benefit of fallowing to the following crop.

By 1970, the benefits of legume pastures on mixed cereal/livestock farms were recognized in Australia and the system was practised almost universally, although details of the rotation varied among farmers, regions and soil types.

In western Australia on clay loam soils around Merredin—a homologous situation to low-rainfall cropping areas in Tunisia and Morocco—a rotation of one year of medic pasture followed by one year of wheat was commonly adopted. There was a decline of medic and increase in annual grasses with time during a longer period of ley, as shown in Table 3.

As the biological processes of ley farming were quantitatively characterized, it could be examined in terms of economics as well as biology. By examining the net income derived from various parts of a rotation it became possible to compare rotations in terms of

Table 3. Dry matter yields (kg/ha) in pasture phase on long-term rotation trial, Merredin, West Australia.

Rotation		Medic	Grass
1:1		2808	1166
4:1	1st year	1343	1777
	2nd year	874	3018
	3rd year	652	3144
	4th year	253	3324

Source: I.C. Rowland, unpublished report, WA Department of Agriculture.

efficiency (White *et al.* 1978). A further stage is the building of bioeconomic models, which include the interaction of the various components of a cereal/sheep farm and enable the selection of optimum economic solutions (Pannell 1987). Farmers are now using the results of such decision-making aids.

This brief historical perspective is given to show that there has been an evolution in thinking about and using ley farming in Australia. In the beginning, when Dunne and Shier published their paper in 1934, it was a new and unproven idea. Later, when the trickle of successful experiments became a flood, the concept of ley farming became a dogma to Australian agricultural scientists. It was then that our most zealous missionaries went from Australia to WANA. Now the use of legume leys is a tool that farmers may select depending upon product prices and their own situation. In practice, most farmers still use it on a large part of their farm.

Problems of Introducing New Farming Methods

In any long-established farming system, the experiences and observations of farmers lead to optimization of the components within the environment in which the farmers operate (Schultz 1964). The environment includes many constraints, which may well result in a system that does not operate at a biological or economic optimum. The identification of these constraints in terms of yield gaps has been discussed by De Datta *et al.* (1978).

One such constraint is a lack of knowledge of alternative technologies. However, agricultural scientists transported from another environment often are too inclined to assume that because there is a better technology available, it is only lack of knowledge that prevents its adoption.

This is, of course, a naive concept and in many cases problems of land tenure, capital availability, food pricing policies, livestock ownership, or other factors constrain the adoption of the new technology. As Bunting (1978) puts it, "The technology is inappropriate ... because it was designed to maximize yield rather than to resolve felt or real problems of real producers in real life systems with the real resources actually available."

Recognition of this has led to the 'farming systems approach', where before any new technologies are introduced, there should be a study of the system in order to identify the parts that limit productivity and are susceptible to improvement (Byerlee *et al.* 1979). Ideally, such improvements can be introduced without requiring major changes in the socioeconomic environment. However, in many cases, some other changes, such as additional working capital for farmers, will need to be provided with the new technology.

In most Australian attempts to introduce ley farming, there has been no preliminary study of the farming systems of the area of their work. It is important to recognize this in making any assessment of the success or failure of the introduction of these systems (Springborg 1985).

The role of socioeconomic constraints to development of rain-fed farming has been discussed by Nygaard (1980). His discussion, although not specific to the introduction of ley farming, is written from the background of the farming systems work in ICARDA.

Australian Work in the WANA Region

Early Work

Algeria and Tunisia

Carter (1974, 1978) reviewed the potential for ley farming in WANA and strongly supported the concept of introducing clovers and medics in place of fallow. He estimated that a potential area of 23 million hectares existed in nine countries and suggested that this should lead to large increases in crop yield and feed supply.

Some of the earliest Australian work on ley farming in the region was in Tunisia (Doolette 1976) and Algeria (Saunders 1976). John Doolette worked with Australian cultivars of barrel medic (*Medicago truncatula*) in Tunisia and David Saunders started selecting locally adapted medic ecotypes to suit the cold winter conditions he encountered in Algeria. Although there has been a continuing interest in the use of medics, neither project led to widespread commercial adoption of the system.

Libya

Starting in 1973/74, the south Australian and western Australian Departments of Agriculture commenced projects in Libya. The south Australian project was located around Al Marj in the hinterland of Benghazi on clay soils receiving 350-400 mm annual rainfall. In 1974, western Australia was invited to join a land development project in the coastal plain behind Tripoli and in the Jebel Nefusa, an escarpment running up to 700 m high. Initial attempts were to develop 100 000 ha but the project actually established 45 000 ha in nine different sites ranging from 130 to 250 mm annual rainfall. Climatic data for Azzizia (Tables 1 and 2) are similar to the most favorable parts of the project area. Soils throughout the area are fine aeolian sands with water-holding characteristics suited to dryland agriculture.

Although the project was aimed at cereal growing, the western Australian feasibility study (Halse 1974) recommended that "benefits to livestock and better cereal yields should make ley farming more productive and stable than continuous cropping." The study also predicted that Harbinger medic (*Medicago littoralis*) would be a satisfactory pasture species. The recommendations were accepted and it was planned to sow the whole area to barrel and Harbinger medics with cereals in rotation. All medic sowings were to be made with phosphorus fertilizer at 10-20 kg/ha.

Many difficulties associated with large-scale land development were encountered but these were overcome and medic pastures were successfully established (Halse 1978).

Wheat and barley grown in rotation with medic were not so successful, although good crops were grown in some seasons. The main problems were drought and weed control; the introduction of medic pasture together with more fertilizer increased the range, density and vigor of weeds. As experience was gained, it became apparent that more than one year of medic was needed. Indeed, in the drier areas this was necessary to ensure adequate seed set. This also was economically sensible, the livestock being more profitable than the cereal. Nevertheless, cereals continued to be grown to meet government goals.

A number of specific problems arose, the most spectacular of which was the increase in rodents, specifically a jird (*Meriones libycus*) that ate the green medics and, more importantly, collected and ate seeds after the plants had matured. It seems likely that this problem was associated with large-scale development and that small farmers could have dealt more easily with the problem.

Overall, the medic pastures and livestock production were outstanding. When all the area was sown to pasture the project carried 15 000 breeding ewes with an overall lambing of nearly 100%, equivalent to well over 20 000 sheep. Lamb growth rates were very good (Lightfoot 1988).

Partly owing to the design concepts but largely because of the dedication of the Libyan officials, the project was technically highly successful, despite the problems it uncovered. It continued for two 5-year periods and ended in 1984. During this time Australian scientists, farmers and mechanics had spent about 150 person-years in Libya and a number of Libyan agricultural scientists had trained in Australia.

The reason that the impact on agriculture was less than hoped was that there was no existing stable farming system in the area and that policy changes prevented the intended land settlement scheme from being established. If the proposals developed during the project had been implemented, the newly established farmers would have provided a framework for the new ley farming system. The land and the sheep would have been owned by settled farmers and the pastures, crop residues and barley grain would have provided year-round sheep feed. Grain production would have been very variable, depending on rainfall, but the use of failed crops would have provided a useful buffer feed reserve for livestock production.

The south Australian project produced similar results, although the impact was probably greater on cropping and less on livestock production.

Iraq

In 1978 Iraq commenced negotiations with both south Australia and western Australian agencies to develop agricultural projects. The negotiations finally resulted in a western Australian project at Tel Afer west of Mosul (300 mm rainfall) and a south Australian project near Erbil at Ain Kawa (500 mm rainfall). The south Australian project involved a single large farm; the western Australian project included two development areas and six experimental sites ranging in rainfall from 150 to 400 mm. Both projects were hampered by the war with Iran but both continued until the end of their 4-year contracts.

My comments concern the western Australian project with which I am familiar. Preliminary consideration of conditions in northern Iraq suggested that Australian medics would not be suited to the cool winters (Francis 1987). For this reason seeds of two cultivars of *Medicago polymorpha* were increased: Serena and Circle Valley.

Although large-scale seeding was carried out, medic establishment was unsatisfactory at the low-rainfall sites near J'Ravi. The reasons were poor seeding techniques, dry cold conditions and damage by skylarks (*Alauda arvensis*), the latter being the most serious problem (Halse and Trevenen 1985). Other birds causing damage were calandra larks (*Melanocorypha calandra*) and sand grouse (*Pterodes alchata*), which dug for seedlings and ate seed. In later years, problems were encountered with weeds in cereals following medic pastures.

The J'Ravi area subsequently was returned to its previous owners because the project had few sheep of its own, the land tenure gave no protection from nomadic sheep and grazing was therefore uncontrolled.

Many specialist reports were provided during the project on inoculation of medics, medic distribution, medic collection and selection, cereal variety testing and bird damage, as well as experimental reports on a large agronomic program. The recommendations on medic cultivars suggested that a number of local *M. polymorpha* selections collected in northern Iraq should be developed for larger scale testing. That report drew attention to two selections of *Medicago rotata*, which showed high cold resistance and seemed to be completely resistant to bird attack.

In the final report on the project it was suggested that pasture improvement with legumes could be used with benefit in three situations in northern Iraq (Halse 1985):

- on the margin of cropping areas under low rainfall where original rangeland vegetation has been grazed out,
- on non-arable land such as steep hills within the cereal-growing area,
- in medic pasture/cereal rotations if further investigations into the rotation system are successful.

However, the report also concluded that crop/fallow systems would dominate the region for at least the next decade (1984 to 1994). It predicted that which farming systems are adopted in the future would depend on the interaction of medic ley farming with economic, social and other forces such as land tenure, tradition and grazing rights. The degree of adoption of the system could range from adaptation into the existing system of land tenure and grazing rights to adoption of a new farming system enabling fuller exploitation of a ley farming crop/livestock system.

The south Australian project had better control of the project area and with a higher rainfall achieved better crops and medic establishment. However, difficult conditions in the area due to the war and other political problems prevented any serious attempts to spread the technology.

Jordan

Unlike the Libyan projects, which resulted from bilateral government agreements, and the Iraqi projects, which were carried out as contracts to the Government of Iraq, the Australian Dryland Farming Project in Jordan has been carried out as an Australian aid project funded by the Australian International Development Assistance Bureau. The project has operated for more than 8 years. The objective of the project was to introduce self-generating medic pastures into the fallow phase of the cereal/fallow cropping system.

As in other areas, the project encountered a number of initial difficulties with the biology of the system, including the lack of adaptation of the available commercial (Australian) medic cultivars. However, it was able to show that medic pastures could be grown. Cultivars of the species *Medicago rigidula* and *M. rotata* appeared well adapted to the conditions of the project. Work on the medic pasture/crop rotation system has not made as much progress as might have been expected, particularly in relation to quantitative information on cereal yields.

This project, unlike others reported, did include an extension component. The extension developed a successful activity on cropping technology but has not been successful in relation to medic pastures. This was partly due to initial biological problems with the system and to lack of support from the national extension system. However, the main problem was in adapting the ley farming system to local socioeconomic conditions (Allen, personal communication).

Biological Constraints in Australian Projects

Lack of adapted cultivars

The only commercial quantities of seed are of cultivars adapted to south or western Australia. The immediate problem that arises in places with cool or cold winters (Table 1) is cultivars that lack cold tolerance. Australian cultivars grow perfectly well at mild temperatures in low altitudes but are not suited where mean monthly temperatures are below 9°C in the coolest month. Frost damage is the main problem but slow growth also seems to be a problem.

Because many projects are only of short duration there is inadequate time to select locally adapted cultivars and use them for establishment, agronomic and rotation experiments. This has been a problem in all Australian projects except Libya, where cultivars of *M. littoralis* and *M. truncatula* were well adapted and successful in all but the driest sites.

The need for inoculation with rhizobia

Usually this has not been a problem, other than in the short term (but see other chapters in this volume). For example, in Iraq, where strain specificity was a major issue, inoculation problems were quickly overcome (Chatel 1982) by selecting a local strain and using it for all subsequent plantings; it also is widely used in Australia.

The need to apply phosphorus

In many areas phosphorus is needed for successful pasture growth. Although this is easily identified and solved technically, it presents an additional cost barrier to the system. Even where economic benefits can be shown, farmers' attitudes to risk, their lack of working capital and government policies on fertilizer distribution can prevent use of the necessary phosphorus.

Bird damage

This problem was most severe in Iraq where slow winter growth and lack of other food increased grazing by skylarks on seedling medics. Grazing by skylarks also occurs on cereals, particularly with exotic cultivars (Halse and Trevenen 1986). It also is a problem in Syria (P.J.M. Cooper, personal communication).

Rodents

In Libya, rodents in medic pastures appear to increase in good seasons. Natural predation seems insufficient to control numbers and in some instances heavy seed sets of medic were virtually eaten out. On heavier soils in Iraq, rodents also caused damage but did not build up to the plague proportions encountered in Libya.

Sowing methods

In the fine sands of western Libya, medic establishment was simple because the sandy soil enabled sowing at shallow depths and good seedling emergence. On the heavy soils that predominate in most of WANA, the sowing of small seeds is not as easy owing to inadequate depth control and a high incidence of soil crusting.

Low cereal yields
In the Australian projects there has been difficulty in demonstrating that cereal yields after medic are better than after fallow. This should not be surprising: if the soil has plenty of nitrogen and the fallow is clean, cereal yields will be higher because of stock water and better weed control. The benefit of using pastures lies in the fact that there is income in both years, not only in the crop year. However, many early proponents of ley farming emphasized its benefits to cereal yields. Doolette (1980) even suggested that livestock are not necessary to justify use of ley farming.

The major problem in all Australian projects has been weed control. In Australia this is achieved by careful control of grazing (to virtually eliminate grasses) in the pasture year(s) plus herbicide treatments in the crop year. In the new environment, workers have struggled with lack of control of grazing, inexperience with and sometimes unavailability of herbicides and frequently new weeds such as wild barley (*Hordeum spontaneum*).

Additional Constraints to Ley Farming in WANA

Livestock ownership and grazing rights
Throughout WANA a large proportion of the livestock are owned by farmers who have inadequate land to support them. These animals graze steppes, common land and wasteland, and may have certain grazing rights on farms. Under the traditional system, Bedouin livestock owners could graze volunteer 'weeds' (as opposed to planted crops) and crop residues. This created a problem for self-generating medic pastures if they were regarded as weeds. However, traditional practices are breaking down; on the one hand, Libyan shepherds would graze project crops if they could, and on the other hand, nomads expect to pay for the grazing of stubble.

The opposite problem applies to farmers who do not own livestock. This occurs in some areas of Iraq, particularly with sharecropping where three parties are involved: the Bedouins who own the sheep and goats, the farmer who leases or sharecrops the land, and the landowner, which might be a village cooperative. In such a case, farmers are not interested in sowing pastures because they do not get the benefit of the additional feed resource.

Government policies
Both in Libya and Iraq, aspects of the projects did not fit into existing government policies. In Libya, the main difficulty lay with changing government priorities resulting in rapid changes in land use. For example, areas suitable for farming often were allocated to other uses, sometimes when the work was well advanced. In Iraq, the problem lay with identifying farmers and their rights in the cooperative village system, which only recently had been imposed by the government.

Ley farming requires investment both in finance and knowledge for benefits that will be received in the future. When government policies are constantly changing, farmers seek opportunistic solutions (growing a crop of melons or raising turkeys) rather than embarking on a new farming system for long-term land improvement and future profit.

The agricultural extension system
In Australia, ideas arising from research are communicated quickly to farmers through professional extension officers who are regarded as equals by research workers. If farmers find the recommendations difficult or unreliable they tell the extension officers who very quickly go back to the research workers.

This close, frank communication between research workers, extension officers and farmers is of the utmost value to the whole system of research and adoption. There are many countries in the WANA region where these close linkages do not exist.

Conclusion

Australian attempts to introduce the ley farming system into the Mediterranean basin have not yet been successful. Although I have discussed a number of biological and socioeconomic constraints responsible for the lack of success, one stands out as a major obstacle: grazing rights and land tenure system.

It cannot be expected that governments will alter traditional land tenure and grazing rights simply to facilitate the adoption of ley farming. However, the matter is more important than this because land tenure also is related to land degradation or improvement.

Land tenure needs to give a long-term right and responsibility for all care and use of a piece of land to an identifiable person or group. That person then has an interest in improving the land. This increases productivity and, wisely implemented, will decrease erosion and degradation. In the absence of such a long-term interest, any scheme of increasing pasture or forage is doomed to failure.

References

Bunting, A.H. 1978. Science and technology for human needs, rural development and the relief of poverty. *In* Proceedings of the OECD Workshop on Scientific and Technological Cooperation with Developing Countries, 21 p. OECD, Paris.

Byerlee, D., S. Biggs, M. Collinson, L. Harrington, J.C. Martinez, E. Moscardi and D. Winkelman. 1979. Towards a methodology for developing technologies appropriate to farmers. *In* Proceedings of the 17th Conference of the International Association of Agricultural Economists. Banff, Canada.

Carter, E.D. 1974. The potential for increasing cereal and livestock production in Algeria. Report for CIMMYT and the Ministry of Agriculture and Agrarian Reform, Algeria. Waite Agricultural Research Institute, Adelaide, Australia.

Carter, E.D. 1978. A review of the existing and potential role of legumes in farming systems of the Near East and North African region. Report for ICARDA. Waite Agricultural Research Institute, Adelaide, Australia.

Chatel, D.L. 1982. Responses of annual medics to inoculation. Consultant report no. 5: Development of Dryland Agriculture Jezirah Project, Northern Iraq. WA Department of Agriculture, Perth, Australia.

Cocks, P.S. 1980. Origin and ecology of pasture legumes. Pages 282-315 *in* Proceedings of an International Congress on Dryland Farming. SA Department of Agriculture, Adelaide, Australia.

De Datta, S.K., K.A. Gomez, R.W. Herdt and R. Barker. 1978. A handbook on the methodology for an integrated experiment-survey on rice yield constraints. IRRI, Los Banos, Philippines.

Doolette, J.B. 1976. The strategy of establishing a crop rotation programme using forage legumes. Pages 243-251 *in* Proceedings of the Third Regional Wheat Workshop, Tunis. CIMMYT, Mexico.

Doolette, J.B. 1980. The Australian ley farming system in North Africa and the Middle East. Pages 630-649 *in* Proceedings of an International Congress on Dryland Farming. SA Department of Agriculture, Adelaide, Australia.

Dunne, T.C. and F.L. Shier. 1934. A modified rotation for the wheat belt. Journal of Agriculture of Western Australia 11:254-260.

Francis, C.M. 1987. Morocco, a plant collection tour 1987. WA Department of Agriculture, Perth, Australia.

Francis, C.M. 1991. Domestication of indigenous species: Incorporation of useful characters into pasture and forage crops. Pages 394-420 *in* Legume Genetic Resources for Semi-arid Temperate Environments (A. Smith and L. Robertson, eds.). ICARDA, Aleppo, Syria.

Gladstones, J.S. and W.J. Collins. 1983. Subterranean clover as a naturalized plant in Australia. Journal of the Australian Institute of Agricultural Science 44:21-27.

Halse, N.J. 1974. Report of the western Australian survey mission on the possible involvement of western Australians in a dryland cereals and livestock project on the Gefara Plain in Libya. Report to the Council of Agricultural Development, Libya. WA Department of Agriculture, Perth, Australia.

Halse, N.J. 1978. An evaluation of the Libyan cereals project as an example of Australian agricultural expertise overseas. Journal of the Australian Institute of Agricultural Science 44:191-202.

Halse, N.J. 1985. Introduction to the final report and recommendations, development of dryland agriculture, Jezira Project, North Iraq. WA Department of Agriculture, Perth, Australia.

Halse, S.A. and H.J. Trevenen. 1985. Damage to medic pastures by skylarks in north-western Iraq. Journal of Applied Ecology 22:337-346.

Halse, S.A. and H.J. Trevenen. 1986. Damage to cereal crops by larks in north-western Iraq. Annals of Applied Biology 108:423-430.

Halse, N.J. and E.C. Wolfe. 1985. The contribution of science to Australian temperate zone agriculture. 5. The wheat and sheep zone. Journal of the Australian Institute of Agricultural Science 51:185-195.

Lightfoot, R.J. 1988. Selection for lamb growth in Libyan Barbary sheep. Pages 145-154 *in* Increasing Small Ruminant Production in Semi-Arid Areas (E.F. Thomson and F.S. Thomson, eds.). ICARDA, Aleppo, Syria.

Nygaard, D.F. 1980. Socio-economic constraints to the future development of the dryland farming regions of the world. Pages 650-675 *in* Proceedings of an International Congress on Dryland Farming. SA Department of Agriculture, Adelaide, Australia.

Pannell, D.J. 1987. Crop livestock interactions and rotation selection. Pages 64-73 *in* Midas—a Bioeconomic Model of a Dryland Farm System (R.S. Kingwell and D.J. Pannell, eds.). Pudoc, Wageningen, The Netherlands.

Saunders, D.A. 1976. Early management issues in establishing wheat-forage legume rotations. Pages 254-259 *in* Proceedings of the Third Regional Wheat Workshop, Tunis. CIMMYT, Mexico.

Schultz, T.W. 1964. Transforming traditional agriculture. Yale University Press, New Haven.

Springborg, R. 1985. Comment on opportunities for and transfer of Australian farming systems to developing countries. *In* Agricultural Systems Research for Developing Countries 11:172-177. ACIAR, Canberra.

Tuohey, C.L. and A.D. Robson. 1980. The effect of cropping after medic and non-medic pastures on total soil nitrogen and on the grain yield and nitrogen content of wheat. Australian Journal of Experimental Agriculture and Animal Husbandry 20:220-228.

Tuohey, C.L., A.D. Robson and D.R. Rooney. 1972. Moisture and nitrate conservation and responses to fallowing after medic ley in the Wimmera. Australian Journal of Experimental Agriculture and Animal Husbandry 12:414-419.

White, D.H., B.R. Elliott, M.J. Sharkey and T.G. Reeves. 1978. Efficiency of land use systems involving crops and pastures. Journal of the Australian Institute of Agricultural Science 44:21-27.

Constraints to Introducing the Ley Farming System in the Mediterranean Basin

F. Riveros, D. Crespo and M.N. Ben Ali

FAO, via delle Terme di Caracalla, 00100 Rome, Italy

Abstract

Constraints to the introduction of ley farming in the Mediterranean Basin include many factors. One of the most obvious is the lack of commercial quantities of locally adapted seed, which is needed to sow large areas. Researchers used seeds that were easy to procure and found their adaptability less than satisfactory, especially for the higher, colder areas. Technical constraints include those of inadequate farm size, improper agronomic practices and grazing management. Socioeconomic constraints include the failure of development workers to understand the rationale for decision-making used by farmers. The introduction of ley farming is a long-term effort that will require focus and attention to be successful.

Introduction

Our contribution to this forum is a discussion of the constraints that face the introduction of the ley farming system in the Mediterranean basin, particularly in the eastern and southern countries, which are part of FAO's Near East region. This region also includes North Africa.

The ley farming that we will discuss is the one in which self-reseeding annual legumes are grown in a systematic rotation with cereals. However, for the sake of practicality and in order to focus the arguments of this discussion on the present concerns in the region, we will limit our thoughts to ley farming systems where annual medics, and to a lesser extent subclovers, are associated with cereals in a 2-year rotation.

For the last two decades, the cereal/medic ley farming system has received the most attention and its introduction into the Mediterranean zone has benefited from the most sustained efforts. It aims to replace the fallow of the traditional cereal/fallow rotation, and intensify and integrate the cropping and livestock components of farming.

Fallowing is an old concept and practice in the Mediterranean region. Its advantages are well recognized by traditional, risk-avoiding small-farm operators (compared with US or Australian farms). There are three main types of fallow (Oram 1956):

- uncultivated fallow, a traditional system in which the fallow is usually grazed,
- worked fallow, where the ground is worked for about 14 months between harvest and seeding of the new cereal crop,
- summer fallow, where the long period of cultivation in the worked fallow is replaced by a short-lived crop.

Historically, the cultivated fallow had, and still has, a large number of followers. Its advantages include moisture conservation, weed control and organic matter mineralization that releases nitrogen for plant use; all these are very important even today to the farmers in Tunisia, Turkey, Portugal, or even Pendelton, Oregon in the USA.

In the 1930s, south Australian farmers started to introduce the cereal/medic rotation in response to declining cereal yields and soil erosion, as well as to integrate livestock with cropping, and diversify and stabilize production. The ley farming system has many benefits. Summarized, they would include an appreciable increase in cereal yields in the rotation through increased nitrogen fertility in the soil, increased fodder and livestock production, a longer grazing season, lower costs of machinery and cultivation, reduced soil erosion and improved soil organic matter and structure. Because of these and other advantages, the farming system has been so successful that almost all wheat and barley produced in southern Australia is grown after pasture, the latter comprising either *Trifolium subterranean* or *Medicago polymorpha* (acid soils), or various other species of *Medicago* (medics) on alkaline soils.

To put the different categories of constraints in the proper context, I briefly describe how the ley farming system came to many of the countries in the Mediterranean zone. In the late 1960s, during the beginning of the famous green revolution in India when cereal production development intensified, the subject of fallow in rotation with cereals became the object of a strong debate among development specialists. This was particularly true in many southern Mediterranean countries where self-sufficiency in cereal production was of paramount importance. The Australian cereal/medic ley farming system was operational then and, through the contacts between scientists, development specialists and politicians, projects sprang up here and there around the Mediterranean to try the system. The basic strategy was to buy the seed in Australia and introduce the system to progressive wheat farmers. The Mediterranean countries assumed that what worked in Australia, with cultivars selected there, would do well in their area. Unfortunately, the assumption did not turn out to be totally correct, and results were far from being consistently positive.

So what happened?

The Bio-environmental Constraints

Perhaps the most important constraint in this regard is the lack of seed, in commercial quantities, of plant materials adapted to the edapho-climatic conditions of the Near East and North Africa. Although much of the original annual medic plant material was collected around the Mediterranean, its development was accomplished under specific Australian conditions and for specific goals such as high biomass production, medium hard seed content and spineless burrs. Large quantities of seed of such cultivars became available and when the Mediterranean countries attempted the introduction of the medic-based ley farming system, these seeds were relatively easy to procure.

One of the many examples is the use of *Medicago truncatula* Jemalong in Tunisia. During the years when adequate (more than 350 mm) rainfall came early and was well distributed, and when winter temperatures were mild (above 5°C), Jemalong had a tremendous growth and biomass production (9 tons DM/ha at Jebibina, Tunisia, 1985) and would surpass all the native medic growing in the area. However, during the years when rainfall was below 300 mm and/or was poorly distributed, and when winter temperatures fell even temporarily below 5°C, Jemalong produced little biomass (0.5 tons DM/ha at Jebibina, Tunisia, 1986), barely survived and did not produce sufficient seed for regeneration. At the same time, native medics grew slowly but produced a relatively high biomass (1.3 tons DM/ha at Jebibina, Tunisia, 1986) and sufficient seed for subsequent regeneration (Ben Diaf, personal communication). In Syria, the lack of frost tolerance in the introduced Australian cultivars was a major reason for the lack of success of ley farming (Cocks and Ehrman 1987).

Animal feed deficiency around the Mediterranean is probably most critical during late autumn and winter. Legume cultivars replacing fallow should be able to tolerate and resist drought and grow rapidly, in spite of low winter temperatures, to produce forage during this critical period. Australian imported seed, used in the introduction of the ley farming system, does not seem to tolerate the erratic distribution of Mediterranean rainfall. Although similar in many respects, rainfall distribution appears to be more reliable in Australia than in the Mediterranean basin. Low temperatures also seem to be more predictable and less frequent in Australia.

During years of unusual drought or cold temperatures, such as this past year in Syria (Salemieh), seemingly well-adapted cultivars such as *M. polymorpha* and *Medicago rotata* were largely outperformed by *Medicago rigidula* and other native legume species (Ben Ali 1989).

When seeded medics of Australian origin performed well following adequate rainfall in North Africa and the Near East, little notice was taken of them because weeds and other native vegetation also performed well. However, during poor rainfall years, farmers constantly pointed out the poor performance of the seeded medics vis-à-vis the weeds and other native vegetation which they say "happen spontaneously, without the expense of seeding or phosphorus fertilizer."

In some areas of the northern Mediterranean countries, the introduction of the ley farming system was curtailed because of the lack of plant material adapted to acid soils. Subterranean clover does well in these soils. However, its insufficient hardseededness precludes it from a large-scale adoption. *Medicago murex* Zodiac, recently developed in Australia, seems to be adapted to acid soils (pH 5.5) and has a relatively high hard seed content.

In some instances, poor nodulation was the cause of the poor performance of the seeded medics, and hence of the ley farming system. Although many still insist that inoculation of medics is not needed in most of the Mediterranean region, research has indicated that indeed some benefit is obtained, and that inoculation frequently reduces the risk of failure of newly sown stands of introduced medic cultivars.

In some cases, unexpected results negatively affected the introduction of the ley farming system. Poorly managed medic pastures replacing fallow in Algeria have left weed-infested fields for the following wheat crop and reduced cereal yields (Bakhtri 1983). In Libya, successful medic pastures increased the population of rats in the area which, in turn, caused damage to growing and stored cereals (B. Quinlivan, personal communication).

Technical Constraints

These are well documented and probably the easiest to solve. At the forefront of these constraints is the inability of farmers and technicians of the Mediterranean area to master the sensitive techniques of sound pasture establishment and management, which are essential to the self-regeneration of full stands of medic during a good number of years.

Because of the small size of farms in the cereal areas of the Mediterranean (Bakhtri 1983), farmers do not always own soil-tilling machinery. Although a few still use animal-drawn implements, most call upon other farmers or government institutions to rent tractors with plows, haymaking equipment or combine harvesters. These farmers, because of the nature of available tilling equipment designed for farming methods learned during past colonial times, have to plow their soil very deep and do not achieve the necessary smooth, firm seed bed that small medic seeds require (Quinlivan 1987).

Seed drills suitable for medic seeds are not readily available to farmers. Even the small cyclone hand-operated seed broadcasters are not always available, so farmers sow by hand as they normally do with cereals. Even after mixing the medic seed with inert materials such as sand, they often do not achieve the even distribution necessary for the establishment of full stands of medic; the bare spots are rapidly colonized by weeds, which in turn decrease the value of the pasture and the interest of the farmer in it.

Another major constraint to the adoption of the ley farming system is management of the medic pastures. Correct management is supposed to regulate the stocking rate so that maximum biomass is produced and grazed by animals, while ensuring sufficient seed production for subsequent regeneration. Farmers, even when they own the grazing livestock, have been unable to adjust stocking rates to plant growth and development. During cold or poor rainfall years, feed is so scarce that they graze the pasture before it has a chance to reach its full production potential. Trespassing by neighbors is common and also increases overgrazing. During the few favorable years, when everyone has enough to graze, the pastures are sometimes understocked. Because of the rapid plant growth and the inability of most farmers to increase animal numbers to fit the available forage, some of the pasture is trampled and wasted, and many weeds grow unchecked to produce seed, which will cause problems for subsequent cereal crops. When they do not own livestock, farmers commonly rent, for a few months, their fallow or legume pastures to landless livestock owners. These, wanting to get the maximum for their money, will graze every bit of vegetation that is available.

The practices described above indicate that improper management of medic pastures can derive from a lack of technical skills or can be dictated by socioeconomic factors that farmers cannot ignore. These socioeconomic constraints are detailed further on.

In some North African countries, bloat of animals (sheep) grazing on annual medics (native or introduced) was, on many occasions, mentioned by farmers. This problem seems to stem from the intermittent grazing of the annual legume pastures. Reports suggest that animal deaths could occur very rapidly even after a very short (15 minutes) grazing period. Farmers who have suffered animal losses from bloating are not likely to continue with the legume pastures of the ley farming system.

In spite of initial good establishment, several medic pastures do not reach a satisfactory level of production because of insufficient phosphate fertilizer. Extension specialists and farmers often overlook the need to apply phosphorus to promote legume growth and production. Micronutrient deficiencies also have been suspected as causing poor establishment and low levels of production. These problems need to be addressed by a sustained research effort and solutions found and extended to farmers. The absence of comprehensive research and development programs in farming systems, including ley farming, is a major constraint to the integration of livestock and cropping in the Mediterranean basin.

Socioeconomic Constraints

Farmers and livestock owners in the semi-arid and arid Mediterranean areas, particularly those who own small farms, have for generations adopted very conservative farm management strategies. These are characterized essentially by an opportunistic attitude, aiming at minimizing risks and taking the most advantage of favorable environmental conditions, to ensure their survival and obtain maximum gains and status in their communities. This opportunistic farming strategy cannot therefore be fixed; it is allowed to fluctuate with factors such as climate, market conditions and other socioeconomic considerations. For these opportunistic farmers the ley farming approach was too constraining and was therefore abandoned.

Another typical social attitude of farmers in the region is their concept of livestock raising. They do not view their sheep flock solely as a regular economic venture which, given certain inputs, will give a corresponding amount of output. Livestock are considered to be a source of revenue like all economic activities, but also a source of nutrition, well-being and an indication of status in the community. They are also a savings deposit account and source of financial liquidity. In many areas livestock not only supply a large proportion of the farmer's food, they also provide his major source of energy. In the Middle East, sheep's milk and milk products form an essential part of the human diet; dung made into cakes is used as fuel for cooking and heating in many cold areas. Farmers sell some of their livestock to send children to school, in case of sickness or death, to marry or to buy animal feed. They will buy livestock whenever they come into an appreciable amount of money, as when they harvest a good crop.

Farmers feel that the more livestock they own, the more security they have. Therefore, when the question of destocking is raised, they will not accept the argument that fewer but better-fed animals will provide the same revenue and security. They have historically based their thinking on exactly the opposite view. Any change of attitude on the farmer's part must take time and a lot of effort. This will happen only when they feel that risks to their livelihood and their livestock have been minimized effectively.

We feel that it is this opportunistic attitude that is at the base of the farmer's decision to keep stocking rates far in excess of the potential of his pastures. When ley farming is first brought to his attention, the farmer is often interested and excited by the prospect of producing more animal feed. However, his tendency to graze every bit of pasture as soon as it grows (to put as much into the bank account as possible) destroys any possibility of adequate seed production for regeneration. Seed production and survival of legumes, particularly medics, are almost nonexistent under overstocking. There is an urgent need, therefore, to develop plant material with small seeds that can escape grazing or survive after being ingested by ruminants. Better yet, the development of drought-resistant, amphicarpic (producing seed below the ground) plant material, such as the many native *Vicia* species in the region, could go a long way toward easing the regeneration of legume pastures. Initially the plant material to be developed need not be as productive as the Australian cultivar. However, it must be able to regenerate and coexist with the farming system being used by farmers.

The decision on how much cereal to grow and how much fallow to have is made yearly by most small farmers in the Mediterranean basin. It is dictated by the amount of rainfall received in the autumn. Large amounts of rain mean more land in cereals and smaller areas for fallow, since good rains will produce a lot of native vegetation. Less rain in the autumn means less cereal being seeded and more land left fallow. Also, if the agricultural year starts well and then dries out, farmers will graze their cereals or sell them for grazing when they have given up hope of a decent crop.

Unlike in Australia, livestock in these Mediterranean areas do not depend only on one or two sources of feed. Private pastures/fallow or sometimes collective range areas serve as a base for livestock. Animals can leave their base in search of feed in rented grazing areas (fallow, cereal stubble, etc.) or the feed may be brought to them in several forms: hay, straw or farm-produced grain; agroindustrial by-products (bran, barley, malt, olive by-products) and imported grain and concentrates, when subsidized by government. In central Tunisia, as in many other parts of the Mediterranean, entire flocks have lived for several months on subsidized barley. Sometimes the price per forage unit of subsidized barley is much cheaper than the forage unit derived from hay or even pastures (Johnson *et al.* 1987).

Some of the socioeconomic constraints that have so far faced the introduction of the ley farming system can best be resolved by an on-farm research/demonstration program where the farmer's ideas and viewpoints are taken into account in the development of acceptable farming and livestock management systems.

Technological Constraints

Here we have included all the important constraints that did not seem to fit in the three preceding groups. In this category, the most important constraint is the poor focusing of extension efforts on the ley farming system. Its introduction was indiscriminately aimed at small farmers who did not pursue a set farming system. With small farmers, several fallows could succeed a cereal crop, or vice versa: several cereal crops could succeed a fallow during adequate rainfall years. There was poor focusing when attempts at introducing the ley farming system were directed toward larger farms (> 100 ha) in north Africa with no livestock component. Often these large-farm owners lived in the town or city because adequate roads and other infrastructures (water, electricity) were not available at their farms. Even though they followed a relatively steady farming program where cereals alternated annually with fallow, the introduction of a legume did not seem important to them. They could rent their fallow or weedy pasture for the same price as a medic pasture, and sometimes more, because medic-dominated fallows were considered to pose a bloat risk.

Another important drawback to the adoption of the cereal/medic ley farming system is the lack of locally produced, inexpensive medic seed. Some attempts were made by government agencies to produce seed (multiply local ecotypes and introduced ones) in a few countries like Tunisia and Morocco. Seed yields were low and land levelling and management of the production fields and harvesting were the major limiting factors.

Interest in continuing with seed production is mounting and FAO has been requested to assist[1].

Another important reason why the ley farming system did not fare well in the Mediterranean basin is because insufficient attention and long-term research were devoted to it. A lot more needs to be done to study the system and make it fit the farming conditions and existing practices in the region. FAO is committed to this approach and is assisting its member countries to follow this strategy. I am glad to note that ICARDA also is following this same approach. Its native plant material development and on-farm research/demonstrations are a sure way of securing the necessary farmer/scientist interaction to develop acceptable farm/livestock development systems. To be successful, this approach should take into account the socioeconomic and financial limits that farmers are facing daily.

References

Bakhtri, N. 1983. La rotation cereale—Luzerne annuelle en Afrique du Nord et au Proche Orient. FAO Report AGPC Misc/78. Rome, Italy.

Ben Ali, M.N. 1989. FAO report on the preparatory assistance to integrated dairy/sheep development project in Syria. FAO Report TCP/SYR/8851. Rome, Italy.

Cocks, P.S. and T.A.M. Ehrman. 1987. The geographic origin of frost tolerance in Syrian pasture legumes. Journal of Applied Ecology 24:678-683.

Johnson, D., M.N. Ben Ali and M. Borman. 1987. Economic and ecological perspective on rangeland improvement: Central Tunisia. A case study. Submitted as technical paper no. 8315, Oregon Agricultural Experiment Station, Corvallis, Oregon, USA.

Oram, P.A. 1956. Pastures and fodder crops in rotation in Mediterranean agriculture. FAO Agricultural Development Paper No. 57. Rome, Italy.

Quinlivan, B.J. 1987. Annual medic seed production and harvesting in Tunisia and Morocco. FAO Report. Rome, Italy.

---

1 A course on annual medic seed production took place in Al Jadida, Morocco from 2 to 8 July 1989. Participants came from Algeria, Morocco and Tunisia. The course was organized by the Moroccan Ministry of Agriculture and Agrarian Reform with the assistance of FAO. ICARDA provided a Harvesting Specialist to participate in the course.

Ley Farming System Research in Southern Spain

M. Granda, V. Moreno and P.M. Prieto
Servicio de Investigacion Agraria, 06080 Badajoz, Spain

Abstract

In southern Spain, which has a semi-arid Mediteranean climate, the development of ley farming could provide the benefits of increased soil fertility and persistence of legume pastures, thus providing fodder reserves for livestock. Several research teams are working on topics related to ley farming, such as breeding medics and subclover ecotypes adapted to the edaphic and climatic conditions, isolating effective rhizobial strains, and conducting pasture and grazing trials in which annual legumes and wheat are grown in rotation. The soil acidity of the region restricts the choice of introduced legume to subclover. A cropping system in Spain must provide grain for human use and be economically viable for livestock production. If improved legumes can be developed, the ley farming system could improve agricultural productivity.

Introduction

Ley farming systems are not traditionally applied on pastoral farms in southern Spain. Climatic aridity (low rainfall and cold winters) of the calcareous soils in the east and nonarable acid soils (Dehesa Range) in the west are the main factors constraining the diffusion of this system.

The improving effect of legumes on the next crop is well known and rotations of alfalfa/cereals and sativa vetch/cereals are widely used. The European Common Market restrictions (prices, penalties) on cereals will limit the future application of such a system in Spain.

The spontaneous annual medics, mainly *Medicago polymorpha* and *Medicago murex*, would be an alternative to other legumes in the less acidic soils, which are cropped with cereals eventually. Farms that need hay, straw and some grain to supplement their own animals should be interested in seeding medics in the west; better-adapted varieties in the east could provide solutions to low productivity.

Research Work

We are working on many aspects related to the ley farming system. Seeds of different annual legumes, including medics, have been collected from the Mediterranean areas and

Portugal. The new material has been evaluated and breeding of *M. polymorpha* has been done. We are selecting for plants with spineless pods and good winter and spring growth, but the crosses are still in segregation. Tables 1 and 2 show data of the most promising lines.

The Rinconada (Sevilla) *Rhizobium* research team is isolating and characterizing strains of:

Rhizobium meliloti from plants of *M. polymorpha*, *Medicago arborea* and spontaneous *Medicago sativa* from all over central and southern Spain.

Rhizobium trifolii from plants of *Trifolium striatum*, *Trifolium subterraneum* and *Trifolium glomeratum* from the southwest of Spain.

Selected lines of rhizobia are produced and used for our pasture introductions.

Pasture introduction teams are comparing *Medicago* species with subclover varieties, measuring productivity and persistence. The objective of such introductions, besides getting a good crop of forage, is to increase the fertility of the system, increase seed density, identify better pastoral species, increase the level of organic matter in the soil, etc. To reach these goals, wise grazing management and the absence of tillage for a long period are needed.

Olea *et al.* (1987) have conducted trials in the calcareous areas of west Andalucia, introducing commercial varieties of medics (*Medicago rugosa*, *M. scutellata*, *M. littoralis*, *M. tornata* and *M. sativa*). *Medicago truncatula* Jemalong had the best and most regular performance. Also reported was the good performance of medics (*M. doliata* and *M. polymorpha*) that spontaneously appeared in the paddocks. It was suggested that more adapted varieties for the different edapho-climatic conditions are needed.

In another trial conducted in acid soil areas of southwest Spain (Olea *et al.* 1988), *M. polymorpha* has shown poor persistence and productivity in a site with pH=5.4 (1:2.5 H_2O). Nodulation problems seem to be involved. Table 3 shows *M. polymorpha* productivity in comparison with other introduced pasture species at a site with a soil pH of 6.0.

A pasture/cereal rotation is being studied in a grazing trial from 1981 to 1991. Twenty-one treatments compare: continuous wheat cultivation, fallow/wheat, 2-4 years natural fertilized pasture/wheat and 1-4 years of subclover pasture/wheat. All the paddocks receive 150 kg/ha of superphosphate each year; pastures are cropped after such periods without any nitrogen fertilization. The experiment measures the effect of different sheep-grazing treatments on soil fertility (organic matter and phosphorus) and wheat grain production.

Table 1. Characteristics of *Medicago* ecotypes.

Ecotype	Winter growth†	Spring growth†	Date of flowering	Flowers per peduncle
M. polymorpha				
CP-14-B	5.0	10.0	2 April	4
3	4.5	6.5	2 April	4
9	5.5	8	1 April	4
CP-12	5.0	7.5	22 March	5
M. truncatula				
Cyprus	5.0	5	12 March	-

† 0-10 point scale with 10 = the best.

Table 2. Pod and seed characteristics in Mediterranean ecotypes.

Ecotype	Whorl number	Spines	Seeds per pod	Seed prod. (g/m^2)
M. polymorpha				
CP-14-B	4	Shorts	28.7	232
3	5	Longs	25.6	218
9	5	Shorts	29.3	178
CP-124	4	Shorts	26.7	233
Circle Valley	-	Incrmis	-	148

Three kinds of records are being taken during the trial:

- botanical and pasture productivity evolution,
- organic matter and P level in the soil,
- wheat grain production after different pasture treatments.

We have noticed a high dominance of subclover in the first and second year after sowing. In the second year, the spontaneous annual grasses (*Vulpia*, *Bromus*, *Aegilops*) become an important part of the production and botanical composition, which increases in the third and fourth years. This increment is so important that without appropriate grazing control, legumes are dominated and the paddock becomes an annual grass pasture in the fourth and fifth years. Other species, mainly composites and annual legumes from the spontaneous flora, also become an important part of the pasture in the third year and more clearly in the fourth and fifth (Fig. 1).

Table 3. Natural and introduced pastures containing *Medicago*, *Trifolium*, *Ornithopus* and other species in Fregenal (SW Badajoz).

Treatment	Plants per m²	Percent legume	Percent spontan.	DM (kg/ha)	Seed (kg/ha)
Fertilized natural pasture	-	-	54	2273	-
O. compresus	43	37	20	1825	125
M. polymorpha	90	10	38	2053	36
T. glomeratum	59	15	26	2656	61
T. subterraneum					
Gaitan	73	29	28	2388	47
Valmoreno	115	29	27	2620	123
Seaton Park, Clare, Trikkala, Esperance	89	20	47	2723	70

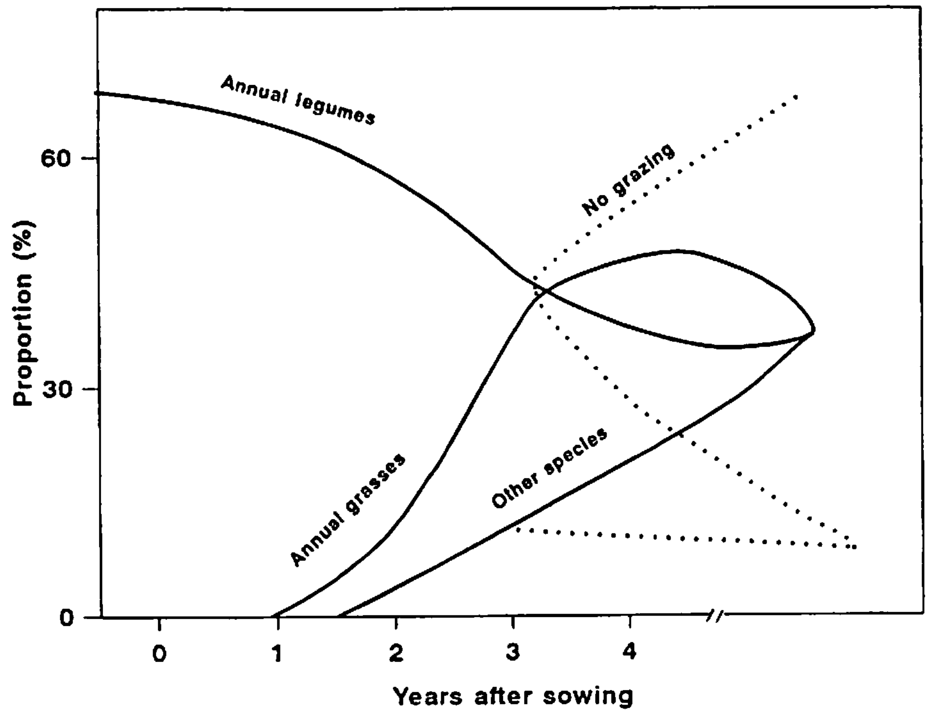


Fig. 1. Evolution of different botanical components after a sowing of subterranean clover.

Pasture production 1-4 years after subclover sowings is presented in Table 4. Significant differences in pasture production have been found among years but not among treatments in the second, third, or fourth years after subclover sowings.

The evolution of the organic matter and phosphorus content of soils in paddocks after such treatments is shown in Figure 2. Natural fertilized pastures and the treatment of 4 years after subclover sowing have the higher organic matter soil content. Phosphate fertilization increases the content of this element in the soil in natural pastures, but this does not happen during the sowing of subclover.

Figure 3 shows wheat production in paddocks after 1, 2, 3 and 4 years of subclover pastures, fallow/wheat rotation, and 4 years of fertilized natural pastures. Maximum production is obtained in paddocks after 2 years of subclover cultivation and 4 years of natural fertilized pastures. The grain wheat production decreases in the third and fourth years in paddocks of subclover cultivation, indicating annual grass infestation problems (Cocks *et al.* 1980).

In Murcia, southeast Spain, a research team is studying the herbage productivity of cereal fallows to evaluate their fodder contribution (Robledo *et al.* 1989) and is working on the identification and mapping of native natural resources to determine their contribution to livestock feeding (Correal *et al.* 1988).

Table 4. Subterranean clover pasture productivity (dry matter in kg/ha) in the years after sowing.

Date of sowing	Years after sowing				Natural fertilized pasture
	1	2	3	4	
1982/83	2355	-	-	-	-
1983/84	1682	3368	-	-	-
1984/85	4794	3338	5428	-	4211
1985/86	2580	2793	2510	2982	1794
1986/87	3346	3080	3777	3082	1782
1987/88	-	2123	1698	2075	1648

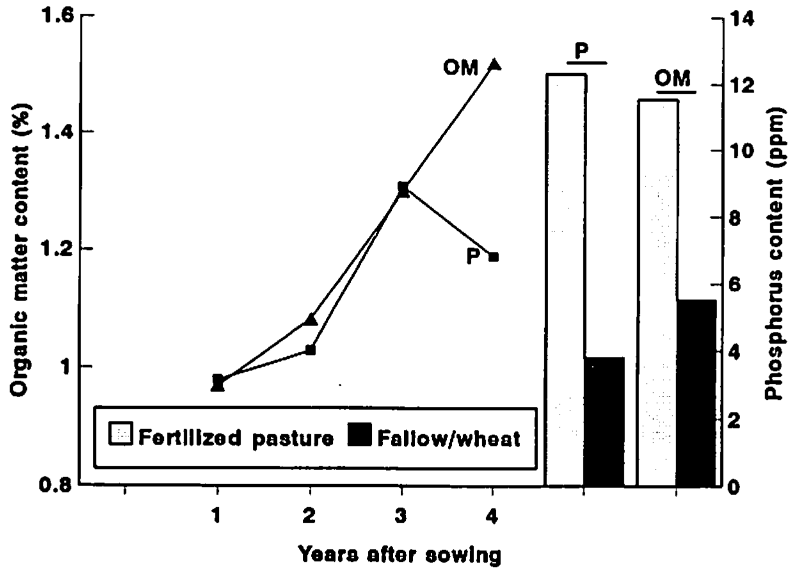


Fig. 2. Organic matter and phosphorus content of soil after different cropping treatments.

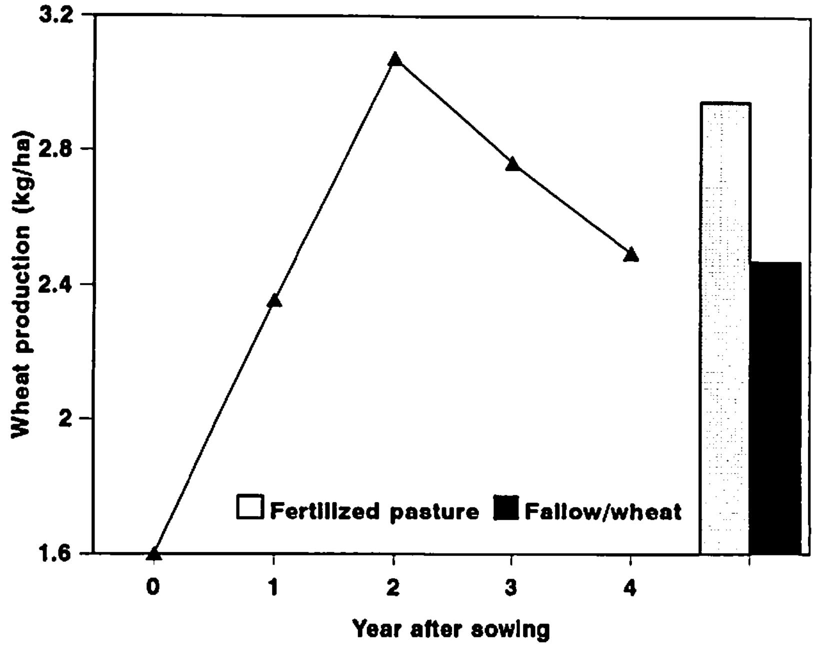


Fig. 3. Wheat grain production after different cropping treatments.

The Future of Ley Farming Systems in South Spain

The dehesa area (southwestern Spain) will need to produce in a cheap but efficient way. This can be achieved by increasing livestock production. A cropping system will be required to obtain straw, hay and stubble as well as some cereal grains for localconsumption. The high transport prices of such materials do not allow producers to obtain them from outside the region or the farm. Sowing annual legumes can be a reasonable solution (Hycka *et al.* 1987) but the cost of such introductions, the probabilities of failure in their establishment and the persistence of such improvements will play a decisive role in the acceptance of ley farming systems.

References

Cocks, P.S., M.J. Mathison and E.J. Crawford. 1980. From wild plants to pasture cultivars: annual medics and subterranean clovers in southern Australia. Pages 569-596 *in* Advances in Legume Science (R.J. Summerfield and A.H. Bunting, eds.). Royal Botanic Gardens, Kew.

Correal, E., S. Rios and A. Robledo. 1988. The native pastoral resources of NW Murcia (Spain). Fifth meeting of the subnetwork on Mediterranean Pastures, FAO, Montpellier, France.

Hycka, M. and A. Armero. 1987. Praderas temporales y cultivos forrajeros anuales en la comarca aragonesa de lo Hoya de Huesca. Ensayo de rotacion de cultivos. Proceedings of the XXVI Reunion S.E.E.P., Mallorca, Spain.

Olea, L., J. Paredes and P. Verdasco. 1987. Produccion y persistencia de pastos mejorados en areas de suelos basicos de Andalucia Occidental. Proceedings of the XXVI Reunion S.E.E.P., Mallorca, Spain.

Olea, L., J. Paredes and P. Verdasco. 1988. Mejora de leguminosas de pastos mediterraneos. Memoria de Actividades 1988. S.I.A. Extremadura, Spain.

Robledo, A., S. Rios and E. Correal. 1989. Produccion herbacea en los barbechos cerealistas del N.O. de Murcia. Pages 353-361 *in* Proceedings of the XXIX Reunion S.E.E.P., Elvas-Badajoz, Spain.

Practical Experiences with the Implementation of an Annual Medic-based Ley Farming System in Morocco

G. Jaritz[1] and M. Amine[2]

[1] *Gesellschaft für Technische Zusammenarbeit and Institut National de la Recherche Agronomique, Rabat, Morocco*

[2] *Ministere de l'Agriculture et de la Reforme Agraire, Direction de la Production Végétale, Rabat, Morocco*

Abstract

Practical experiences obtained during the implementation of an annual medic-based ley farming system at an advanced sheep-raising farm, Had Soualem, and from broad agricultural practice are discussed. At Had Soualem, establishment data, botanical composition and seed set were assessed. Data from an ongoing pasture survey that compares medic with volunteer pastures also were analyzed. The ley farming campaign was evaluated for general farm data on a sample of 326 farms representing 2315 ha sown between 1985 and 1987, and for agronomic data such as establishment, botanical composition, seed set and pasture utilization at 110 farms. Establishment was 309 and 327 plants/m^2 on average at Had Soualem and for the ley farming campaign, respectively and was not considered a major constraint. Medic pastures at Had Soualem are valuable because of their high production of about 2000 fodder units (1 unit = 1 kg barley). However, their productivity is partially offset by heavy weed infestation and, possibly, by reduced ewe fertility. Medic pastures generally have too high a stocking density, which reduces average May seed yields of first-year stands. This fact and farmers' perceptions of medic pastures as a grazed forage crop instead of a land-use system component support the view that self-regenerating medic pastures fit poorly into the predominant socioeconomic conditions of the Moroccan agricultural society and therefore will be restricted mainly to bigger farms in the semi-arid zone. The available data suggest that annual sowings of 7500 ha for the next few years with a 25% persistence rate are possible.

Introduction

The potential economic value for Morocco of the annual medic-based ley farming system, as practised over large areas in the Australian winter rainfall zone, has been emphasized by several authors (Bounejmate 1984; Carter 1978; Jaritz and Kuba 1978; Leeuwrik 1975). Leeuwrik estimated the potential Moroccan medic-based ley farming area at 1.12 x 10^6 ha. However, substantial efforts to test the technical and socioeconomic feasibility of introducing this land-use system in Morocco started relatively late compared with other North African and Middle East countries. In 1981, two new projects were implemented, the first an integrated rural development project in the Fes-Karia-Tissa region, the second a GTZ/INRA applied agricultural research project with small-plot experiments associated with commercial field tests at selected animal husbandry farms scattered over an important part of the agricultural zone.

Promising results from these projects and strong positive impressions about the Australian land-use practices received by a group of Moroccan agricultural policy makers during a visit to South Australia led in 1985 to a national campaign called Opération Ley Farming. The objectives of this operation, which is still ongoing, are to improve the productivity of grazed fallows, improve soil fertility and control soil erosion by introducing annual legume-based pastures. Target groups are farmers in the cereal zone possessing grazed fallows and willing to develop their animal husbandry and those using cropping practices that deplete soil fertility and cause soil erosion. Opération Ley Farming was evaluated during the agricultural year 1987/88. The outcome of this evaluation, together with the overall experiences and experimental results gained so far, allow us now to assess in more detail the chances for the adoption of ley farming.

Our presentation is a mixture of our own experimental results and contributions to the evaluation of the Opération Ley Farming as well as a review of our findings and other results from Morocco. The first part illustrates the more technical aspects with results from a big sheep-raising farm. The second part deals with the implementation of ley farming in broad agricultural practice based mainly on the outcome of the evaluation described above.

Materials and Methods

The Société Nationale de Developpement de l'Elevage (SNDE) Sheep-raising Farm, Had Soualem

Site characteristics

The location is 40 km southwest of Casablanca; mean minimum temperature of the coldest month is 6.8°C; average annual rainfall during the last seven years was 332 mm; farm size is 1314 ha; soils are mostly Regisols.

Agroecological characteristics of medic and volunteer pastures

Routine monitoring. Medic pastures have been monitored regularly in the sowing year by assessing establishment, botanical composition at winter/early spring and seed yield at late spring. Establishment was counted at 2-3 leaf stage using 5 x 50 cm frames and 2-6 samples/ha, depending on the homogeneity, scattered at predetermined distances over the field. For botanical composition and seed yield assessment, frame distribution was similar but frames of 30 x 40 cm size were used. The botanical composition was estimated visually. Other legumes with less than 4% of the total growth were combined with the medics in one group. Medic pods were harvested by hand, with vacuum cleaners or with a small-seed vacuum harvester. In years following the establishment year, generally only the botanical composition was assessed.

Pasture survey 1989. A study to compare medic and volunteer pastures older than 1 year started this season assessing, in addition to the routine monitoring, the seed quantity stores in the soil before seed set, seed produced in this season at the end of May and seed remaining in September. The soil-stored seeds were assessed by samples taken to a depth of 10 cm and with a steel cylinder of 13-cm diameter with a frequency of one sample/ha. Medic pods were picked by hand from the soil fraction ($\geq$ 2 mm particle size) after washing the sample with water. They were then dried at 50°C and weighed. Dehulling was done by hand using all pod samples from one field as a combined sample. Seed yield was then calculated using a single fixture for seed weight per total pod weight. May samples were harvested as indicated for the sowing year. Pods were separated for each species and seed yield calculated from the average percentage of total pod weight of five samples per species. In this paper only the sum of the seed yields of all medic species is presented. This survey will be continued for the investigation of additional aspects during next season. It is undertaken on two subunits of the Unité Regionale d'Elevage Ovin (UREO)-Had Soualem, each representing a former French colonial farm, one with almost all arable land sown to medic (normally a sowing mixture of *Medicago littoralis* Harbinger, *Medicago truncatula* Cyprus and *Medicago tornata* Tornafield with 12, 3 and 3 kg/ha, respectively) and the other without medic sowings.

Evaluation of Opération Ley Farming

General farm data. A random sample of 326 farmers who tried annual legume pastures during the ley farming campaign was used. It represents 2315 ha or 5.5% of the surface area sown to annual pasture legumes. The evaluation had two distinct parts (further information in Anonymous 1989b).

In the first and more detailed questionnaire, general data about farm size, conditions of land tenure, actual land use, animal husbandry, available agricultural machinery and manpower were collected. Farmers were asked about their incentive for introducing the system, their access to technical information, the evolution of their pasture plots, including data about sowing and utilization techniques, fertilization and the method of cereal cultivation after ley phase. Long-term acceptance was assessed by farmers' appreciation of the ley farming in general, as well as the establishment, production and persistence of their annual legume pastures, and particularly by their intention to continue and expand annual legume pastures.

Agronomic data of annual legume pastures. From a subsample of 132 farmers, data were collected about establishment, fertilization, phenology and utilization of pastures from 110 plots. Establishment of medics, grasses and other species was assessed by counting plants inside 10 frames (25 x 25 cm) placed at random over the plot. Seed on the soil surface was assessed in May and at the end of September using the same frames similarly distributed. Dehulling of the pods and weighing of the samples was done by the technical staff of the INRA Central Forage Research Station at Rabat. Information dealt with in this paper concerns the 110 medic field questionnaires only. Conversion of different grazing species to cattle units followed Anonymous (1986a), i.e., 1 cattle unit = 6.7 sheep or goats = 1 horse or donkey.

Results

The SNDE Sheep-raising Farm, Had Soualem

Routine monitoring

Farm-scale pasture improvement started in 1982/83, 1 year after the beginning of small-plot experimentation. Average medic establishment over 6 years was 309 plants/m^2 (Table 1), which allows dense first-year stands. Grass and *Emex* numbers varied widely between years. There was a high number of 'other species', some of them harmful weeds such as *Scolymus hispanicus* and *Silybum marianum*.

Table 1. Plants/m^2 established in first-year medic pastures at Had Soualem.

Year No. ha monitored	82/83 17†	83/84 29	84/85 31	85/86 125	86/87 60	87/88 46	 Avg.
Medicago spp.	113	350	302	309	480	298	309
Grass and cover crops	137	268	111	117	147	62	140
Emex spinosa	157	103	3	53	8	7	55
Other species	231	88	108	104	80	123	122

† Seed rate = 14.2 kg/ha; following years = 18-20 kg/ha.

Except during the first 2 years, the medic proportion of total growth in early spring was as high as 64 to 79% (Table 2). The proportions of grass and *Emex* were higher during the first 2 years and dropped to average values of 12 and 6% respectively during the last 4 years. The average of other species was 8% over all years. No significant relationship was found between medic proportion and establishment number nor between the proportion of other species and their establishment number. However, the relationship between establishment number and proportion in early spring was significant for the grasses and for *Emex spinosa*.

The average pod yield was 1152 kg/ha with extreme values of 621 in 1982/83 and 2059 in 1985/86. The seed weight percentage of total pods has not always been assessed. However, using the available data and 26.6% as an average percentage, average seed yield can be estimated at 306 kg/ha.

Table 3, which summarizes average botanical composition of one of the five UREO Had Soualem subunits, shows a decline of medic in the second year followed by an increase to 50% in the third and fourth years and again a decline after cropping. *Emex* and other

Table 2. Botanical composition of first-year medic pastures in early spring (estimated percentage of total growth) at Had Soualem.

Year	82/83	83/84	84/85	85/86	86/87	87/88	Avg.
No. ha monitored	17	29	31	125	60	46	
Medicago spp. and other legumes	30	46	76	79	64	75	62
Grasses	31	33	13	11	17	6	18
Emex spinosa	30	18	5	3	8	6	12
Other species	9	3	6	7	11	13	8

Table 3. Botanical composition of medic pastures in early spring (estimated percentage of total growth) at the Alloud subunit of UREO Had Soualem.

Year	1	2	3	4	1A†
No. ha monitored	228	208	143	27	86
Medicago spp. and other legumes	64	35	50	49	42
Grasses	17	26	24	38	17
Emex spinosa	9	17	9	5	27
Other species	10	22	17	8	14

† After cropping

species were highest in the second year and dropped to lower values in the third and fourth year, but also were high after cropping. Grasses tended to increase with the age of the pasture, being lower in the establishment year and the first year after cropping. No correlation was found between second-year medic proportion and the pod yield in the sowing year.

Pasture survey 1989. Results of this survey comparing medic with volunteer pastures showed that medic proportion in sown pastures was 30-37% higher (Table 4). Indicated medic proportions for sown pastures are similar to the average values over years from Table 3. Other legumes in volunteer pastures are relatively more important than in medic pastures and therefore have been presented separately. *Emex* proportion was high after cropping in both medic and volunteer pastures and decreased with the age of the pasture. Other species, often thistle, tended to increase with the pasture age.

The highest medic seed quantities stored in the topsoil were found in the second-year medic pastures, and the lowest in medic pastures after cropping and in volunteer pastures (Table 5). During the cropping phase, 62 kg/ha of seed was stored in the soil. Seed weight as percentage of total pod weight varied widely from 5 to 24 in average figures

Table 4. Estimated botanical composition of medic and volunteer pastures at Alloud and Eraste subunit of UREO Had Soualem at end of March 1989.

	Medic	Vol.	Medic	Vol.	Medic	Vol.
Year	1A†	1A†	2	2	3	>6
No. ha monitored	68	20	46	13	60	20
Medicago spp.	43	13	37	7	45	8
Other legumes	2	5	3	3	2	9
Grasses	12	44	11	37	25	39
Emex spinosa	27	27	15	2	13	0
Other herbs	16	11	34	51	15	43

† After cropping.

of whole fields. Seed yield on the soil surface at the end of May was much higher than seed quantities stored in the soil. In agreement with the botanical composition, third-year medic pastures had higher seed yields than stands after cropping and those in the second year (Table 5). Only 9 kg/ha of medic seed were found on the soil surface in the cropped field. Volunteer pastures also had little medic seed set except the second-year fallow located in the neighborhood of the second-year medic pasture. The predominant medic species in the volunteer pastures was *Medicago polymorpha*, whereas in the sown pastures *M. littoralis* predominated. The proportion of *M. polymorpha* tended to increase with increasing age of sown pastures.

Other aspects. In general, the introduction of medics was valued highly by the Had Soualem farm management mainly because of the additional feed offered, which allowed a substantial reduction in concentrate feeding. Medic pastures were estimated to yield 1960 fodder units (Taaroufi 1987), which is several times more than the common grazed fallows. The advantages of medics are, however, partially offset by heavy weed infestation with *E. spinosa* and thistles (Tables 3 and 4), which occupy a substantial part of the land and therefore reduce the advantages of pasture improvement.

Table 5. Medic seed quantities (kg/ha) and their average percentage of total pod weight (in parentheses) in pastures of UREO Had Soualem†.

	1‡		2		3		>6	Cropping after
	Medic	Vol.	Medic	Vol.	Medic	Vol.		3 years of pasture
In top soil, March 1989	26c** (6.6)	3c (5.4)	148a (24.2)	10c (20.6)	69b (11.5)	1c (7.9)		62b (11.2)
On soil surface, May 1989	215a (27.7)	15 c (29.4)	150b (26.7)	44c (29.9)	266a (26.3)	2c (37.7)		9c (34.6)

† Field size of cropped pasture 59 ha; others as indicated in Table 4.
‡ After cropping.
** Means followed by the same letter are not different at $P<0.05$.

A more serious aspect is the conviction of the farm management that annual medics cause a decline in ewe fertility and an increase of the abortion rate. This opinion is based more on observation than on hard data (Fig. 1). It was first claimed for one subunit of the Had Soualem farm when the proportion of medic pastures reached 72% of the arable land in the season 1986/87, and was assumed to be restricted to first-year stands. It is worth mentioning that the neighboring nonmedic subunit showed a similar decrease in ewe fertility (Fig. 1).

Record of Opération Ley Farming

In Opération Ley Farming altogether 47 300 ha of medic pastures were established in predetermined target areas, which have been defined based on edaphoclimatic data and the ecological requirements of available commercial cultivars. Subsidized seed was used and considerable efforts were made to assist extension staff and farmers by training, field days and demonstrations. The overall result based on data of annual reports of the agricultural ministry shows a decline in the area sown each year, which on average has been only 53% of the planned area; in addition, the proportion regenerating successfully was very low (Table 6) (Anonymous 1986b, 1987, 1988, 1989a).

Table 6. Overall result of the Opération Ley Farming.

	1985/86	1986/87	1987/88	1988/89
New sowings (ha)	19,571	15,083	6,914	5,732
New sowings, % of planned area	57	55	45	53
Proportion of medic pastures, %	94	93	95	85
Proportion of regenerating to sown pastures			37	14

Evaluation of Opération Ley Farming

All results presented here concerning general farm data are quoted from the ministry report (Anonymous 1989b). The objectives of the evaluation, which took place in 1987/88, were to identify the level of technical mastery and bottlenecks as well as the acceptance of farmers of the annual legume-based ley farming system. The evaluation was executed by the provincial extension service staff and coordinated by the plant production department of the agricultural ministry.

Using the results of the study of general farm data it was stated that the favored rain-fed agricultural zone is characterized by diversified cropping, a very small proportion of fallow land and a dominance of cattle in animal husbandry. The scope for the introduction of annual legume pastures here is limited by the competition of alternative crops including fodder crops and therefore is very small.

In the drier part of the rain-fed agricultural zone, the farmers investigated grow predominantly cereals, possess substantial proportions of fallow land, especially properties ≥ 20 ha, and raise predominantly sheep. These are more favorable conditions for the introduction of annual legume pastures which are, however, partially offset by small farm size, public forms of land ownership and a scattered holding structure. The access to common grazing land has been found unimportant for farmers' attitudes with respect to the introduction of medic pastures.

The analysis of acceptance of ley farming, as indicated by the degree of interest in continuing and expanding medic pastures, showed a relationship between farm size and interest. Farmers with large farms were more interested than those with small farms. The analysis of farmers' appreciation in respect to pasture utilization, production and persistence proved that farmers compare medic pastures with other forage crops and do not consider it as an integral part of a ley farming system.

From the study of agronomic data, average medic establishment was assessed to be 288 plants/m^2 with some regional variations and clear differences in respect to the age of the pasture. Highest values (327 plants/m^2) were found in first-year stands. In second- and third-year stands establishment was 210 and 236 plants/m^2, respectively. Related to farm size, above-average values were found on farms of 41 to 160 ha (Table 7). Cases of poor establishment have been attributed to late and/or deep sowing and sometimes to a wrong choice of cultivar. High medic density was significantly correlated with favorable spring growth score (Table 7). Weed competition at establishment was not very important with average values of 56 grasses and 96 other species/m^2.

Table 7. Results of the agronomic inquiry in relation to farm size (sample no. in parentheses).

	Farm size (ha)					
	10	11-20	21-40	41-80	81-160	160
Medic establishment	238	280	202	328	365	259
(plants/m^2)	(19)	(16)	(14)	(19)	(16)	(12)
Spring growth	2.3	2.1	2.2	2.1	2.3	2.3
score†	(19)	(16)	(13)	(19)	(16)	(12)
Seed on soil surface (kg/ha)						
May	145	186	100	199	72	161
	(19)	(16)	(14)	(20)	(16)	(12)
September	77	28	43	98	45	119
	(7)	(3)	(5)	(9)	(7)	(4)
Stocking density, medic pasture						
(cattle units/ha)	10.0	8.9	13.0	9.0	11.2	6.0
	(15)	(14)	(12)	(18)	(16)	(11)
Medic plot size (ha)	1.1	1.2	1.5	5.2	7.3	11.7
	(19)	(16)	(14)	(19)	(16)	(11)

† 1 = very good, 2 = good, 3 = fair, 4 = poor.

Seed present on the soil surface in May and September averaged 151 (N=110) and 71 (N=36) kg/ha respectively with considerable variation between regions. In relation to pasture age, seed yields of the first year in May and September were 139 and 76 kg/ha, in the second 227 and 105, and in the third 154 and 41 respectively. Related to farm size, above-average values for both May and September yields were only found in the 41 080-ha class, whereas below-average values were recorded in the 21-40 and 81-160 ha class (Table 7). There was no significant correlation between May seed yield and medic establishment nor between seed yield and spring growth score.

Stocking density was found to be very high in general, with some variation between regions and farm sizes (Table 8). With 10.1 cattle units/ha, first-year stands had higher stocking densities than second- and third-year stands, which had 8.1 and 8.4 cattle units/ha, respectively. Depending on the region, grazing was dominated either by cattle or by sheep; goats, horses and donkeys were of minor importance (Table 8). Utilization of medics by cutting was unimportant.

Table 8. Stocking density (cattle units/ha) and grazing species structure (% of total) in nine regions.

Region†	1	2	3	4	5	6	7	8	9
Stocking density	10.0	12.9	10.0	14.8	13.5	7.6	4.1	8.9	4.2
Sheep	64	37	58	16	62	29	59	73	58
Cattle	32	57	39	73	38	71	40	23	30
Goats	4	1	2	1	0	0	1	2	4
Horses, donkeys	0	5	1	10	0	0	0	2	8

† 1 = Settat, 2 = Fes, 3 = Taza, 4 = ORMVAD, 5 = Khemisset, 6 = Benslimane, 7 = Meknes, 8 = Beni Mellal, 9 = ORMVAH.

Discussion

Sheep-raising Farm, Had Soualem

Except for the sowing in 1982 when a lower seed rate and a direct drill had been used, medic establishment was satisfactory, showing that successful establishment is possible with the available unspecialized equipment. The high variation in grass number (Table 1) between years derives from the irregular contribution of volunteer species and also from the use of cereal rye, or as in 1987, of triticale as a protective cover crop. *Emex* number was found to be low if abundant early rains allowed effective weed control by cultivation and high in seasons with poor early rains (Jaritz 1986). The control of other species (most common were *Raphanus raphanisturum*, *Diplotaxis catholica*, *Reseda alba* and *Scolymus hispanica*) depends less on the quantity of early rains because they germinate over a long period. The high weed infestation is due to an atypically low proportion of only 25% cropland of the total arable land and because pastures were sometimes sown after grazed fallow. Weed control was improved after the first 2 years by sowing later and consequently achieving more effective mechanical weed kill. This also is indicated by the evolution of botanical composition and of the pod yields in the establishment year (Tables 2 and 3).

Average medic percentage increased from 38 in the first 2 years to 74 in the following 4 years; pod yields for the same periods ranged from 708 to 1374 kg/ha. The pods were saved from grazing by very shallow disc harrowing in summer as a routine measure in the first year. Consequently, according to standards given by Carter (1982), these pastures can be considered as adequately established and managed in the sowing year. This is not the case for the botanical composition in the following years when medic does not exceed 50% and *Emex* as well as other species constitute an important part, especially in the second year and first year after cropping (Tables 4 and 5).

The proportion of grasses (about 25%) is supposed to be beneficial because it provides early feed. The botanical composition has to be considered as an overall expression of all the management measures, including herbicide spraying. Field trials have proved that without herbicides *Emex* and other species reach higher proportions. The high proportion of *Emex* in second-year pastures and after cropping can be explained by its increased competitiveness in soils of high nitrogen status and its ability to produce huge amounts of seed that are partly conserved in the soil and germinate after cropping (Weiss 1980). Apparently, this seed bank in interaction with grazing and soil nutrient status is of major influence on the botanical composition and masks partly the relationship between medic seed set in the first year and medic proportion in the second year, which was not correlated.

From the data presented and in accordance with the dependence of *Emex* seed set on soil nitrogen status shown by Weiss (1980), a trend of decrease in *Emex* proportion accompanied by an increase of nitrogen-consuming grasses (Tables 3 and 4) has been observed with rising pasture age, which can be intensified by herbicide application. This has practical implications for improvement of the current management practice: a rotation of one crop followed by 3 years of medic pasture sprayed with asulame, MCPA or a combination of both if it is believed necessary. Improvement of general weed control and particularly of *Emex* might be achieved by applying a short rotation (1-year pasture/1-year crop) combined with regular chemical weed control in the pasture year. If, however, the actual crop proportion has to be maintained, it seems advantageous to split the arable area to one-half with such a short-term rotation and another with long-term medic pastures. In the latter pastures the trend toward higher grass and lower *Emex* proportion should be assisted by management, especially by the systematic use of herbicides.

Medic seed quantities in the soil (Table 5) in the first year after cropping were low, which can be at least partially attributed to deep cultivation. The high seed quantity in the second year stands is in agreement with adequate seed set in the sowing year. The relatively low seed quantity of third-year medic pasture is due to very poor seed set in the preceding year because of damage by herbicide treatment. The relatively low seed quantity of 62 kg/ha in the cropped pasture can again be partially attributed to deep cultivation. However, on the basis of recent experiences this might still allow sufficient re-establishment.

The soil of the three volunteer pastures studied contained very little medic seed, which is in agreement with the botanical composition of these pastures but remarkable in view of the low cropping frequency. This year seed set recorded in May added only marginal quantities to two of the three volunteer pastures and to the cropped medic plot, but still 44 kg/ha to the volunteer pasture adjacent to medic pasture. In medic pastures, May seed yield together with soil-stored seed resulted in 290 kg/ha seed present on average; this can be considered adequate in spite of the losses to be expected during summer.

Fecundity rates (Fig. 1) support the view of the farm manager that reduced fertility caused by the coumesrol content of medics is restricted to first-year pastures; since 1989 without new sowings there was a clear increase of the fecundity rate. The similar evolution of fecundity rate of the medic and the adjacent nonmedic farm (Fig. 1) can be explained by an almost unlimited access to medic pastures for the flocks of both farms. Reduced fertility was not reported from other medic farms in Morocco using one lambing/year compared with the system of three lambings per 2 years practised at Had Soualem and therefore may be restricted to the unusual system of Had Soualem.

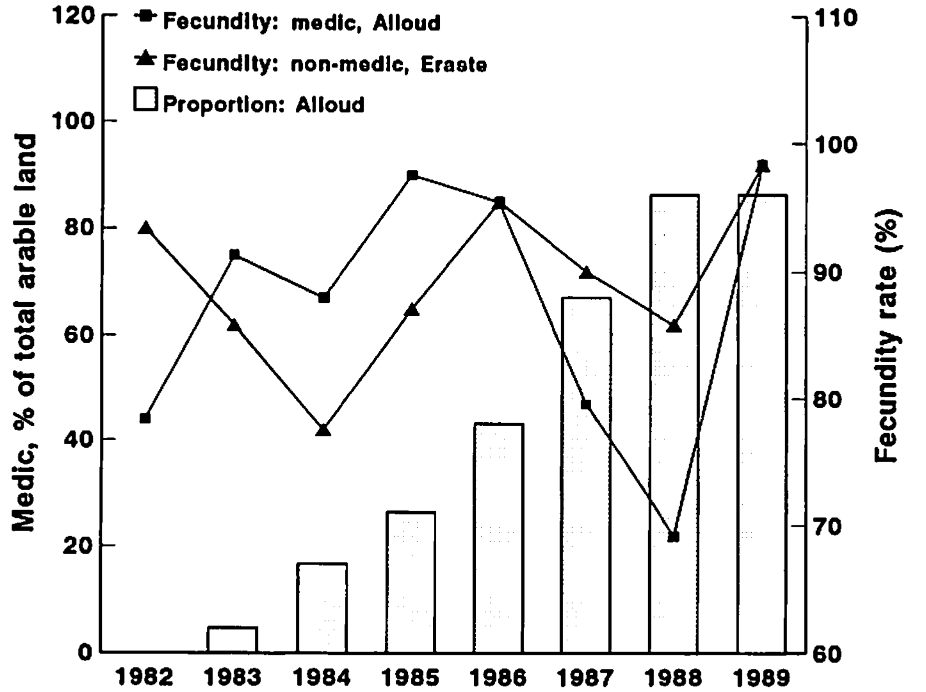


Fig. 1. Fecundity rate and medic pasture proportion at UREO Had Soualem.

Opération Ley Farming

The results of the campaign presented by the annual ministry reports and the reports on the two studies agree (Anonymous 1986b, 1987, 1988, 1989a,b; Jaritz 1989). The campaign has the merit of making known annual legume pastures and ley farming in an essential part of the Moroccan agricultural zone. This is an important step toward their voluntary integration into farm practice. However, the declining areas sown annually and the small proportion of regenerating pastures indicate that the campaign was prevented by socioeconomic constraints from reaching the declared objectives.

Sowing techniques were shown to be no major technical constraint in spite of the widespread lack of specially adapted machinery. The most important finding of the evaluation is the deficiency of farmers' appraisal of the system. Farmers consider medic pastures mainly as a grazed fodder crop but not as part of the ley farming system. Consequently, they try to get the maximum yield by continuous heavy grazing and they do not care about persistence. The data from the agronomic study support this with low seed yields in the establishment year, higher stocking densities in the first year than in the second and third, and by the generally very high stocking rates used. Thus, a farmer's intention to continue or expand annual legume pastures can only be considered as an interest in these pastures but not necessarily an interest in ley farming as a land-use system.

The lack of understanding of the ley farming system by farmers and the resulting destructive pasture utilization practices tend to obscure other aspects that also are important for successful implementation of medic pastures.

Structural aspects such as farm size, status of land ownership, presence of fallow land, the existence of competing crops and the system of animal husbandry are as important as technical aspects such as proper stocking rate and shallow cultivation in the cropping phase of the rotation. The available data suggest that the implementation of medic-based ley farming would be favored by the following combination: intermediate to big farm size, private land ownership, location in a semi-arid winter mild climate, presence of a substantial proportion of grazed fallows, absence of competing crops and dominance of profit-oriented sheep-raising at a technical level above average.

This does not mean that without these combined circumstances medic pastures are out of the question. However, it makes clear that favorable conditions for persistent ley farming are only present on a small part of the statistically declared fallowland and are associated mainly with a group of farmers who represent only a minority in the Moroccan farmer society. Nobody knows definitely how many hectares of potential medic pastures can be realistically anticipated, but assumptions for the future can now be based on the experiences obtained with the ley farming campaign. The last 4 years of data on medic sowings and the observed regenerating rates of 37 and 14% in 1988 and 1989, respectively, suggest a total functioning area of approximately 46 000 ha at the year 2000, of which about 50% will be in pasture and 50% in crop. This is very little compared with the potential area of 1.1 x 10^6 ha proposed by Leeuwrik (1975) and still small compared with the 150 x 10^6 ha additional fodder units to be produced by medic pastures in the year 2000 as envisaged by the national forage plan (Anonymous 1986c). Therefore, additional efforts for improvement of management practices are necessary to reach better medic pasture performances than are indicated by actual trends. Nevertheless, the evaluation of the ley farming campaign showed also that medic will be grown essentially on a restricted number of farms, which limits substantially their potential contribution to forage production.

Conclusions

Medic pastures fit well into the edaphoclimatic conditions of an important part of the Moroccan cereal zone. Poor adaptation of the existing cultivars to specific environments can be overcome by the development of new cultivars.

The data from the Had Soualem farm illustrate that the system can be adopted successfully in spite of some specific problems that have to be resolved locally. We guess that we need many similar farms scattered over the target region and long-term technical advice to develop useful rules for adoption of the system. Such farms could function as pilot units from which expansion into broad practice can take place. The results of evaluation of the ley farming campaign may be helpful in identifying private farms that can fulfil this role in the future.

Nevertheless, the evaluation showed that the system fits poorly into the predominant socioeconomic conditions of the Moroccan agricultural society and medic pastures will only occupy certain areas, which can be estimated from recent experiences. However, its contribution will be substantially less than anticipated (Anonymous 1986c) and therefore alternative feed resources must be developed to meet the expected demand of the increasing livestock population. This also has to be considered by planning forage research priorities, which should be in balance with the likely contribution of the various forages.

Acknowledgements

The authors acknowledge Ms Saidi and Mr Airoud for technical assistance, Mr Batke for the preparation of computer drawings, Mr Kansari (SNDE) for the communication of the Had Soualem fecundity rate figures, Mr. Beale (ICARDA) for correcting our English and Mrs Bouinidane for typing the manuscript.

References

Anonymous. 1986a. Développement de la production fourragère systèmes animaux. Vol. 1. MARA/FAO, TCP/MOR/4402, 123 p.

Anonymous. 1986b. Opération Ley Farming. MARA, mimeographed draft, 18 p.

Anonymous. 1986c. Maroc développement de la production fourragère, rapport de synthèse. TCP/MOR/4402, FAO.

Anonymous. 1987. Bilan d'Opération Ley Farming. MARA, mimeographed draft, 15 p.

Anonymous. 1988. Opération Ley Farming. MARA, mimeographed draft, 21 p.

Anonymous. 1989a. Bilan d'Opération Ley Farming. MARA, mimeographed draft, 16 p.

Anonymous. 1989b. Evaluation de l'Opération Ley Farming. MARA, DCLF/SLF, Rabat, 96 p.

Bounejmate, M. 1984. La place de *Medicago* spp. au Maroc. Hommes, Terres et Eaux 14:11-15.

Carter, E.D. 1978. A review of the existing and potential role of legumes in farming systems of the Near East and North African region. A report to ICARDA, Aleppo, Syria.

Carter, E.D. 1982. The need for change in making the best use of medics in the cereal-livestock farming systems of south Australia. Australian Agronomy Conference, Wagga Wagga, NSW, 180 p.

Jaritz, G. 1986. La place de *Medicago* spp. annuelles dans le systeme fourrager des unités ovines de la SNDE à Had Soualem et Chtouka, 16ème Journées de l'ANPA, Rabat, mimeographed draft, 10 p.

Jaritz, G. 1989. Rapport sur l'analyse des questionnaires "Observations agronomiques sur la parcelle de *Medicago*-Trèfles". Mimeographed draft, 10 p.

Jaritz, G. and F. Kuba. 1978. La production fourragère au Maroc. GTZ/Eschborn, mimeographed draft, 116 p.

Leeuwrik, D.M. 1975. The relevance of cereal-pasture legume rotation in the Middle East and the North African region. Pages 266-291 *in* Proceedings of the Third Regional Wheat Workshop, Tunis. CIMMYT, Mexico.

Taaroufi, A. 1987. Production, valeur nutritive et exploitation des prairies à base de *Medicago* par les ovins dans l'UREO de Had Soualem (SNDE). Ph.D. thesis. IAV, Rabat, Morocco.

Weiss, P.W. 1980. Germination, reproduction and interference in the amphicarpic annual *Emex spinosa* (L.). Campd. Oecologia 45:244-251.

ICARDA's Approach to Introducing Ley Farming

P.S. Cocks
Crops and Pasture Science Department, School of Agriculture, University of Western Australia, Nedlands, WA 6009, Australia

Abstract

ICARDA uses a systems approach with three critical components — ecology, agronomy and people. All three are necessary for the success of ley farming. The ecology of annual medic seed banks mimics the behavior of weeds in natural ecosystems. Research has revealed how plants regenerate from seed banks and the need to capture diversity in pasture mixtures. Selection of pasture plants at ICARDA is based on surveying the legume flora of any area to determine those likely to succeed, collecting ecotypes of the most abundant species and growing them in rotation with cereals, preferably in the presence of grazing animals. The agronomy studies of ley farming at ICARDA are large-scale and realistic and the results are assessed economically. We include all aspects of basic research including nitrogen cycling and rotation effects on grain yields of cereals. The people approach used at ICARDA blends an appropriate balance of research, extension and farmer participation. The research approach allows targeting of appropriate farmers — those with land and animals — and those who are willing to participate with the introduction of a completely new farming system to the region.

Introduction

The ICARDA approach to ley farming is based on the need to develop practical answers to the problems of its region. It accepts that ideas from outside need modification to take into account the social and physical realities of the different environment. Guiding values include small, not large farms; indigenous, not exotic components; low, not high inputs; listening to, not lecturing to farmers; participatory, not 'top-down' planning.

Ley farming, an integrated crop/livestock system, originated in southern Australia, the word ley referring to a year of spontaneously regenerating legume pasture in a cereal/pasture rotation (Puckridge and French 1983). In Australia most temperate cereals are produced after pasture, either subterranean clover (*Trifolium subterraneum*) or one of several medics (*Medicago* spp.). The use of medic pasture underlies the research at ICARDA.

Carter (1978) estimated that there were approximately 30 million hectares of weedy fallow in West Asia and North Africa (WANA); in Syria alone there are more than 2 million hectares. This huge area is potentially the most important source of feed for the region's ever-increasing population of sheep and goats, projected to reach 490 million by the year 2000.

The concept of ley farming is the replacement of weedy fallows with pasture legumes, pasture being more productive than weeds because it is independent of soil nitrogen. Any legume can be used provided that, like weeds, it persists without reseeding. Most wild legumes produce hard seeds that enter a seed bank, a small proportion of which germinates each year. The concept of a seed bank, and that the improved pastures are simply weedy legumes, is central to the understanding of ley farming.

This paper describes the approaches used by ICARDA. Essentially a systems approach (Simmonds 1986), it is described under three headings: ecology, agronomy and people. The essence of the ICARDA approach is integration, where ecologists, agronomists, microbiologists, livestock scientists, economists, sociologists, extension agents and farmers work together. As far as possible the paper draws on results from WANA, much of it from ICARDA's headquarters at Tel Hadya in Syria. It ends with a discussion on participatory research and extension.

The Ecological Approach: Seed Banks, Sustainability and the Use of Wild Legumes

The ecological approach recognizes that the pasture phase in ley farming differs from cropping in that it mimics natural and weedy ecosystems. As an example, I discuss the banks of seeds from which pastures regenerate and how, by understanding their behavior, we can select improved pasture cultivars. Seed banks are the key to sustainability of ley farming.

Clearly it is important to understand the way in which species survive and their ability to persist in adverse conditions. In this respect the development of cultivated pasture legumes proceeds in the opposite direction to that of grain legumes, a point not always appreciated by plant breeders. Pasture legumes use seed dispersal systems and dormancy mechanisms considered undesirable in grain legumes (Zohary 1989).

Surprisingly little is known about seed banks in ley farming. That seeds are protected by hardseededness is known (Quinlivan 1971), but not how long the seeds live, rate of hard seed breakdown beyond the first year and interaction of these with genotype (or even species) and environment. We do not even know the optimum size of a seed bank or how many seedlings should emerge in the pasture phase. Lack of this information makes it difficult to advise farmers on grazing or drought management.

In the absence of reliable data, Puckridge and French (1983) suggest that 1000-2000 seedlings/m^2 are needed to produce legume-dominant pasture. This is equivalent, if mean seed size is 4 mg, to 40 kg/ha of germinating seed. If germination rate is 20%, a seed bank of 200 kg/ha is needed to sustain these numbers. In fact, 1000 seedlings is close to the optimum density for seed production (Cocks 1988) but far below that for maximum herbage production (Abd El Moneim and Cocks 1986).

If 40 kg/ha of seed germinates in both the cereal and pasture years, 80 kg/ha is needed to replenish the seed bank in the pasture year. Pasture legumes have the capacity to produce up to 1500 kg/ha of seed (Cocks 1989), the excess being available for summer grazing. In this way the system is robust, tolerates heavy grazing and, once established, is easy to manage. It is necessary to take advantage of heavy seed set in good years to maintain the seed bank in years of drought or overgrazing.

Of course no medic behaves in exactly the required way. The germination percentage of some species (e.g., *Medicago noeana*) is below 20% and for others (e.g., *Medicago polymorpha*) above 40%. Some species (e.g., *Medicago truncatula*) germinate better in the year after seed set than in the following year, while the reverse is true of others (e.g., *Medicago rotata*). Burial decreases hard seed breakdown. There is also an interaction between genotypes and environments, highlighting one of the differences between Australia and WANA; in the cooler summers of Australia, genotypes producing the required levels of soft seed will be too soft in WANA. There is thus both a need and an opportunity to select species and genotypes with seed characteristics suitable for ley farming in WANA.

Burial provides an interesting example of the effect of environment (Taylor 1984, 1985; Taylor and Ewing 1988). It had been assumed that buried seeds lost dormancy at the same rate as those on the surface. In fact breakdown is substantially slower, an observation that is important because it suggests that buried seeds represent a stable reserve of dormant seeds which re-enter the system when recultivation brings them to the surface.

With its emerging understanding of seed banks, ICARDA is developing an ecologically based method for selecting pasture plants. It involves surveying the legume flora of any area to determine the species most likely to succeed, collecting ecotypes of the most abundant species and growing them, either in mixtures or as pure swards, in rotation with cereals, preferably in the presence of grazing animals. In this way, cultivars will be adapted both to the environment and to the ley farming system.

The frost-tolerant medics have been selected in this way. Away from the coast, WANA rapidly assumes a continental climate where lengthy and severe frost periods occur. Australian cultivars are more likely to be killed by frost than locally collected ecotypes (Cocks and Ehrman 1987). The evidence suggests that if the mean temperature of the coldest month is below 9°C the Australian cultivars will be killed at least one year in five. Frost-tolerant medics will increase the area in which ley farming can be used by 300%.

The Agronomic Approach: High Productivity with Low Inputs

The agronomic approach looks at productivity of both livestock and cereals. Central to this approach is the impact of low-cost inputs: biologically fixed nitrogen, self-regenerating pastures and the grazing of straw and pasture residues.

Naturally, farmers will not adopt new practices unless they are confident that, without adding to risk, profits will increase. The lack of data on productivity and profitability of ley farming is a major constraint to its introduction in WANA. Unfortunately, gathering the data is both time-consuming and expensive. It involves using livestock, measuring the effect of rotations on yields, determining the long-term effects on soil fertility, the impact of pests, diseases and weeds and the effects of fluctuating climate.

A start has been made on biological nitrogen fixation, which is crucial to ley farming's role as a low-input system. At Tel Hadya uninoculated *Medicago rigidula* and inoculated *M. truncatula* have fixed 60-100 kg/ha of nitrogen in a single year. This is similar to amounts fixed by medics in Australia, although the soil nitrogen accretions reported by White *et al.* (1978), more than 100 kg/ha per year, suggest that in some sandy soils nitrogen fixation can be considerably higher. Evidence of soil nitrogen increases in Australian soils is widespread (see also Mullaly *et al.* 1967; Tuohey and Robson 1980; Watson *et al.* 1977) but remains to be collected in WANA.

Materon (this volume) discusses some of the problems of nitrogen fixation in WANA. I will emphasize that the need to inoculate with rhizobia is difficult to predict, species that do not need inoculation should be used wherever possible, inoculation itself is difficult and unreliable and responses to inoculation can be as high as 500%.

To incorporate these results, and to study the integration of crops and livestock, rotation experiments are needed. For example, at Tel Hadya ICARDA has established an experiment in which pasture/cereal rotations supporting 2, 3.5 and 5 sheep/ha (including the wheat-growing area) are compared with other common rotations. All inputs and outputs are monitored to facilitate economic analysis and indicators of sustainability (size of the seed bank, soil fertility and yields) are monitored. Different price regimes can be used to give the results wide applicability. An important objective is to demonstrate that, using frost-tolerant cultivars, ley farming is profitable in areas where it could not have been used previously.

Under Australian conditions, wheat yields after medic are generally higher than after traditional rotations. However, in all three seasons of the Tel Hadya experiment, yields after medic have been lower than after clean fallow, markedly so in 1988/89, which was a dry year (220 mm) following a wet year (499 mm). Yields after other crops are approximately equal to those after medic. These results give me an opportunity to ask two questions: why do such reductions occur and in what circumstances?

There seem to be two reasons. The first involves a factor that occurs at or soon after the wheat germinates, apparently associated with tillage. A second tillage seems to overcome the problem, which is probably caused by excessive soil strength and, in some instances, the presence of pseudomonad bacteria (Chan *et al.* 1987; Cornish and Lymbery 1987). The second reason is lack of water storage. Deep, fine-textured soils store water where enough rain falls on the fallow, allowing crops to grow in years when water would otherwise be limiting. This set of events is uncommon in WANA but highlights the point that ley farming is not a panacea for all problems.

The results help decide which environments are best for ley farming: shallow soils, dry areas where there is insufficient rain for storage, and in general where farmers either use weedy fallows for feeding livestock or are turning away from cereal/fallow toward continuous cropping. In both Australia and Syria, wheat yields after medic in such environments are 20-40% higher than after fallow (Cocks *et al.*, this volume; White *et al.* 1978).

In any event, reduced yields even at Tel Hadya are more than offset by increased livestock production. Dependence on barley grain is reduced and, perhaps more importantly, dependence on steppe and grassland is almost eliminated (Cocks and Thomson 1988). Unlike in Australia, sheep body mass is maintained (even increased) on pasture residues, probably because quality is not reduced by summer rains.

The People Approach

Attitudes to Introducing Ley Farming

The essence of the people approach is that it links scientists to farmers, keeps the research relevant and orients it toward solving real-life problems. I will talk briefly of the people introducing the system before turning to farmers.

In a thoughtful paper, Springborg (1986) classifies the proponents of ley farming into two groups: those who believe that a simple transfer of technology, requiring little basic or adaptive research, is involved, and those who believe that technical problems look so large there is little point in working on farmers' fields until they are resolved. The first school, to which Chatterton and Chatterton (1984) belong, argues that there is no time for research, the need for extension is urgent, and seeds and machinery must be imported and land sown to medics as quickly as possible. The second argues that ley farming as practised in Australia is simply not suited to WANA. It was developed in and for Australia where climate and soils differ, farmers are comparatively highly educated and resources for development are readily available. Extremists contend that even research is a waste of time, but most agree that the problems are soluble. Chatterton and Chatterton (1984) say that this school has a vested interest in finding problems: it keeps them employed.

We believe that a middle way is best. There are indeed technical problems and research is needed to overcome them, some of which needs to be done on research stations. We have discussed two examples: the susceptibility to frost of the Australian medics and the need for inoculation. There are also social and economic problems associated with the size of farms and the poverty of farmers; these need careful research on farmers' fields. But, it is important that we do not fall into the trap described by the Chattertons, but become involved as soon as possible in extension.

Participatory Research, the Key to Extending Ley Farming

Farrington and Martin (1988) have developed the concept of Farmer Participatory Research (FPR), which appears well suited to difficult and heterogeneous environments. In FPR farmers participate in the design, implementation and interpretation of experiments. They provide the 'demand-pull', as Farrington and Martin put it, necessary to ensure accuracy of focus. Properly conducted, FPR should avoid the "have technology, look for farmers to use it" approach (Roling 1988) that has characterized attempts to extend ley farming.

Our research at Tah, Syria (see Cocks *et al.*, this volume) is close to FPR. It was initiated after discovery of a field of native medic, which prompted the interest of the local community. Their interest in adapting and promoting their discovery has been the key to our project's success. There will not always be convenient fields, but the research at Tah shows that if ley farming is to be relevant, it must address real community problems. For example, farmers for whom it will be relevant will probably be crop/livestock producers, face feed shortages, obtain feed from weedy fallows and native pasture, and have climatic or edaphic conditions suitable for ley farming. They will not be landless, grow only crops, nor produce lambs in feedlots.

Participation by extension agents is implied in FPR and, as with farmers, is necessary to obtain commitment. It is significant that many of the early proponents of farming systems research are turning their attention to extension (Byerlee 1987; Simmonds 1988) and drawing the same conclusion: that rural development involves the whole community. Bunting (1988) points out that the old 'top-down' approach of scientists to extension agents, and of extension agents to farmers, is gradually disappearing. This is his reservation about criticism of 'training and visiting' (T&V), the concept introduced by the World Bank (Benor and Baxter 1984), although he concedes that it provides technical, logistic and moral support to extension workers.

These attributes, perhaps undervalued by Bunting, are so important that I believe a modification of T&V to make it more participatory will help extend ley farming. Training and visiting is expensive, although economic analysis reveals that it pays (Feder *et al.* 1987). It uses high ratios of extension agents to farmers, a structured work program based on regular visits to scheduled farmers, technical training and updating for agents, close supervision by subject matter specialists and exclusive attention to extension. It lacks only the community participation provided by FPR.

Conclusion

ICARDA's approach to the development of ley farming has three prongs: ecological, to account for the self-regeneration of pastures; agronomic, to account for the needs of crops and livestock; human, to account for the needs of farmers and rural communities. It ranges from the fundamental, where it seeks better understanding of seed dormancy, the establishment and survival of seedlings and host/rhizobia relationships, to the practical, where it seeks to involve farmers and extension agents in developing and propagating the system. It is intended to provide backup to national scientists and go beyond the normal relationship between an international center and a national program.

It is proposed that ICARDA develop its participatory approach to research, involve extension agents and seek to assist national programs in the extension of ley farming.

References

Abd El Moneim, A.M. and P.S. Cocks. 1986. Adaptation of *Medicago rigidula* to a cereal-pasture rotation in north-west Syria. Journal of Agricultural Science, Cambridge 107:179-186.

Benor, D. and M. Baxter. 1984. Training and Visiting Extension. The World Bank, Washington, DC.

Bunting, A.H. 1988. Extension and technical change in agriculture. Page 8-12 *in* Reading Rural Development Communications, September 1988. Reading University, UK.

Byerlee, D. 1987. From adaptive research to farmer recommendations and extension advice. Agricultural Administration and Extension 27:231-244.

Carter, E.D. 1978. A review of the existing and potential role of legumes in the farming systems of the Near East and north African region. A report to ICARDA, Aleppo, Syria.

Chan, K.Y., J.A. Mead and W.P. Roberts. 1987. Poor early growth of wheat under direct drilling. Australian Journal of Agricultural Research 38:791-800.

Chatterton, B. and L. Chatterton. 1984. Alleviating land degradation and increasing cereal and livestock production in north Africa and the Middle East using annual *Medicago* pasture. Agriculture Ecosystems & Environment 11:117-129.

Cocks, P.S. 1988. Seed production and seed survival under grazing of annual medics (*Medicago* spp.) in north Syria. Journal of Agricultural Science, Cambridge 110:455-463.

Cocks, P.S. 1989. Pages 30-41 *in* Annual Report of the Pasture, Forage and Livestock Program. ICARDA, Aleppo, Syria.

Cocks, P.S. and T.A.M. Ehrman. 1987. The geographic origin of frost tolerance in Syrian pasture legumes. Journal of Applied Ecology 24:678-683.

Cocks, P.S. and E.F. Thomson. 1988. Increasing feed resources for small ruminants in the Mediterranean basin. Pages 51-66 *in* Increasing Small Ruminant Productivity in Semi-Arid Areas (E.F. Thomson and F.S. Thomson, eds.). Kluwer Academic Publishers, Dordrecht, The Netherlands.

Cornish, P.S. and J.R. Lymbery. 1987. Reduced early growth of wheat in southern New South Wales: causes and consequences. Australian Journal of Experimental Agriculture 27:869-880.

Farrington, J. and A.M. Martin. 1988. Farmer participatory research: a review of concepts and recent field work. Agricultural Administration and Extension 29:247-264.

Feder, G., L.J. Lan and R.H. Slade. 1987. Does agricultural extension pay? The training and visiting system in north-west India. American Journal of Agricultural Economics 69:677-686.

Mullaly, J.V., J.B. McPherson, A.P. Mann and D.R. Rooney. 1967. The effect of length of legume and non-legume leys on gravimetric soil nitrogen at some locations in the Victorian wheat areas. Australian Journal of Experimental Agriculture and Animal Husbandry 7:568-571.

Puckridge, D.W. and R.J. French. 1983. The annual legume pasture in cereal-ley farming systems of southern Australia: a review. Agriculture Ecosystems & Environment 9:229-267.

Quinlivan, B.J. 1971. Seed coat impermeability in legumes. Journal of the Australian Institute of Agricultural Science 37:282-295.

Roling, N. 1988. Extension and the development of human resources: the other tradition in extension education. Pages 13-17 *in* Reading Rural Development Communications, September 1988. University of Reading, UK.

Simmonds, N.W. 1986. A short review of farming systems research in the tropics. Experimental Agriculture 22:1-13.

Simmonds, N.W. 1988. Observations on induced diffusion of innovations as a component of tropical agricultural extension systems. Agricultural Administration and Extension 28:207-216.

Springborg, R. 1986. Impediments to the transfer of Australian dryland agricultural technology to the Middle East. Agriculture Ecosystems & Environment 17:229-254.

Taylor, G.B. 1984. Effect of burial on the softening of hard seeds of subterranean clover. Australian Journal of Agricultural Research 35:201-210.

Taylor, G.B. 1985. Effect of tillage practices on the fate of hard seeds of subterranean clover in a ley farming system. Australian Journal of Experimental Agriculture 25:568-573.

Taylor, G.B. and M.A. Ewing. 1988. Effect of depth of burial on the longevity of hard seeds of subterranean clover and annual medics. Australian Journal of Experimental Agriculture 28:77-81.

Tuohey, C.L. and A.D. Robson. 1980. The effect of cropping after medic and non-medic pastures on total soil nitrogen, and on the grain yield and nitrogen content of wheat. Australian Journal of Experimental Agriculture and Animal Husbandry 20:220-228.

Watson, E.R., A. Lapins, G.W. Arnold, R.J.W. Barron and G.W. Anderson. 1977. Effect on cereal crop and seed production of two rotations in a ley farming system in the south-west of Western Australia. Australian Journal of Experimental Agriculture and Animal Husbandry 17:1011-1019.

White, D.H., B.R. Elliott, M.J. Sharkey and T.G. Reeves. 1978. Efficiency of land-use systems involving crops and pastures. Journal of the Australian Institute of Agricultural Science 44:21-27.

Zohary, D. 1989. Pulse domestication and cereal domestication: how different are they? Economic Botany 43:31-34.

Introduction of Ley Farming System in Syrian Villages

P.S. Cocks[1], B. Mawlawi[2] and H. Sawmy-Edo[1]

[1] *ICARDA, Aleppo, Syria (Present address: Crops and Pasture Science Department, School of Agriculture, University of Western Australia, Nedlands, WA 6009, Australia)*

[2] *Directorate of Agricultural and Scientific Research, Douma, Damascus, Syria*

Abstract

This paper reports on the progress of a ley farming trial conducted with farmers who were mostly from Tah Village in Idleb Province, Syria. Tah was chosen as the focus of the project because of the presence of a farmer who had himself identified pasture legumes as a means of resolving his problem of feed deficiency. He was managing a 4-ha site of native *Medicago polymorpha*, which was attracting wide interest in the community as a whole. A preliminary assessment of the project along with results and constraints to adoption are presented.

Introduction

There are 355 million sheep and goats in west Asia and north Africa and a further 121 million cattle and buffalo (FAO 1987a), projected to increase to 490 and 150 million respectively by the year 2000. Together with poultry they represent 31% of the total agricultural value of the region compared with 25% for cereals, 3% for food legumes and 41% for all other food commodities (FAO 1987b).

The huge livestock population is accompanied by increasing land degradation. There is ample evidence of long-term changes in vegetation and of the beneficial effect of excluding livestock on native vegetation. Legumes, which are essential for the nitrogen supply of low-input agricultural ecosystems, are present in decreasing numbers. There is a decline in soil fertility, both in physical and chemical terms (Cocks *et al.* 1988).

If nothing is done the increasing livestock population will further accelerate land degradation. Increasingly, animals will become dependent on concentrates, especially cereal grains. Yet, if FAO is correct, barley yields will have to increase from a regional average of 800 to 2600 kg/ha to meet the projected demand. Even if this unlikely target were attained it would be at the cost of more intensive cultivation of marginal areas, a process that would of itself accelerate land degradation. The provision of improved pastures and more efficient production systems will therefore have a major impact on productivity.

Farming Systems Research

The farming systems approach is something that divides agricultural scientists into those who claim to practise it and those who are skeptical, and within the first group, those who see it as a discipline in its own right, and those who use its concepts as a means of resolving problems. The essential concepts are two-fold: firstly, and more importantly, farmers must be involved in the research process, and secondly, because farms are complex biological units, scientists of different disciplines must collaborate. These concepts are especially important in livestock research where there are complex interactions between soils, plants, animals and farmers.

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

1. description and diagnosis,
2. scientist-managed on-farm (and on-station) research,
3. farmer-managed on-farm research, and
4. extension of results and monitoring of impact.

In this case study, the first step (description of the farming systems and diagnosis of the problem) was brief. Indeed the problem (shortage of feed for sheep) was taken for granted and the concept to resolve the problem, replacement of fallow with self-regenerating pastures, was already available. Most of the research discussed in this paper is about step 3 (farmer-managed research) and part of step 4 (assessment of impact). The paper therefore describes the concept of pasture legumes, the farming community which is the subject of the research, some of the relevant scientist-managed research, the farmer-managed research, and briefly, constraints to adoption and why we believe the project to have been successful.

Pasture Legumes and the Ley Farming System

An inexpensive strategy to replace fallows in cereal/fallow rotations is to use self-regenerating pastures of annual legumes. The concept is to replace the weeds in weedy fallows with pasture legumes, the legumes being more productive because of their independence of soil nitrogen. Any legume can be used provided, like weeds, it has the ability to persist without reseeding. Because they produce hard seeds (which are not permeable to water), many wild Mediterranean legumes have this capacity and it is common to see such species as *Coronilla scorpioides*, *Scorpiurus muricatus* and *Medicago* *polymorpha* in the weed flora of fallow. The concept of a 'seed bank' containing hard seeds of the pasture legumes is central to the use of self-regenerating pastures (Fig. 1).

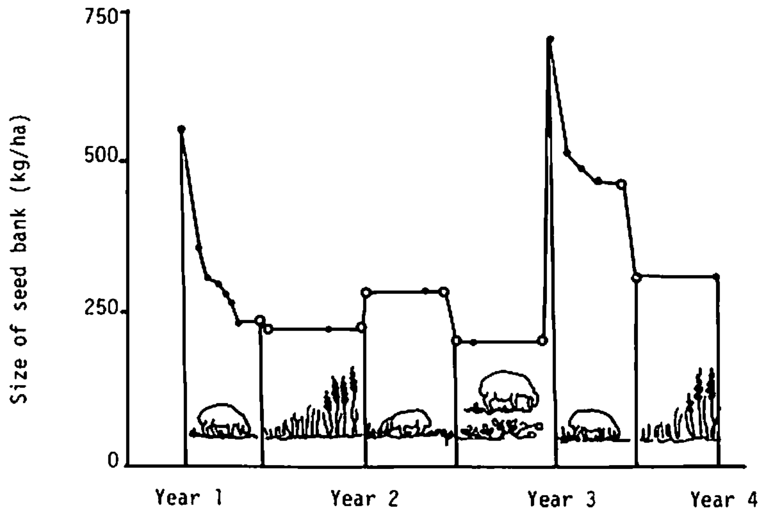


Fig. 1. Size of the seed bank during the cereal and pasture phases of the ley farming system. The figure shows that the seed bank falls while pasture residues are grazed in summer and as a result of germination during the cereal phase. It is replenished during the spring of each pasture phase. The vertical lines represent (approximately) May and December each year, beginning May 1985 and ending May 1988.

The use of self-regenerating legume pastures originated in southern Australia (Puckridge and French 1983) in ley farming, the word 'ley' referring to the year of spontaneous pasture. Ley farming has been so successful that almost all wheat or barley produced in southern Australia is grown after pasture, the latter comprising either *Trifolium subterraneum* or *M. polymorpha* (on acid soils), or various other species of *Medicago* (medics) on alkaline soils.

The target area in the Mediterranean basin is where it is too dry for lentils. However, much of the initial development has been inside the lentil area (including this case study), a strategy justified by the range of socioeconomic and technical problems to be resolved if the system is to succeed.

To introduce ley farming requires consideration of all its components: pastures, livestock, cereals, soil fertility and, perhaps most importantly, the farmers themselves. Critics of early attempts to introduce ley farming claim that there has been a lack of consideration of socioeconomic conditions and an excessively academic approach (e.g., Springborg

1986). While the latter is probably not true—there really is a range of technical problems—the former is certainly true and for this reason use of farming systems research, especially on farmers' fields, was considered essential.

The Farming Community

In the beginning the focus of the project was the village of Tah, in Idlib province of northern Syria. Since 1984/85, the project has widened to include 11 villages, most near Tah, but also in Jazira, Houran and Hama provinces. The new villages are in areas both wetter and drier than Tah (which receives approximately 350 mm annual rainfall).

Tah was chosen as the focus of the project because of the presence of a farmer who had himself identified pasture legumes as a means of resolving his problem of feed deficiency. He was managing a 4-ha site of native *M. polymorpha*, which was attracting wide interest in the community as a whole. It was therefore a simple matter to interest other farmers in the project, which aimed to provide seed to help them implement what they perceived to be a useful innovation.

A survey of farming practices in Tah and nearby villages was conducted in 1984/85 (Nordblom 1987). The survey included only livestock owners, as pasture legumes are part of improving livestock production. In Tah itself, the farmers use crop rotations including both wheat and barley (on the better and poorer soils respectively) in mainly three-course rotations with lentil and watermelon. In areas drier than Tah (250-350 mm) cereal/fallow rotations are the most common, while in wetter areas (350-600 mm) rotations are diverse, but always include either wheat or barley. Surprisingly, cereal/fallow rotations are more common in the wetter areas than in Tah itself (about 20% of all land use in the 350-500 mm zone).

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

Of the rotations at Tah a two-course rotation of cereals and lentils was the most profitable, although not the most widely used. Therefore, to be successful, pasture legumes would need to be more profitable than lentils and so displace lentils and watermelons on part of the land.

Scientist-managed Research

There is a history of unsuccessful attempts to introduce ley farming to west Asia. Cocks

(1986) considered that the reasons were fourfold: lack of adapted pasture legume cultivars, lack of resident rhizobia, inability of farmers to manage the system and lack of acceptable economic evaluation. The first two of these problems were resolved by on-station research.

The approach to selecting adapted cultivars was to use indigenous material (Cocks 1985). An extensive survey of Syrian rangelands revealed that the species from which the Australian cultivars were selected were either rare (*Medicago truncatula*) or occurred only in coastal or high-rainfall mountain regions (*T. subterraneum*, *Medicago scutellata*, *Medicago rugosa* and *Medicago littoralis*). Widespread in the cereal zone were *Medicago rigidula* and *Medicago rotata*. The one exception was *M. polymorpha*, for which there are Australian cultivars, although at the time (1984) they were not used commercially.

The success of this approach is shown in Table 1, which compares the frost tolerance of Australian cultivars with the locally collected material (Cocks and Ehrman 1987). Clearly, lack of frost tolerance in the Australian cultivars was a major reason for the lack of success of ley farming. The frost-tolerant medics in Table 1 form the basis of the project described in this paper.

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

Table 1. Establishment and frost survival of seven medics.

Medicago spp. and genotype	Establishment† (seedlings/m^2)	Frost survival (%)‡
M. scutellata Robinson	232	5 c§
M. truncatula Cyprus	536	7 de
Jemalong	432	14 cd
M. polymorpha Circle Valley	856	21 c
M. rotata selection 2123	1144	90 b
M. rigidula selection 716	816	95 ab
selection 1919	864	98 a

† On 7 February 1985.
‡ Survival of seedlings to 12 March 1985.
§ Survival percentages followed by the same letter are not significantly different at ($P < 0.05$); analysis of variance after angular transformation.

instances where even the indigenous legumes must be inoculated: on land that has been fallow and legumes absent for decades. Wherever possible, legumes should be chosen that do not require inoculation, a powerful reason for choosing local ecotypes.

The remaining constraints (poor management and lack of economic evaluation) could only be resolved on farmers' fields.

Farmer-managed On-farm Research

Methodology

There has been very little scientist-managed on-farm research in the project. Even species evaluation has been subject to the farmers' own decisions regarding grazing management. The reason is that the problem (poor grazing management) cannot be resolved by either farmers or scientists acting alone. Farmers find it difficult to appreciate the biological problems and scientists the social and economic problems. The research I shall describe is therefore on the one hand original and innovative, while on the other substantially managed by farmers.

The first fields were sown in the autumn of 1984. Six farmers were chosen on the basis of whether or not they owned livestock and on their reliability as collaborators as judged by the local sheikh. Fields of 1 ha were sown to a mixture of Australian and local medic cultivars and grazing was managed by close consultation between scientists and farmers. The key criterion was seed set during spring, with summer grazing restricted so that approximately 200 kg/ha of seed remained in the seed bank in autumn. In this first year, fields were rented from farmers so that there was no question of farmers taking risks should the new ideas fail. This seemed reasonable on the basis that the system was experimental, had previously failed in farmers' fields, and that the objective of the project was to resolve problems and not to encourage adoption. However, no further incentives were offered even though, for the system to be deemed to have worked, spontaneous regeneration of pastures in the third year needed to be observed. Only machinery available to farmers was used.

The first useful result was the realization that fields of 1 ha are too small; the size of farmers' flocks rendered sensible grazing management in spring difficult because of high stocking rates. Fields sown since 1984 have therefore been large: from 2 to 5 ha.

However, Table 2 shows that the first year was successful, there being only one farm where the seed bank was substantially less than the targeted 200 kg/ha. After stubble grazing in the following year the seed bank increased in all but one field, where medics grew as weeds in the cereal. The establishment phase could therefore be deemed successful.

Table 2. Size of the seed bank (kg/ha) for six medic pastures after grazing in the year of sowing and in the following year.

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

† After grazing cereal stubble, except in farm 2 which was left as second-year pasture.

‡ After regenerating medic pasture, except farm 2 which was sown to wheat.

Given the size of the seed banks, it was not surprising that regeneration after the cereal was good. In three of the six original fields, seedling number exceeded 1500/m^2, while in the other two there were 300-500/m^2 (Table 3). Since Puckridge and French (1983) consider that 1000 seedlings/m^2 defines a successful re-establishment, clearly in farms 1, 3 and 5 the system is working successfully. Incidentally, the owner of farm 2 elected to have a second year of medic pasture, itself an indication of acceptance.

At the end of 1987/88, there were 22 farms in the project including farms in the second cereal cycle (four of the original six farms) through to farms with first-year pasture (four new farms). Table 4, which shows that the mean size of the seed banks for all groups of farms was at or above 200 kg/ha, indicates that the system had been satisfactorily established. Indeed, of the 22 farms, only three could be considered failures.

Productivity of the farms is being monitored and compared with adjacent fields where the farmers are continuing their normal practices. In the wheat phase, scientists are imposing treatments to assess the response of crops, after both pasture and the

Table 3. Residual seed in 1985/86 and regeneration of medic in autumn 1986 after a cereal crop in 1985/86.

Farm	1985/86 Residual seed (kg/ha)	1986/87 Seedling number/m^2
1	447	1640
3	148	520
4	449	1920
5	74	390
6	769	1850

Table 4. Size of the medic seed bank after grazing in summer 1987/88.

Cropping cycle	Seed bank (kg/ha)
After 1st-year medic (mean of 4 farms)	212
After 2 years of medic (mean of 2 farms)	360
After 2nd-year medic cycle (mean of 7 farms)	257
After 1st wheat crop (mean of 4 farms)	199
After 2nd wheat crop (mean of 5 farms)	286

alternatives, to nitrogen and weed control. Otherwise, all crops are being managed by farmers with no assistance or advice from scientists. More advice is given on pasture management but the ultimate decisions are those of the farmer, as are the decisions about rotations. Indeed two of the farmers, both on poor soils, have decided to abandon cropping altogether.

Results

Figure 2 shows the productivity of regenerating pasture on the three original farms (sown to medic in 1984/85) where regeneration in 1986/87 was greater than 1000 seedlings/m^2. Total productivity was between 6 and 8 t/ha, and perhaps more significantly, available herbage in early February was up to 1 t/ha. These yields were exceeded in the wetter year of 1987/88 when between 9 and 10 t/ha were produced by grazed pasture. As can be expected with legume pasture, quality, including protein content, was high.

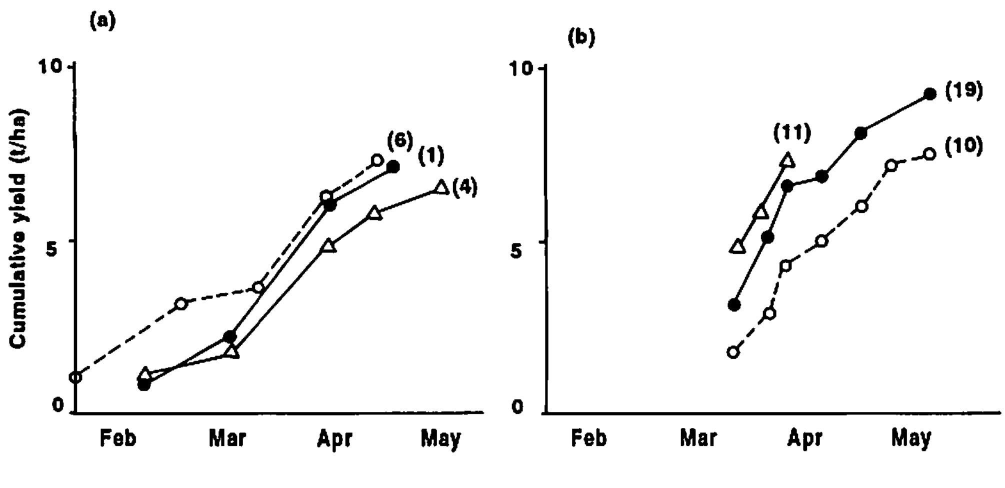


Fig. 2. Cumulative dry matter yield of medic pasture in (a) 1986/87 and (b) 1987/88. Number of the farm is shown in parentheses.

The stocking rate of the three fields represented in Figure 1, calculated on a year-round basis, was between nearly 7 and nearly 11 ewes/ha. In fact the farmers did not stock the pastures continuously although continuous grazing is often the practice in Australia. In Syria, farmers prefer to stock heavily from March to August; in the latter part of the period the ewes eat pasture residues, legume pods and cereal stubble. What we believe to be the effect of introducing pasture on the feed cycle of sheep is shown schematically as 'grassland' in Figure 3.

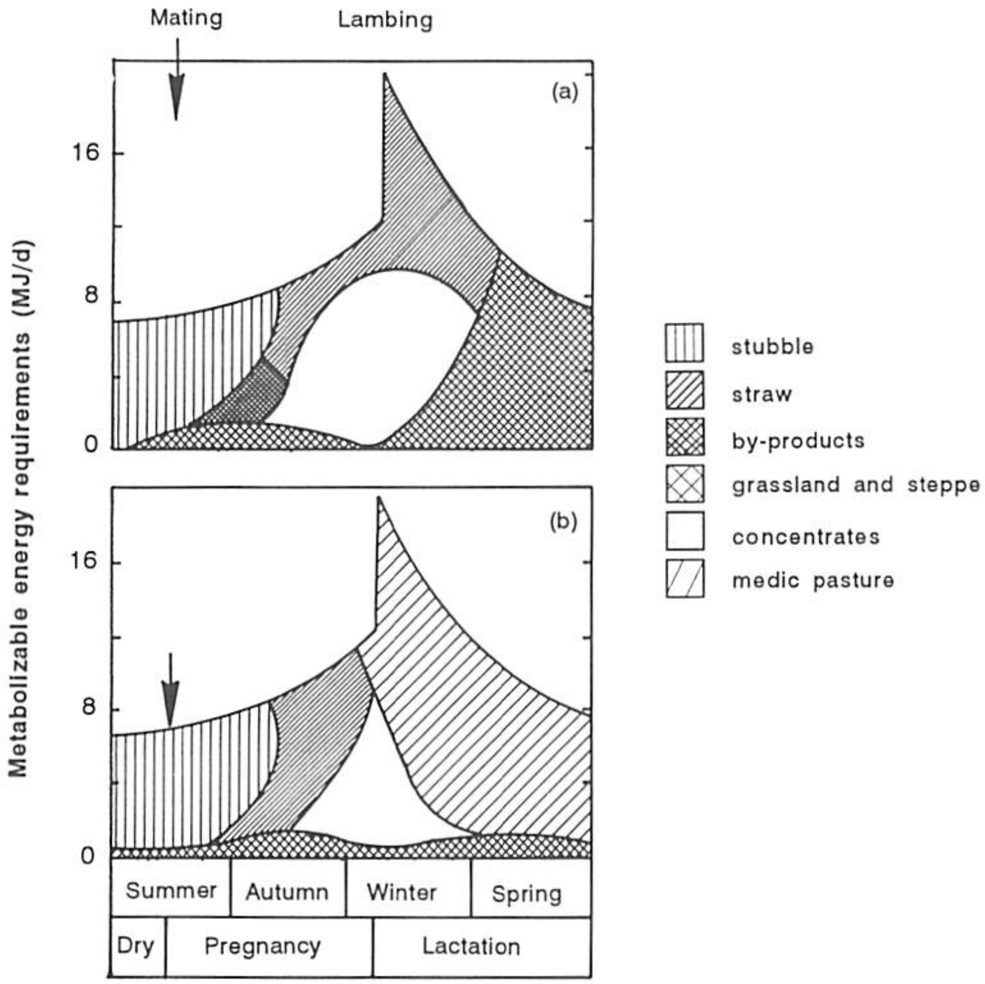


Fig. 3. Schematic presentation of the metabolizable energy requirements of sheep and the contribution of different feedstuffs during (a) traditional and (b) improved feeding cycles in northwest Syria. Note the greatly decreased dependence on marginal lands, grasslands and steppe in the second scenario (Cocks and Thomson 1988).

The Syrian system of grazing management, compared with the Australian, works well provided that grazing stops before seed in the seed bank falls too low. As was stated earlier we use a critical level of 200 kg/ha on first-year pasture; in regenerating pastures, by taking account of existing seed, the critical level of newly produced seed need only be 100 kg/ha. Assessment of this critical level is the most difficult new skill to be learnt by farmers.

We were able to monitor milk production and liveweight changes during the period of grazing and compare the grazing ewes with ewes fed traditionally: common grazing in spring and ration of concentrates and straw in summer. Milk production is consistently higher on legume pasture than on alternative feed sources. We are not sure why this is so, but it is possible that small amounts of oestrogen in the forage tissue could stimulate milk production. If present in large amounts these oestrogens reduce ewe fertility (Branden and McDonald 1970; Francis and Millington 1965), but there has been no suggestion of infertility at Tah.

Wheat yields after pasture and after control crops are shown in Table 5. Again, these results repeat those of earlier years in that wheat yields after pasture are higher than after other crops. In 1987/88 yields after first-year pasture were not significantly greater than after the controls, although in previous years (1985/86) even this difference had been significant.

Table 5. Wheat yields (t/ha) after first year and regenerating medic compared with wheat yields in traditional rotations.

	First Year		Regenerating	
	Medic	Control	Medic	Control
1985/86	1.29	1.24†	NA	NA
1986/87	1.40	1.08‡	NA	NA
1987/88	1.95	1.64†	2.67	1.77‡

NA = not applicable. The first crops sown after regenerating medic were in 1987/88.

† Difference between after medic and after controls not significant.
‡ Difference between after medic and after control significant at $P<0.05$.

At 1986/87 prices the net returns from pasture (including depreciation and mortality costs of ewes) greatly exceeded that of the alternative crops (Table 6). Otherwise wheat/lentil rotations were the most profitable. Since wheat yields after pasture exceeded yields after lentils, and since the profits from pasture were nearly three times that of lentils, the wheat/pasture rotation at 1986/87 prices was therefore the most profitable. What we have not calculated is the effect of including pasture on risk, nor have we calculated threshold prices, beyond which the rank of profitability of the various rotations will change.

Table 6. Estimated profitability from alternative forms of land use (1986/87 prices).

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

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

Constraints to Adoption

Before considering constraints to adoption it is worth listing some of the factors which, as a result of this work, are no longer constraints.

- In Syria ICARDA's new medics have resolved the problem of lack of adapted cultivars
- Use of indigenous medics has partially resolved the rhizobia problem, and a wide range of adapted rhizobia strains is available for areas where nodulation remains a problem
- The ley farming system can be managed by farmers, and farmers who are given advice are able to manage grazing
- Preliminary economic evaluation shows that, at current prices, ley farming is the most profitable land-use system in the project area

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

Our on-farm pasture project will now be used to develop methodology for extending the ley farming system. We hope to hold workshops attended by extension workers, scientists and farmers to develop a methodology that initially establishes a working example of the system in any area and uses that example as a focus to extend the system.

In the existing project we will provide (and later sell) seed to interested farmers, with a view to monitoring new problems that become evident when farmers are working without continuous access to expert advice; in fact, a continuation of the fourth stage of the farming systems process.

Finally, and briefly, we will list the reasons we believe this project has been successful:

- The scientist in charge of field operations was a Syrian national and therefore understood the language, customs and needs of the farming community
- The project was based on an innovation developed by a farmer and this provided a focus for the project
- The major technical constraints were recognized and resolved before the project began
- Scientists were open-minded about how the innovation should be managed and thus appropriate management was developed on a collegial basis with farmers
- Apart from seed, the project used only resources normally available to farmers, even though research station equipment often would have been more efficient
- Local research and extension workers were involved from the beginning and, as far as possible, given credit for the project's success both within the farming community and within government circles.

References

Braden, A.W.H. and I.W. McDonald. 1970. Disorders of grazing animals due to plant constituents. Pages 381-391 *in* Australian Grasslands (R.M. Moore, ed). ANU Press, Canberra.

Cocks, P.S. 1985. Utilization of local resources for pasture plant cultivars. Pages 99-107 *in* International Symposium on Pastures in the Tropics and Subtropics. Tropical Agriculture Research Series No. 18. Tropical Agriculture Research Centre, Tsukuba, Japan.

Cocks, P.S. 1986. Integration of cereal-livestock production in the farming systems of north Syria. Pages 186-211 *in* Potentials of Forage Legumes in Farming Systems of Sub-Saharan Africa (I. Haque, S. Jutzi and P.J.H. Neate, eds.). ILCA, Addis Ababa.

Cocks, P.S. and T.A.M. Ehrman. 1987. The geographic origin of frost tolerance in Syrian pasture legumes. Journal of Applied Ecology 24:673-683.

Cocks, P.S. and E.F. Thomson. 1988. Increasing feed resources for small ruminants in the Mediterranean Basin. Pages 51-66 *in* Increasing Small Ruminant Productivity in Semi-arid Areas (E.F. Thomson and F.S. Thomson, eds.). Kluwer Academic Press, Dordrecht, The Netherlands.

Cocks, P.S., E.F. Thomson, K. Somel and A.M. Abd El Moneim. 1988. Degradation and rehabilitation of agricultural land in north Syria. ICARDA-119 Ar, En. ICARDA, Aleppo, Syria.

FAO. 1987a. Agriculture: Toward 2000. C87/27. FAO/UN, Rome.

FAO. 1987b. CGIAR Priorities and Future Strategies. FAO/UN, Rome.

Francis, C.M. and A.J. Millington. 1965. Weather bio-assay of annual pasture legumes. IV. The oestrogenic activity of annual medic pastures. Australian Journal of Agricultural Research 16:927-935.

Nordblom, T.L. 1987. Farming practices in southern Idlib Province, Syria: 1985 survey results. ICARDA-107 En. ICARDA, Aleppo, Syria.

Puckridge, D.W. and R.J. French. 1983. The annual legume in cereal-ley farming systems of southern Australia: a review. Agriculture Ecosystems & Environment 9:229-267.

Simmonds, N.W. 1986. A short review of farming systems research in the tropics. Experimental Agriculture 22:1-13.

Springborg, R. 1986. Impediments to the transfer of Australian dryland agricultural technology to the Middle East. Agriculture Ecosystems & Environment 17:229-251.

Attempts to Introduce the Ley Farming System in Jordan

A. El-Turk
JADCO, SKAKA-JOF, Saudi Arabia

Abstract

In Jordan, about 50% of the rain-fed fields are left fallow. Recently, special attention was given to forage legumes. The ley farming system was first introduced to the country in 1980, through the Jordan-Australian Dryland Farming Project. As a result, some farmers have replaced fallow with medics, vetch or forage mixtures (barley and vetch). Some farmers were successful in handling the medic/cereal system, which has a promising future in Jordan. However, more effort is needed, especially in the extension of the new system.

Introduction

Agriculture in Jordan is the main source of income for about 20% of the labor force in the country. In spite of the growth in this sector, it has not been able to meet the increasing demands, especially for meat and dairy products. As a result, imports have increased from JD 41 million for the period 1973-75 to JD 94.4 million for 1976-80 and JD 179.9 million for 1981-85 (Ministry of Planning 1986).

Imports of red meat and dairy products are high; self-sufficiency in these two products in 1982 was only 24 and 20%, respectively (Harb and Khalid 1984). The imports of red meat cost the country over JD 27 million in 1982 (Department of Statistics 1982).

One of the major factors that prevents the rapid increase in meat production is the shortage of feed supply. The main feed produced locally is barley. Only a very limited area is planted for green fodder or hay, as indicated in Table 1. As a result, large quantities of concentrated feed are imported (Table 2).

The recent 5-year economic and social development plan (1986-90) recognized the need for increasing green and dry fodder production in Jordan, and included several projects that will encourage the improvement and development of the rangeland as another major feed source in the grazing and feeding cycle.

The ley farming system, through the Jordan-Australian Dryland Farming Project, was and still is a major activity in the effort to increase green and dry fodder production in Jordan.

Table 1. Area ('000 ha) and production ('000 t) of crops used for animal feed in Jordan.

Crop	1975 Area	1975 Prod.	1980 Area	1980 Prod.	1982 Area	1982 Prod.
Barley	52.90	11.8	51.30	38.1	47.90	18.5
Vicia ervilia	4.20	2.0	2.35	1.8	3.37	2.6
Corn	0.59	0.7	0.06	0.5	0.01	0.1
Sorghum	0.38	0.5	0.12	0.1	0.25	0.1
Beekia	0.25	0.1	0.04	0.1	0.04	0.1
Trifolium	0.06	0.6	0.21	2.5	0.11	1.0
Alfalfa	0.06	0.6	0.37	4.7	0.08	1.0

Table 2. Quantities ('000 t) of animal feed imported to Jordan, 1982-1988.

Feed	1982	1983	1984	1985	1986	1987	1988
Barley	69.3	17.4	179.8	74.9	143.5	114.7	98.0
Corn	151.5	169.9	132.1	205.4	233.5	182.8	270.3
Concentrate	24.5	22.8	53.1	55.2	78.0	34.7	35.9
Soybean	46.0	51.2	37.9	53.2	76.3	74.4	62.2

Rain-fed Agriculture in Jordan

Agricultural Areas in Jordan

Rain-fed agriculture in Jordan occupies the major areas under cultivation in the country and constitutes around 9% of the total area of Jordan. Rain-fed field crops are mainly planted in the areas that receive between 200 and 500 mm of annual rainfall.

The country can be divided into the following agroecological zones:

1. Desert zone: represents 91% of the total area of Jordan and receives less than 200 mm of rain annually.
2. Marginal zone: receives between 200 and 350 mm and represents 6% of the total area of Jordan.
3. Semi-arid zone: rainfall between 350 and 500 mm, represents about 3% of the total area of Jordan.
4. The Jordan Valley: located 200-300 m b.s.l.; most of the land is under irrigation, where vegetables are the major crop.

Climate

Jordan has a Mediterranean climate with dry summers and mild winters. The rainfall is received during the winter season. The amount and distribution of rainfall in three major locations in Jordan are presented in Table 3. The characteristics of rainfall are fluctuation from season to season and poor distribution during the growing season. Some seasons have a total rainfall that significantly exceeds the long-term average, whereas others are far below that average.

Table 3. Monthly rainfall (mm) in Ramtha, M'shagar and Rabba stations (50-year average).

Month	Ramtha	M'shagar	Rabba
October	7	5	5
November	31	36	32
December	49	59	72
January	65	72	80
February	57	78	73
March	48	58	72
April	16	17	20
May	2	4	4
Total	275	329	352

The 1988/89 growing season was an unusual season for temperature and rainfall. This growing season recorded a below-zero temperature for several days during January. Moreover, the temperature was much higher than the average in March and April. Rainfall stopped by mid-March and crops were under moisture stress the rest of the growing season at a very critical stage in their growth and development.

Cropping System and Crop Rotations

The major field crops grown by farmers in the rain-fed areas in Jordan include winter crops (wheat, barley, lentil, vetches) and summer crops (tobacco, chickpeas, vegetables such as tomato, melons, okra).

Farmers use either 2- or 3-year rotations. Most farmers include fallow in the rotation, especially in the low-rainfall areas. The 2-year rotation will have a cereal crop (wheat or barley) and fallow. A legume crop such as lentil or vetch will rarely be included in such rotations as a fallow replacement.

In the area with high rainfall (above 300 mm), a 2-year rotation is practised where wheat and lentil or wheat and vetch are included. However, some farmers are still practising fallow in this area. A 3-year rotation is also used in the high-rainfall areas where wheat-lentil (or vetch) and summer crops are used.

Recently, some farmers have started replacing fallow with forages, especially forage legumes such as medics, vetches or barley x vetch mixtures.

Ley Farming System in Jordan

The ley farming system was first introduced to Jordan with the start of the Jordan-Australian Dryland Farming Project in 1980 (Bull *et al.* 1983, 1984). The objectives of this project were to introduce a legume forage crop into the wheat/fallow rotation, concentrating on areas with annual rainfall below 350 mm, and to carry out research and extension activities aimed at improving rain-fed wheat-growing practices.

Our major concern in the present paper is the first objective of this project. The introduction of forage legumes into the wheat/fallow rotation is very important in Jordan and will result in the following:

- increased soil fertility and improved soil structure,
- decreased soil-borne cereal diseases,
- reduced soil erosion by discontinuing the fallow,
- increased cereal and red meat production, and
- improved diversity of farming income.

The ley farming system in Jordan concentrates on the introduction of medic to wheat areas to replace the fallow year and to encourage animal production. On the other hand, work on vetch (Beekia) was done side by side with medic to give the farmer the option best suited to his farm conditions. At the start, the work concentrated on medic species that were introduced from Australia. In later years, work focused on the evaluation of local *Medicago* species that were collected from Jordan (Bull *et al.* 1983, 1984; Harvey *et al.* 1982; Heysen *et al.* 1986). The work started in the center of Jordan at M'shagar area and then extended north to Ramtha and south to Rabba.

Achievements

The activities involved in assessing forage legume potential in the farming system in Jordan covered several areas of research and provided information on planting date, seeding rate, cultivar evaluation, rhizobial inoculation, medic regeneration and its role in the rotation stage of grazing or harvesting, dry matter production, stocking rates and animal weight gain (Bull *et al.* 1983, 1984; Harvey *et al.* 1982; Heysen *et al.* 1986; Shorat 1986).

The results obtained provided good evidence about the potential benefit of the system to the Jordanian farmer and encouraged the Jordanian and Australian governments to approve a third phase, which is now being implemented, and concentrate on extension to transfer the results to farmers throughout Jordan. This activity will be discussed by Mr. Rod Reeve in his presentation.

The following is a brief discussion of some of the major results that were achieved. The major emphasis is the role of forage legumes in the cereal rotation. The results of 3 years of experiments at Ramtha in northern Jordan (Table 4) indicated the economic benefit of forage legume/barley compared with a fallow/barley rotation. Grazed forage/barley rotations gave consistently greater net returns than the other two rotations. In a very dry year (1985/86) each rotation showed a net loss (Heysen *et al.* 1986; McArthur 1985).

Table 4. Economic summary of a rotation trial' at Ramtha in northern Jordan, 1985-88.

Treatment	Net return (JD/dunum)			
	1985/86‡	1986/87	1987/88	Mean
Rainfall (mm)	165	297	311	258
Grazed forage/barley	-2.42	13.43	10.11	7.03
Fallow/barley	-1.82	6.13	9.05	4.45
Forage hay/barley	-2.43	12.79	3.79	4.72

† The experiment consisted of two treatments of each of the listed farming systems. For example, fallow/barley and barley/fallow were included each year. The figures presented are the average of each rotation and its reverse farming system for each year.

‡ Establishment year.

Grazing trials on the forage legumes of *Vicia* and medic gave very important information about the potential of these plant species as animal feeds and also indicated the variability that exists between the medic cultivars. The results of liveweight gain of Awassi lambs at M'shagar for the 4-year period from 1986 to 1989 are presented in Table 5. The weight gain in the first 2 years (1986 and 1987) was greater from the feed on Beekia than that on snail medic. However, with the introduction of new locally adapted medic cultivars such as *Medicago rigidula* sel 716 and *Medicago rotata* sel 1943, the weight gain from these two cultivars was equal to or greater than that obtained from Beekia. This indicates the potential of the local selections of medic, which are now under evaluation (Heysen *et al.* 1986; McArthur 1985; Shorat 1986).

Several trials were conducted at the three sites and for several growing seasons to determine dry matter production. The results (Fig. 1) indicate the high yield potential of the different species, especially in relatively high-rainfall seasons.

The seed yield of several medic species (Fig. 2) exceeded the production of the well-known Australian cultivar Jemalong (Heysen *et al.* 1986; McArthur 1985; Shorat 1986).

Table 5. Mean liveweight gain of Awassi lambs at M'shagar (1986-1989), expressed in grams/lamb/day. Grazing time varied from 44 to 48 days, depending on the season.

Annual legume	1986	1987	1988	1989
Vicia sativa Beekia	121	239	224	171
Medicago scutellata Snail	71†	172	181	—
M. rigidula sel 716	—	—	218	152
M. rigidula sel 1919	—	—	207	—
M. rotata sel 1943	—	—	235	—
M. rotata sel 2123	—	—	—	178
LSD 5%	47			25

† Establishment year of medic.
— Not included.

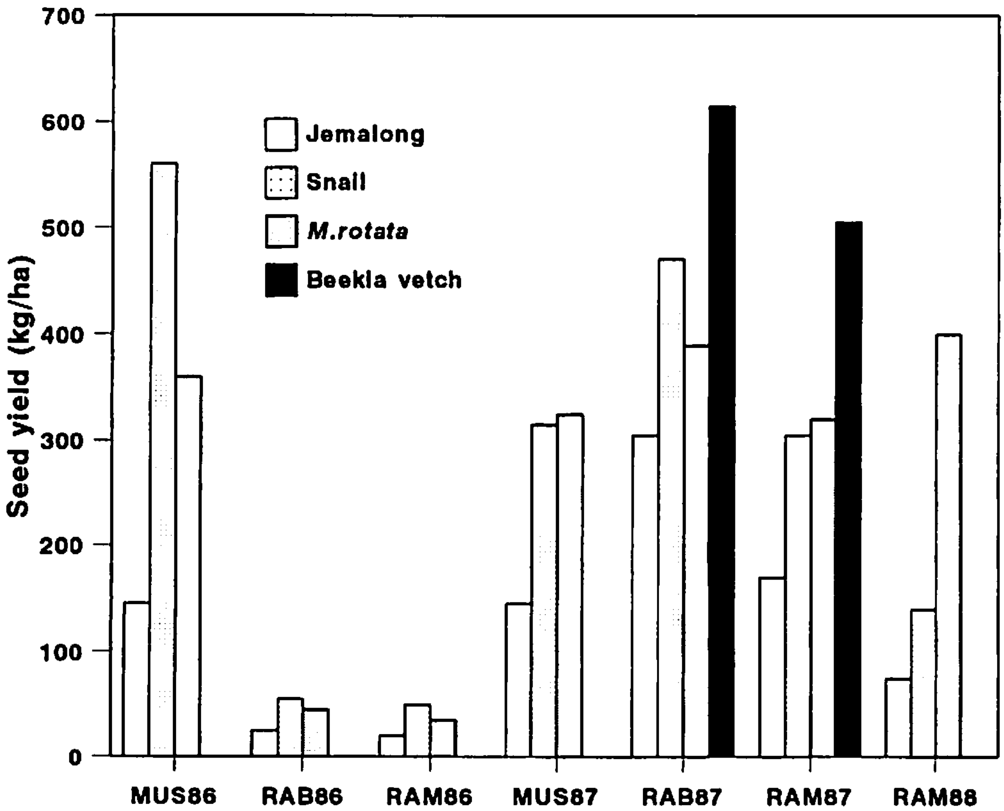


Fig. 1. Seed yields of medic and vetch at three sites (M'shagar, Rabba and Ramtha) from 1986 to 1988.

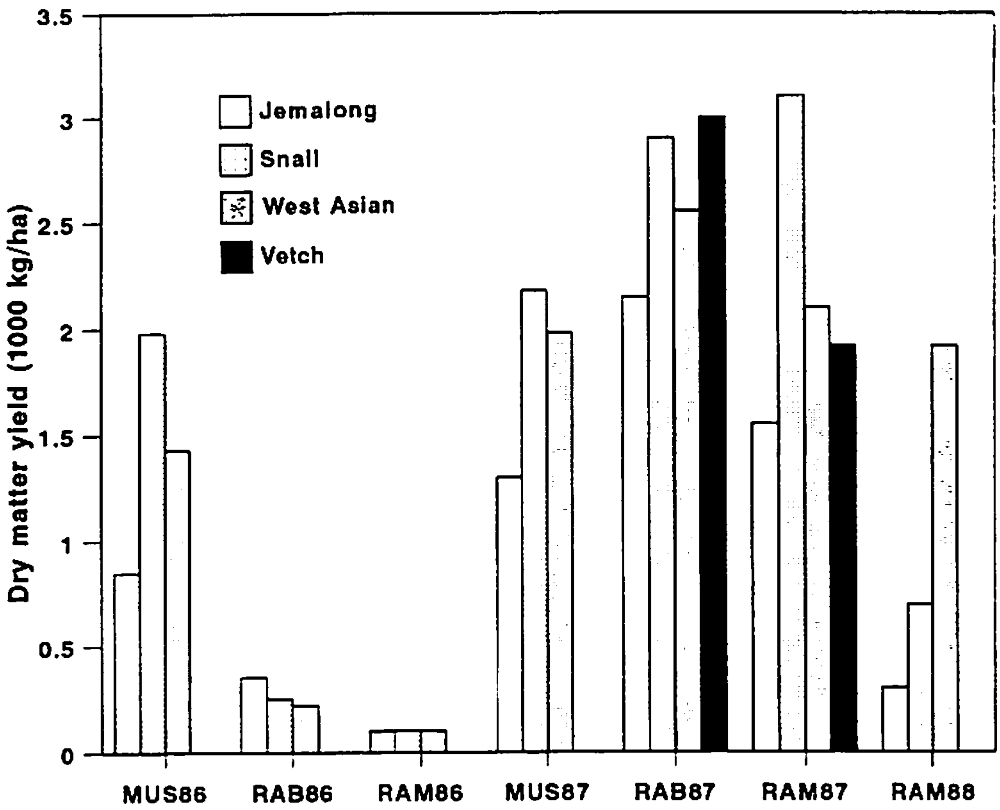


Fig. 2. Dry matter yields of medic and vetch at three sites (M'shagar, Rabba and Ramtha) from 1986 to 1988.

Summary

The introduction of forage legume crops such as vetch or medic to the cropping system in the rain-fed areas of Jordan has great benefits for the Jordanian farmer and the country. Forage legumes are starting to replace the fallow land and thus the area under cultivation is increasing. The system improves the soil fertility and structure and in turn will provide the farmer with high-quality feed for his animals. It also will encourage farmers who do not own sheep to own and invest in sheep production.

The question that might be asked is whether the farmer will grow vetch or medic. The answer will depend on many factors and facts. Vetch could be planted more easily by some farmers because it is similar to other pulse crops, is native to the area and does not need special care during the season. However, in the long term, medic could be a good choice, especially for farmers who own sheep and can practise direct grazing. However, medic cultivation requires special care in establishment, regeneration and animal/crop management. That some elite farmers in Jordan have been successful in handling the medic/cereal system promises a good future for this system in Jordan.

References

Bull, B.C., D.R. Harvey and T.E. Peckover. 1983. Jordan Australia Dryland Farming Project. Annual Report No. 3. Season 1982/83. Amman, Jordan.

Bull, B.C., D.R. Harvey and T.E. Peckover. 1984. Jordan Australia Dryland Farming Project. Annual Report No. 4. Season 1983/84. Amman, Jordan.

Department of Statistics. 1982. Foreign Trade Bulletin. Amman, Jordan.

Harb, M. and M.K. Khalid. 1984. Sources of animal feed in Jordan. Pages 3-11 *in* Agricultural Engineers. No. 20. Year 13. Amman, Jordan (in Arabic).

Harvey, D.R., D.C. Bull and T.E. Peckover. 1982. Jordan Australia Dryland Farming Project. Annual Report No. 2. Season 1981/82. Amman, Jordan.

Heysen, C.S., P. Tow, S.R. McArthur and J.R. Pearce. 1986. Jordan-Australia Dryland Farming Project. Phase II. Annual Report No. 2. Season 1985/86. Amman.

McArthur, S.R. 1985. Jordan-Australia Dryland Farming Project. Phase II. Annual Report No. 1. Season 1984/85. Amman.

Ministry of Planning. 1986. Five year plan of economic and social development. 1986-1990. Hashemite Kingdom of Jordan. National Press, Amman.

Shorat, Z.Y. 1986. Evaluation of two legume species for forage and animal production. M.Sc. Thesis. Faculty of Agriculture, University of Jordan, Amman.

An Extension Strategy Currently Used in Jordan to Introduce the Ley Farming System

R. Reeve
SAGRIC International, Adelaide 5000, Australia

Abstract

An extension strategy being implemented by the third phase of the Jordan/Australia Dryland Farming Project follows a workplan used widely in Australia. The objective is to increase adoption of the ley farming system mainly by improving the extension service within the government extension organizations. The strategy analyzes the barriers to adoption and exploits current reasons for adoption. The main barriers to adoption and methods used to overcome them are: technical constraints such as frost and drought susceptibility of medics and practical difficulties involved in achieving effective nodulation (overcome by intensified research with ICARDA); lack of cereal/livestock integration in Jordanian farming systems (*Vicia* species already grown in Jordan are promoted in rotation with cereals to integrate cereals and livestock into farming systems); new government extension services poorly trained in ley farming techniques (services are strengthened by training, on-farm research, technical exchange visits, post-graduate scholarships, workshops, seminars, production of a practical training manual and extension leaflets); low acceptance of medic by farmers (demonstrations farms belonging to cooperating farmers are operated at seven key sites in Jordan), and lack of seed and machinery (seed multiplication and machinery operation programs have been established).

Introduction

The Australian International Development Assistance Bureau (AIDAB) has been committed to the introduction of the Ley Farming System in Jordan since 1980 (AIDAB 1988). The project, known as the Jordan/Australia Dryland Farming Project (JADFP), has completed two phases and is now conducting a third phase, the Extension Phase. Each phase has used a technical team of three or four specialists from Australia and up to 20 Jordanian part-time colleagues. The extension strategy being implemented in Jordan in 1989-92 is built on 8 years of scientific research and an extensive on-farm research program across Jordan involving a considerable extension effort.

This paper continues on from that of El-Turk (this volume), in which the technical achievements of the project and the previous attempts to implement the ley farming system are discussed. Even now, in 1989, the major constraints to widespread adoption of the medic-based ley farming system are technical issues and crop management difficulties, the most outstanding being the risk of medic failure due to frost or drought and the difficulties involved in obtaining effective nodulation of the medic in the establishment year.

For this reason, the project's focus now is on widespread adoption of the Integrated Cereal/Livestock Farming System, involving nonregenerating forage legumes such as *Vicia* spp. as well as medics.

The Extension Strategy for the Ley Farming System

The workplan for the extension strategy to introduce the ley farming system in Jordan is one widely used in Australia (Mortiss 1988).

Objective

To assist in increasing the productivity of the main rain-fed, cereal-growing areas of Jordan and, at a more specific level, to integrate livestock and cereal production through the introduction of the ley farming system to Jordan.

Behavior Change Sought

To increase the adoption of the ley farming system by farmers/livestock owners and to establish the capability within the Jordanian Government to maintain the extension program.

Present State of Adoption

Medic-based ley farming in Jordan in the last 10 years has been confined to small areas, which have been closely managed by the JADFP and where seed has been supplied free of charge to farmers. Figure 1 shows the area sown to pure medic pastures during the last 10 years.

Over 20 farmers have been introduced to the system at key locations across Jordan. Farmers who adopt the system have large farms and own livestock as well as land. The economic advantages of the ley farming system have been well established in areas of lamb fattening, milk production and grazing capacity, as well as improved cereal production. These studies, which are conducted each year, consistently show at least a 40% increase in total farm profitability, compared with cereal/fallow, by using the ley farming system. Other advantages of the ley farming system recognized by farmers and leading to adoption are:

- diversification of income,
- sustainability of the farming system,

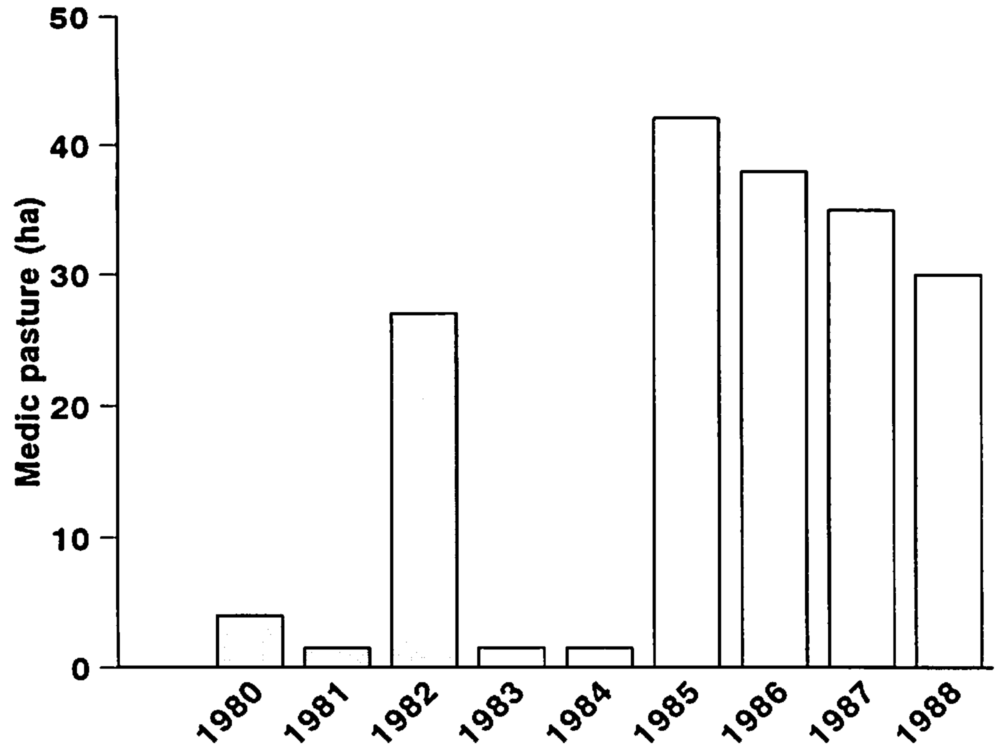


Fig. 1. Area sown to pure medic pastures in Jordan, 1980 to 1989.

- a more even spread of income throughout the year,
- non-exploitative nature of the system, and
- improved soil conditions, including fertility and structure.

Barriers to Adoption

The barriers to adoption of the medic-based ley farming system have been ranked in order of magnitude.

1. The risk of crop failure involved in growing medic is perceived by the extension officers and farmers to be high because of the difficulties of management, in particular in obtaining effective nodulation in the establishment year, and in frost and drought susceptibility. Integrated cereal/livestock farming requires a higher level of management input from farmers than the usual single-enterprise farming.
2. Cereal production is generally not integrated with livestock production. Livestock enterprises are generally located in areas receiving less than 250 mm annual average rainfall.

3. The Government extension service is new and poorly trained in farming systems and is particularly poorly educated in the ley farming system.
4. Livestock production is not as heavily supported by the Government as cereal production and poor markets exist for hay or grazing rights. Cereal farming generally has a higher return per hectare than livestock farming.
5. The management of medic pasture is not known to the farmers because the crop is new in Jordan. Medic pastures are not recognized as being the property of the landowner and as such are overgrazed by nomadic herds, which exhausts the seed supply required for regeneration. It takes at least 3 years to see the benefits of a regenerating medic pasture.
6. Lack of seed and appropriate seeding machinery.

Methods

The extension methods used currently address the constraints outlined above in Barriers to Adoption, as well as exploit the advantages outlined under Present State of Adoption. During the current Extension Phase of the JADFP, the following methods of extension are being initiated, aimed at improving adoption rates.

Technical constraints

Nodulation and frost susceptibility of medics are the chief constraints. Research is currently continuing in Jordan to develop more persistent medic varieties and to reduce the unreliability of rhizobial symbiosis that currently exists. This research is dependent on cooperation between ICARDA and the Jordan Ministry of Agriculture and although outside the context of the extension strategy, it is of primary importance to extension.

All medic sowings in Jordan are currently heavily supervised by the JADFP to reduce the chances of crop failure. Seed bank levels are monitored on most farms and when seed reserves are marginal the medic is grown for two consecutive years if possible. The second-year medic generally does not have nodulation problems and the early start to the growing season means that the medic has fewer problems with winter frosts.

Lack of cereal/livestock integration

Forage legumes that do not naturally regenerate have been more widely adopted. The most successful forage legume has been *Vicia sativa*, known as Beekia vetch. Annual sowings since 1980 have exceeded 1000 ha. The areas sown to Beekia vetch were high during 1981-1986 owing to joint promotion by the World Food Program and the JADFP. This promotion included good financial incentives for farmers opting to grow vetch.

Other forage legumes such as *Vicia villosa*, *Vicia narbonensis*, *Vicia ervillia*, *Lathyrus ochrus* and *Lathyrus sativus* are grown in small areas and have shown potential for high forage production.

The integration of these crops with cereal and livestock production is being promoted by the JADFP because these crops can act as vehicles of introduction for the ley farming system. Farmers growing Beckia, *V. villosa* and *V. narbonensis* are almost assured of high production under most conditions as they are well adapted to the Jordanian environment. In turn, this assured production can be most profitably utilized not by selling the forage, but by grazing or storing it for use by the landowners who own livestock. The JADFP supports the use of these crops in local farming systems by seed multiplication programs, research and evaluation and extension back-up (see below).

The project operates a 20-ha Trial Farm to demonstrate the integration of cereals and livestock.

Extension Services

Training of extension officers

The main constraint in social and economic acceptance of the ley farming system lies in the poor understanding of the system by the extension officers. The technical training of these officers is being intensified during this extension phase by:

- formal technical training courses in each region at post-graduate level,
- an on-farm research program in each region,
- training visits to ICARDA,
- Ph.D. and M.Sc. scholarships in Australia and Jordan, and
- target-oriented extension methodology workshops and seminars.

Support materials

Support materials for the extension service include the production of a practical training manual for the Integrated Cereal/Livestock Farming System in Jordan, extension leaflets, static displays at key sites, field-day resources, farm visits, media and seasonal market reports and newsletters for farmers. Support also includes the coordination of monthly extension planning activities in each region.

Inequitable support for livestock production compared with cereal production

The JADFP endeavors to enhance awareness of the national economic benefits of the Integrated Cereal/Livestock Farming System among politicians and decision makers, including promotion of markets for conserved fodder and grazing rights.

Social acceptance of medic as a crop

The central activity of the JADFP is the operation of seven model demonstration farms at strategic locations in Jordan. These farms serve to introduce the ley farming system into local farming communities, and act as demonstrations to surrounding farmers. The farms are also central to the on-farm research program as they provide important social and physical information. Each farm has at least 50 dunums (5 ha) of legumes and 50 dunums of cereals, in rotations suitable to the environment.

Lack of seed and machinery

The establishment of a permanent seed multiplication capacity in Jordan is now in place with the support of the Ministry of Agriculture and Farmer Cooperatives. Appropriate seeding equipment is scarce but methods of sowing using locally available equipment are being promoted.

Locality and Audience Size

Locality and audience size are limited to cereal-growing areas receiving more than 250 mm annual average rainfall.

Aids

Aids are discussed above.

Cooperators

Cooperators, other than farmers, include private machinery operators, seed and fodder merchants, farmer societies, etc.

Time Period

A time period of 3 years has been set to establish the extension strategy.

Time Allocation and Budget

For the first 3 years: USD 550,000/year, three Australian advisors plus 21 Jordanian counterparts. For subsequent years: USD 400,000/year, with an allocation of 30 Jordanian staff.

Evaluation

Evaluation methods planned are: number of farmers adopting the system each year, areas sown to medics, machinery usage figures, seed sales and time allocation of extension officers to the ley farming system.

References

AIDAB (Australian International Development Assistance Bureau). 1988. Design Document for Phase III of the Jordan/Australia Dryland Farming Project. Government Printer, Australia.

Mortiss, P.D. 1988. Agricultural extension: a practical manual. Queensland Department of Primary Industries. Queensland, Australia.

The Potential and Problems of the Ley Farming System in the High-elevation Areas of Turkey

O. Erkan and I. Yilmaz
Department of Agricultural Economics, Faculty of Agriculture, Cukurova University, Adana, Turkey

Abstract

Most farms in Turkey are in villages or near forests. Farms in the villages are generally small and have low incomes. To understand their socioeconomic structure and to make an economic analysis, a survey was conducted in the mountain villages of the Kozan district of Turkey in 1987. Sixty-three farmers with farms of different sizes were interviewed. The analyses showed that the average area of land cultivated by the farmers was 4.58 ha, the family size was 7.28 persons, the major crops were wheat, goats and sheep, and farmers allocated 21% of their land to fallow. Moreover, family labor was not utilized fully. It was evident that environmental conditions are appropriate for the introduction of ley farming into this region.

Introduction

In Turkey, 62% of the villages are located in or near the forests and on the high plateau. The farms in these villages are generally very small and the farmers' incomes are low. To improve farming and to raise the standard of living in these areas, it is necessary to conduct research in relation to their socioeconomic structure and agricultural activities. Once we know their resources and environmental conditions we can prepare research and present recommendations for better production.

The Cukurova region, which is surrounded by the Taurus mountains, is located in the Mediterranean region. The lowlands have a very favorable climate and productive lands for growing cotton, wheat, citrus and watermelon with high yields, but the same climatic and soil conditions are not true for the mountain farms. Their soils are of poor quality and the yields of crops and livestock are low.

The research activities by research institutions and the universities undertaken so far have been concentrated on farms in the lowland areas of the Cukurova region. The agricultural problems of mountain villages have been neglected and therefore very little research has been done on the problems of these farms.

In 1987, research was conducted in the mountain villages of the Kozan district with the following aims:

- to gain a better understanding of the socioeconomic structure of the farms,
- to analyze economic results of the farms, and
- to investigate income-increasing opportunities.

Materials and Methods

The main material used in this research was data obtained from farmers by questionnaire. Supplementary information from government offices and related institutions also was used in the study.

In the survey area, there are 49 villages and 4125 farm families. Villages were put into five groups at the first stage, to obtain a representative sample. A stratified sampling method was used to determine the number of villages. The results showed that six villages were enough to represent the survey area with a 95% confidence interval. In the second stage the farms in these villages were put into five groups and the number of family farms to be investigated was calculated by the same sampling method (Table 1).

Table 1. Distribution of sample farms by farm-size groups.

Farm size (ha)	No. of farms
0.1-1.5	15
1.6-3.0	12
3.1-5.0	12
5.1-7.5	12
7.6-15.0	12
Total	63

The data collected from sample farmers were stored in the computer center of Cukurova University and several analyses were made.

Results and Discussions

Land Use and Livestock Ownership

Land, its quality and size, are very important in agricultural production. The average area operated by the farmers was 4.58 ha. Most of this land is steep and only 6.9% of it is irrigated. Irrigation possibilities are very limited in the survey area.

The most important crop is wheat, mainly produced for home consumption. Farmers allocated 43.6% of their land to wheat production. Wheat is followed by sesame and cotton, produced for marketing. Farmers also produce barley and oats for livestock feed and some fruit (Table 2).

All farm-size groups allocate some part of their land for fallow and we believe that this is a waste because the average rainfall in this area is 855 mm per year. A forage crop could be grown on this land and contribute to livestock production. In the analysis of production costs we note that farmers usually must purchase fodder for their livestock.

Table 2. Land use (ha) by farm-size groups, 1987.

Farm size (ha)	Wheat	Barley	Oats	Sesame	Cotton	Fruit	Other crops	Fallow	Total
0.1-1.5	0.63	0.06	0.04	0.01	—	0.06	0.10	0.16	1.06
1.6-3.0	1.04	0.17	0.13	0.27	—	0.13	0.12	0.31	2.17
3.1-5.0	1.98	0.34	0.31	0.31	0.11	0.07	0.03	0.89	4.04
5.1-7.5	1.94	0.50	0.39	0.18	0.74	0.31	0.06	2.22	6.34
7.6-15.0	4.91	0.28	0.25	2.15	1.58	0.13	0.18	1.81	11.29
Mean	2.00	0.26	0.22	0.54	0.40	0.13	0.09	0.94	4.58

Table 3. Livestock ownership (head) by farm-size groups, 1987.

Farm size (ha)	Cattle	Sheep	Goats	Others
0.1-1.5	2.47	5.6	11.33	0.07
1.6-3.0	2.58	7.33	10.34	0.50
3.1-5.0	2.91	13.73	14.36	0.45
5.1-7.5	4.66	13.08	3.41	0.33
7.6-15.0	4.68	7.22	6.93	—
Mean	3.29	9.48	10.08	0.28

All farm-size groups have livestock: 3.29 cattle, 9.48 sheep and 10.08 goats on average. Farmers also have other livestock such as horses or donkeys but their number is not important (Table 3). Goat production is the major enterprise in almost all farm-size groups, followed by sheep production.

As an enterprise, livestock is more important in small farm-size groups. This was reflected in the gross production value of farms.

Family Labor Force and its Use

The average family size was found to be 7.28 in the region, which is above the national average (6.4). As farm size goes up, family size increases. Sixty percent of the total population is economically productive; however, 20% of the productive population is illiterate.

To understand how the family labor force is used it is better to convert the family members into Man Power Units (MPU) by taking into consideration their age and sex. This is necessary because the absolute value of family size does not explain the potential labor force.

In terms of MPU the average labor force is 4.60 in the survey area. If we assume the average number of working days is 280 a year in this region, then the average MPU becomes only 1288. Only 35% of the potential is utilized and 65% is wasted. The use of the potential family labor force varied according to size of farm. The big farms used 45% and the middle size farmers (3.1-5.0 and 5.1-7.5 ha) used 27% of their potential family labor (Table 4).

Table 4. Family labor force and its use, 1987.

Farm size (ha)	Family size	Family labor force (MPU)†	Yearly potential days (MPU)	Used on farm (MPU)	Used off farm (MPU)	Used non-agric. (MPU)	Total use (MPU)	Surplus family labor (MPU)
0.1-1.5	6.00	3.78	1058	359	7	68	434	624
1.6-3.0	6.58	4.25	1190	392	3	35	430	760
3.1-5.0	7.46	4.78	1338	313	16	35	760	974
5.1-7.5	8.17	4.90	1372	348	29	—	377	995
7.5-15.0	8.69	5.50	1540	636	28	26	690	850
Mean	7.28	4.60	1288	399	15	35	449	839

† MPU = Man power unit.

The use of family labor force includes on-farm, off-farm and nonagricultural activities. We saw that family members worked outside their farms in all farm-size groups. This simply means that the income they earn is insufficient. The reasons for underutilization of family labor were inadequate land and capital ownership of farms and the limited number of off-farm job opportunities. It appears that under the present farming system the family labor force cannot be better utilized.

Capital Situation

Capital is an important factor in agricultural production. Disposable income is as important as total income. When we analyzed farm capital we saw that the value of land constituted 53% of the total assets. On the other hand, the amount of livestock, machinery, buildings and stock was insufficient for rational production (Table 5). As a result, new technology cannot be applied and the production technique is based on local traditional methods. When we examined the production factors (land, labor and capital) we saw that the land which the average farmer cultivated was inadequate in area and its productive quality low compared with the lowland areas of the region. The average farmer's capital was inadequate for effective production. Consequently, most farmers borrowed from official and private sources at high interest rates (Table 6), mostly from private money lenders as short-term credit.

Table 5. Average assets (USD) by farm-size groups, 1987.

Farm size (ha)	Land	Buildings	Crops	Mech. equip.	Livestock	Stocks	Total assets
0.1-1.5	1048	1288	357	25	1001	211	3930
1.6-3.0	1580	1245	167	42	1225	211	4470
3.1-5.0	3686	1664	276	91	1533	384	7634
5.1-7.5	4615	1393	322	105	1458	359	8252
7.6-15.0	11576	2582	499	232	1641	650	17180
Mean	4170	1616	313	93	1367	354	7913

Table 6. Liabilities (USD) by farm-size groups, 1987.

	Liabilities			
Farm size (ha)	Debts	Rented land	Own capital	Total
0.1-1.5	52	30	3848	3930
1.6-3.0	138	114	4218	4470
3.1-5.0	178	116	7340	7634
5.1-7.5	193	677	7382	8252
7.6-15.0	613	1458	15109	17180
Mean	221	404	7288	7913

Gross Production Value (GPV), Costs and Agricultural Income

The economic analysis of the farms showed that the average GPV was USD 1500 with 1987 prices (Table 7). Most of the GPV came from crops, with wheat and cotton as the dominant crops on the farms. Results showed that 63% of wheat was consumed by the family and 37% was sold on the market, whereas all sesame and cotton was sold. Barley and oats were grown exclusively for livestock feeding.

Table 7. Gross Production Value (GPV) and its components (USD), 1987.

Farm size (ha)	Crop prod.	Livestock production	Income off farm	Rental value of house	GPV total /farm	GPV avg total (USD/ha)
0.1-1.5	292	316	24	38	670	632
1.6-3.0	469	371	14	38	892	411
3.1-5.0	632	405	51	50	1138	282
5.1-7.5	863	458	42	42	1405	222
7.6-15.0	2899	754	184	78	3915	347
Mean	946	446	59	49	1500	328

Livestock production is the second most important source of GPV. The value of livestock products constituted on average 30% of GPV. The percentage of the value of livestock products in GPV was higher in small farm-size groups. In other words, as the farm size increased, the share of livestock production value decreased in the GPV. In the smallest farm-size group the livestock production value was higher than the crop production value. The small landowners tended to increase their income by producing more livestock.

It also was found that farmers wanted to increase their income through off-farm work. Working as labor on other farms could provide some income to the farmers but its potential was very limited.

The average annual costs per farm were USD 692. As farm-size group increased, costs also increased (Table 8). The difference between GPV and costs is called agricultural income. Agricultural income increased as farm size increased. This is the usual case, but when we examined the values of agricultural income per hectare, we saw that small farms had higher values. What was the reason behind this? The analysis of the farms showed that the small farmers are used to having more livestock per hectare than bigger farmers. Small farmers tried to increase their income by producing more livestock. Hence they made more productive use of resources than the big farmers.

Table 8. Costs and agricultural income (USD) by farm-size groups.

Farm size (ha)	GPV	Costs	Agricultural income Total	Per ha
0.1-1.5	670	254	416	392
1.6-3.0	892	370	522	240
3.1-5.0	1138	570	568	140
5.1-7.5	1405	658	747	118
7.6-15.0	3914	1843	2071	183
Mean	1500	692	808	176

Conclusions

Under these circumstances how could we develop ley farming in this region? We saw that farmers allocated 21% of their land to fallow. This land could easily be allocated to ley farming because the annual rainfall in this region is 855 mm. This provides suitable environmental conditions for ley farming.

How can we introduce ley farming to the region? First, we should establish scientist-controlled trials in the region and show the farmers that ley farming can be applied. Second, the Ministry of Agriculture, Forestry and Rural Affairs should take necessary measures to adopt ley farming. Provision of necessary inputs and efficient extension will help the acceleration of ley farming in the region.

Another important reason for farmers to adopt ley farming is that they all purchase hay and feed because they fail to produce sufficient feed for livestock production (Table 9). Ley farming could help to reduce farm costs and increase family income.

Table 9. Livestock feeding costs (USD) by farm-size groups, 1987.

Farm size (ha)	Cost Hay	Feed
0.1-1.5	17.0	39.1
1.6-3.0	21.3	68.4
3.1-5.0	11.6	79.6
5.1-7.5	2.2	39.7
7.6-15.0	—	76.3
Mean	11.6	62.9

The Potential of Medic-based Ley Farming: Constraints and Recommendations for Implementation within Iran

P. Nazari-Dashlibrown
Department of Range, Forest and Range Organization, Shamiran, Tehran 19564, Iran

Abstract

Research on ley farming in Iran is necessarily constrained within the areas where medics will survive low temperatures in high altitudes. This paper presents an inventory of environments where progress with ley farming might be made, especially by concentrating on the selection of indigenous cold-tolerant germplasm and methods of commercial seed production. At present, systems based on stationary threshers and family labor would better fit the Iranian requirements. More attention should be paid to the introduction of the system on farmer's fields, which inevitably calls for improved extension of grazing management techniques.

Introduction

Iran suffers a serious shortage of livestock feed. Of Iran's total area of 164 million hectares, around 90 million are rangeland, i.e., uncultivated land accessible to livestock; about 12 million hectares are cropped under dryland conditions and about 1 million hectares are irrigated.

As the population increased, so did the grazing pressure on the rangelands. Destruction of rangeland pastures increased as they were cultivated for crops. Wind and water erosion usually follows cultivation. In rainfall zones of 200 mm or less and even on steep and stony terrain, cultivation for crops is having a severe effect on the condition of the rangeland. Currently only 14 million hectares (15%) can be classified as having reasonable condition and production (Table 1).

Table 1. Rangeland condition in Iran, 1987/88.

Class	Condition	Area (million ha)
A	Fair to good	14
B	Fair to poor	60
C	Poor	16

The annual marginal production of the range now averages only 111 kg/ha above that needed for its own maintenance and the figure is declining as grazing pressure continues to increase and cultivation removes some of the more favorable areas.

Despite the declining range, Iran's animal population has continued to increase and there are currently 99 million livestock (calculated as dry sheep equivalents) in the country. Of these, 60 million live on the range and crop residues and the remainder in feedlots and irrigated areas. For a satisfactory level of nutrition based on the currently available low-quality feed, 37 million tonnes of dry matter (DM) are required annually for the 60 million livestock units on the range. As Table 2 indicates, there is a feed deficiency of at least 12 million tonnes, currently being met by grazing the range plants beyond their grazing capacity. The result is that the range, and its annual increment of production, continue to deteriorate. As a consequence of poor nutrition, animal performance is affected, resulting in reduced growth rate and lambing percentage and an increased mortality rate.

Table 2. Sources of livestock feed in grazing lands, Iran.

Source	Area (million ha)	Available dry matter (million t)
Range browsing	90	10
Cereal stubble	7	12
Handfed grain, other supplements		3
Total	97	25

In summary, the position is critical and new strategies must be adopted.

Strategies to Increase Livestock Feed

It might be argued that a major reduction in wheat lands or livestock numbers by about one-third is the obvious solution. Neither proposition, however, is realistic, as not only will the import bill be greatly increased, but the already low income of the villagers would suffer, creating more poverty and accelerating migration to the cities. Four other approaches are therefore under consideration by the government.

1. Sow about 2 million hectares of 'converted' rangeland in high-elevation country with lucerne or other perennial forage legumes.
2. Ensure that, of the 12 million hectares cropped to cereals, at least 10 million can be dedicated to ley farming, thus producing about 5 million hectares of dryland medic pasture in rotation with a similar area of wheat or barley each year.

3. Increase the irrigated areas of forages.
4. Improve rangeland, including revegetation of saline lands and dune fixation.

All strategies will be adopted, but (3) and (4) are long term, whilst much saline land has too low a rainfall for reliable plant establishment. Thus, increased lucerne and dryland medic are the obvious strategies for the most immediate benefit.

Dryland Lucerne

Lucerne occurs naturally in the highlands of Iran, a country fortunate in possessing a range of cultivars well adapted to cold winter areas. Seed supplies can be supplemented by cold-tolerant varieties originating from Turkey, Europe and the USA. The lucerne will be located initially on converted range in the high-elevation land now farmed with a rotation of fallow and low-yielding cereals. The problem is that much of this converted rangeland is steep and stony with shallow soils or low rainfall and the persistence of lucerne in such marginal country is not assured.

In either case, dry matter production is unlikely to be much more than 1500 kg/year. Also, 1 million hectares of low-yielding cereals (5 kg/ha) are displaced as a cost to the system. Nevertheless, there is the expectation of an additional 3 million tonnes DM/year of high-quality feed generated by this strategy.

Medic Pastures in Dryland Farming Regions

Iran has at least 12 million hectares of cropped land, of which half is fallowed each year (Carter 1978). After the lucerne sowings, the balance of 10 million hectares might be used for ley farming of medic pasture in rotation with wheat or barley. The estimated 5 million hectares of medic pasture should produce 1500 kg/ha each year or a total of 7.5 million tonnes of dry matter. In addition, wheat after medic produces more DM and an increase in cereal straw of 1.5 million tonnes (20%) can be expected.

Annual medics are likely to be the preferred legume for the ley farming system because they occur naturally in all regions, are well adapted to alkaline soils and are especially suited to rotation with cereals because of their inherently high hard seed content. Hard seed, which in some varieties may amount to 90% at the beginning of the crop phase, allows the species to carry through the crop and successfully regenerate in the following years.

Collectively, the lucerne and annual medics could add the required 12 million tonnes to the livestock feeding system and, because their biological value for growth of animals is at least 2-3 times that of the currently available rangeland feed, the feed gap would be removed and a capacity provided to either increase sheep numbers, or better still, allow exclusion of livestock from selected areas of range, which will permit its renovation.

As well as the high protein that the dry stems (approximately 10%) and pods with seed (20%) contain, medics have several advantages within the context of ley farming:

- Nitrogen fixation of around 50 kg N/ha each year will largely remove the need to apply artificial nitrogen, saving Iran and the farmers an estimated 45 million rials/year.
- Cereal yields and quality are potentially increased compared with long-term fallow wheat or continuous cropping but only if weeds are controlled (Table 3).
- They provide a ground cover during the winter and summer, so that erosion by wind and water is greatly reduced.
- Medics allow soil fertility, in terms of nitrogen, soil organic matter and soil structure to be improved, or at least maintained compared with the fallow/wheat system.

Table 3. Comparison of wheat yields (kg/ha) after medic and in a rotation without medic (data by permission, Dr P. Cocks, ICARDA).

Treatments	No nitrogen	With nitrogen
No herbicide		
After medic	953	915
After melons	1015	1299
With herbicide		
After medic	1584	1688
After melons	1077	1555
LSD (P<0.05): 458		

Regions Suited to Ley Farming within Iran

Despite the vital role that ley farming could play in Iran, consideration of the regional crop distribution indicates that as much as 10 million hectares lies in cold winter regions where the real potential of annual medics remains to be established (Francis 1988).

The degree of research effort required to develop new varieties and management techniques varies a great deal among different regions. Areas with potential for medic and legume pasture development can be divided into seven broad regions. These are shown in Figure 1, along with annual rainfall and January temperature data.

The ley farming system was introduced to Iranian farmers by the Department of Range in 1984. The regions designated I, II and III are those chosen by the Range Department of the Forestry and Range Organization of Iran as those most suited to medics. They are characterized by alkaline soils, moderate topography, low altitude (less than 1000 m) and reliable rainfall (> 250 mm annually). Since implementation of the ley farming system, 73 086 ha in these regions, according to the provincial officers' reports, have been sown for annual medics: *Medicago scutellata* Robinson or Sava, *Medicago truncatula* Jemalong and *Medicago littoralis* Harbinger.

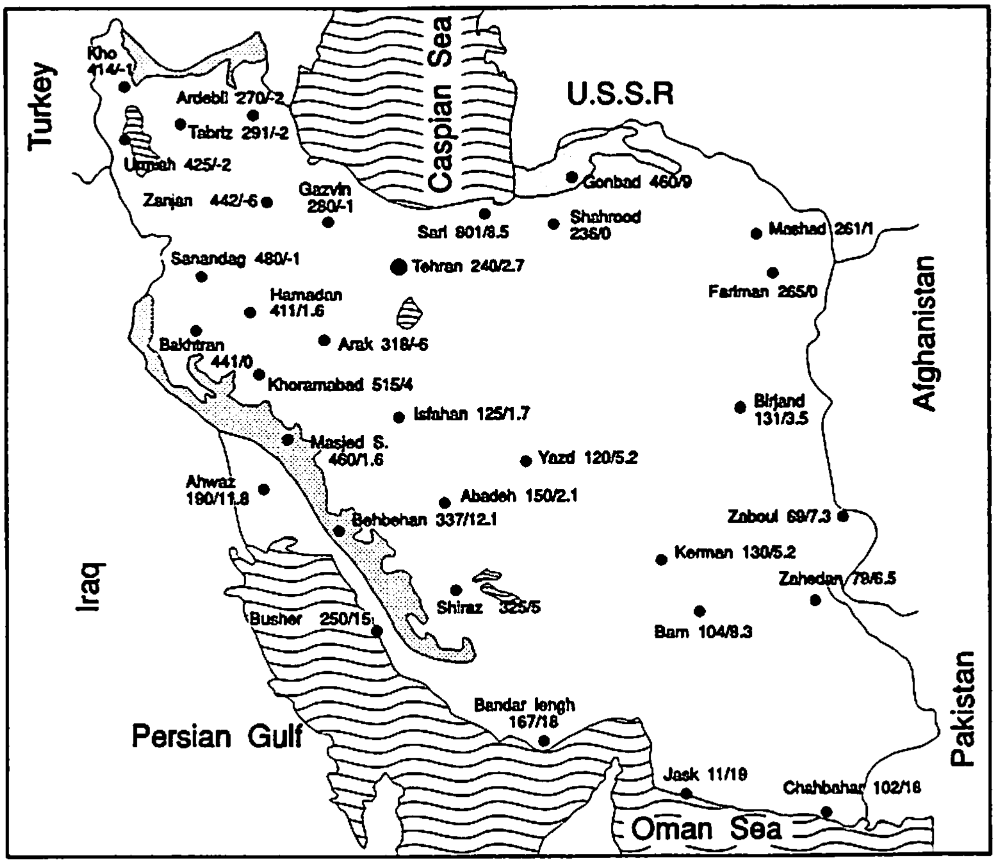


Fig. 1. Current (shaded) medic regions in Iran, defined by the Forest and Range Organization of Iran. Average annual rainfall (mm) and January temperatures (°C) are indicated for meteorological stations.

It could be mentioned that, in most cases, the technology is available for these mild-climate regions and medics already have been established successfully by Iranian farmers under guidance from the Department of Forestry and Range Organization. The problems are those of management and extension.

The Northern and mid-Mediterranean zones near the Caspian Sea (II and III) are cooler than the southwestern area (I) around Dezfuland. The season typically commences in October, permitting growth of longer-season cultivars such as Circle Valley (*Medicago polymorpha*). Borung, Paraggio and Jemalong (*M. truncatula*) sown in association with Sava or Robinson (*M. scutellata*) form productive pasture mixtures.

In the southwest Mediterranean zone (I) the seasons are warmer and shorter, but are suitable for a range of cultivars: Santiago, Serena and Circle Valley (*M. polymorpha*), Parabinga and Cyprus (*M. truncatula*) and Harbinger (*M. littoralis*). In these mild Mediterranean regions, comprehensive research, apart from defining *Rhizobium* responsiveness, is probably not the major requirement, but adoption of the system to local management and measurement and extension of the benefits of the system certainly will be.

The coastal areas along the Persian Gulf, Ahwas, Busheher to Bander Lengh (region V), although dry, are characterized by warm winters and ley farming will work there, if the experience in similar environments in North Africa is any guide. Medics are endemic and have been grown successfully on a large scale in environments with 150 mm annual rainfall on sandy soils in Libya (Francis 1981). For heavier soils, about 50 mm additional rainfall would be needed for the success of medics. Nevertheless, very early medics are available such as Serena (*M. polymorpha*), Ghor, Cyprus (*M. truncatula*) and Harbinger (*M. littoralis*) on sandier soils. Together with the snail medics, they provide useful pasture mixtures for this region. It is a zone to be considered for further development, with high prospects of success.

Another area, fairly restricted but without excessively cold winters, is zone VII, northwest and south of Shiraz (January temperature = 5°C). This type of environment closely parallels that in Aleppo, Syria (mean January temperature of 6°C) where medics can be highly successful providing use is made of local ecotypes of *M. polymorpha* and *Medicago rigidula*. As such, the area is another with good potential for medic.

The major winter cold region, designated zone IV, occupies 8-10 million hectares in the higher altitude northwestern area. This comprises the Tabriz-Ardabil-Urmia region in the north, with a long season characterized by an October seasonal break, whereas further south around Arak, Hamadan and Sanadage, the season normally starts in November. This late start creates an additional difficulty for the establishment of medics in this region because it often coincides with the start of extremely cold winters. These regions will require further research before any attempt is made for large-scale annual medic development. The presence of native ecotypes of *M. polymorpha* and *M. rigidula* makes it likely these species will play a primary role, although others such as *Medicago noeana* and *Medicago orbicularis* also may be useful (Francis 1988).

There are several species that must be considered by our research program, for the region certainly should not be devoted to annual medics alone. Much of the environment lends itself to utilization with perennials, e.g., cold-tolerant lucerne (*M. sativa*), sainfoin (*Onobrychis viciifolia*) or vetches (*Vicia sativa* and *Vicia villosa*) sown annually as fodder crops.

An interesting region is that centered around the Mashad in the northeast (VI), including the towns of Shahrud, Nayshahbour, Fariman and north to the border at Sarakhs. These are also very cold in winter but have a cool spring and a reasonable October rainfall in many years that could be of benefit to the establishment of dryland pastures. These regions are quite extensive, have a comparatively flat topography and the 1-2 million hectares are certainly worthy of research effort. Again, it must be emphasized that the winter cold is considerably greater than in any region where medics have been grown in the past.

Choice of Medic Species and Varieties

The key to a successful ley farming system, i.e., one that does not require reseeding of the medic, is the correct choice of species and varieties and a wider use of mixtures than has been the practice in the past. Iran has a diverse range of environments in terms of rainfall, soil type and altitude on which medics could be grown and clearly the choice of variety is critical to the success of the system.

One feature that is common to all medic varieties, however, will be the necessity to withstand heavy grazing pressure in an environment already overstocked. Heavy summer grazing will be a normal feature, as farmers' sheep, often joined by large flocks of nomads' sheep, graze the cereal stubble and dry medics. Large, easily accessible pods will rapidly disappear and several sites, e.g., Lali (Masjed-Solyman) and Meydan Bozorg (Khorram-Abad), were noted where native ecotypes of *M. polymorpha* had replaced the originally sown snail medic (*M. scutellata*). The native medic in each case was characterized by small pods and seeds.

On some soil types, notably heavy clays, large-seeded types like *M. scutellata* and *Medicago aculeata* have advantages because their vigorous seedlings can emerge more efficiently from hard-surfaced soils. Snail medic, therefore, will be useful in mixtures on heavy soils, particularly where the soil structure is poor. Other soil preferences also must be considered. *Medicago littoralis* will be most successful on sandy soils at low altitudes. *Medicago polymorpha* can succeed on light and heavy soil types and is the universal medic for inclusion in virtually all situations.

Varieties also must be chosen to match the length of the growing season. Australian cultivars cover a very wide maturity range and cover the available growing season for mild winter climates (Table 4). The range and maturity requirements for the high cold areas, however, remain to be assessed.

Eventually, with the use of locally adapted ecotypes, suitable species and varieties can be recommended for all potential medic areas. Table 5 shows that some progress has been made in Iran. The recommendations reveal the deficiency in knowledge and varieties for the cold regions. Kamaraj (*M. polymorpha*), selected by Mr Fatollah Abrahami of Shiraz, should have some cold tolerance and could be used as an interim variety, but continued research is necessary.

Table 4. ***Medicago*** **species and varietal recommendations for the warm Mediterranean region.**

Species	Variety	Soil type
	Rainfall 150—250 mm	
M. littoralis	Harbinger	Sandy soils
M. truncatula	Ghor, Cyprus	Loams
M. polymorpha	Serena, local ecotypes	All soils
M. scutellata	Robinson, mixtures	Only heavy soils
	Rainfall 250—350 mm	
M. littoralis	Harbinger	Sandy soils
M. truncatula	Cyprus, Parabinga	Loams
M. polymorpha	Santiago, Serena	All soils
M. polymorpha	Local-Poldokhtar, Kamaraj	All soils
M. scutellata	Robinson, Sair, mixtures	Heavy soils
	Rainfall >350— ≥450 mm	
M. truncatula	Jemalong, Sephi, Borung	Loams
M. polymorpha	Circle Valley, local-Kmaraj	All soils
M. scutellata	Sava, Robinson, mixtures only	Heavy soils

Constraints

In the current situation there are some constraints to the implementation, development and expansion of ley farming systems in Iran.

Socioeconomic Constraints

Iranian farmers have their own concept of livestock raising. They do not view their flock solely as a regular economic venture which, given certain inputs, will give a corresponding amount of output. They buy livestock, without predicting a reliable source of feed for their animals, whenever they come into an appreciable amount of money, as when they harvest a good crop. Farmers/livestock owners feel that the more livestock they own the more security they have; therefore when the question of destocking is raised, they will not in most cases accept the argument that fewer, better-fed animals will

Table 5. *Medicago* species and varieties for cold winters and/or high altitudes.

Species	Altitude (m a.s.l.) 1000-1500	1500-2000
	Rainfall <300 mm	
No recommendation, ecotypes TBS†		
	Rainfall >300 mm	
M. rigidula	Nahavand‡ Miyaneh‡ ICARDA 716 Local TBS	*M. rigidula*—local TBS
M. polymorpha	Kurdistan‡ Kamaraj‡ Local TBS	*M. polymorpha*—local TBS
M. noeana	Khoramabad	*M. noeana*—local TBS

† TBS = to be selected.
‡ Local ecotypes.

provide the same revenue and security. Any change of attitude on the farmers' part would take time and a lot of effort.

When ley farming is first brought to the farmers' attention, they often are interested and excited by the prospect of producing more animal feed. However, they tend to graze every bit of pasture as soon as it grows, which destroys any possibility of adequate seed production for regeneration. Seed production and survival of medics is almost nonexistent under overstocking. Therefore, proper grazing management of newly established pastures could be difficult. There is an urgent need to develop plant materials that can regenerate and coexist with the crops being used by farmers.

Decisions on size of area to allocate for growing cereals or leaving as fallow are dictated by the amount of rainfall received in the autumn. High rainfall means more land into cereals and smaller areas for fallow. Also, if the agricultural year starts well and then dries out, farmers will graze or rent grazing rights to their cereals when they have given up hope of a good crop.

When ley farming was introduced to the Iranian farmers/livestock owners, some of the district government agencies gave them seed, fertilizer and technical advice. Inputs were either free or half price and the government purchased their seeds at a good price for a period of 2-3 years to encourage them to apply the system. But, unfortunately, when the government reduced or cut the support, the farmers discontinued the system in most cases.

Some of the socioeconomic constraints can be resolved by an on-farm research/demonstration program where the farmers' ideas and viewpoints are taken into account in the development of acceptable farming and livestock management systems.

Technical Constraints

One constraint is the inability of farmers and some technicians of the area to master the sensitive techniques of medic pasture establishment and management.

Soil tillage equipment and seed drills suitable for medic seeds are not readily available to all farmers, so they sow by hand as they normally do with cereals. Therefore, they often do not achieve the even seed distribution necessary for the establishment of full medic stands; the bare spots are rapidly colonized by weeds, which in turn decrease the value of the pasture and the interest of the farmer.

Farmers with small farms do not always own the required machines. Most call upon other farmers or government institutions to rent tractors with plows, hay-making equipment and so forth. Also, on small farms with rough and uneven farmland surfaces, harvesting seeds with combines is difficult.

In some parts of the country (East Azarbaijan and Bakhtaran) sheep rejected green *M. scutellata* pastures. The reason is unknown. Livestock owners who experienced this phenomenon are not likely to continue the ley farming system by sowing *M. scutellata*.

Lack of sound management of the medic pastures is another major constraint to the adoption of the ley farming system. Farmers, even when they own the grazing livestock, have been unable to adjust stocking rates to plant growth and development. Trespassing by neighbors is common.

The absence of comprehensive farming systems research and development programs, including ley farming, is one constraint to the integration of livestock and cropping in Iran.

Bio-environmental Constraints

Animal feed deficiencies in Iran are probably most critical during late autumn and winter; legume cultivars replacing fallow should be able to tolerate and resist drought and grow rapidly, in spite of low winter temperatures, to produce forage during this critical period. Some imported seed, used in the introduction of the ley farming system, does not seem to tolerate the erratic distribution of rainfall in Iran.

Since the largest portion (80%) of the dryland farming area in Iran is located in the high countries and cold regions, the most important constraint is the lack of cold-tolerant medic seed in commercial quantities.

In some instances, poor nodulation was the cause of poor performance of the seeded medics and hence of the ley farming system. Inoculation frequently reduces the risk of failure of newly sown stands of introduced medic cultivars.

Technological Constraints

Lack of locally produced, inexpensive and pure seed of medics is one of the important drawbacks to the adoption of the cereal/medic ley farming system. Some attempts were made by the Range Department of Forestry and Range Organization to produce seed (multiply local ecotypes and introduced ones) in a few regions. Seed yields were low. Land preparation, management of the production fields and harvesting were the major limiting factors. In this regard, a course of annual medic seed production and processing for Iranian technicians and experts would be helpful.

Unfortunately, sufficient attention and long-term research were not devoted to the expansion and development of the ley farming system in Iran and that is why the system did not work well. Much needs to be done to study the system and make it fit the farming conditions and existing practices in the region. Development of native plant material and on-farm research/demonstrations would be a sure way of securing the necessary farmer/scientist interactions.

Conclusions and Recommendations

There are a number of recommendations and conclusions to be gained from my previous studies. They are summarized below:

1. Of the currently available Australian cultivars of *M. polymorpha*, Serena works for the drier areas in the south and Santiago is adapted for more general use. Both have some value in milder areas where a true Mediterranean climate exists. The Iranian ecotype Kamaraj, mixed with Santiago, would be valuable in all but the drier southern areas of less than 250 mm rainfall. In the Ahwaz region, Serena, and on sandy soils Harbinger (*M. littoralis*), would provide a useful mixture for demonstration and farmer trials.
2. Development of ley farming in Iran must emphasize on-farm research using the farmers' own equipment. Grazing management will be the major problem, particularly in the establishment year.
3. Australian harvesting machinery can be used in Iran, but the cost is high and maintenance difficult. Systems based on stationary threshers and family labor would better fit the Iranian requirements at present.

4. When it comes to developing suitable fodder plants and farming systems based on them for the moderately cold winter areas, it is necessary to fully understand the interrelationship of plant, soil and climate together with management techniques.
5. In areas where productivity is limited by cold winters with less than 250 mm rainfall, only low priority should be given to work with annual medics for the time being. In milder winter areas, early maturing Iranian ecotypes could seed successful pastures in rainfall to 200 mm.
6. More staff appointments and facilities are necessary in Iran for managing germplasm resources and annual *Medicago* evaluations. Strengthening mutual cooperation with ICARDA, Western Australia Department of Agriculture, South Australia Department of Agriculture and Fisheries, IBPGR and other research organizations dealing with medics and related matters is important.
7. Iranian medic ecotypes should be commercially developed as soon as possible. West of Meyaneh, an ecotype of *M. rigidula* had vigorous, prostrate and procumbent growth, good for soil conservation and grazing purposes, highly productive herbage and pods smooth or bearing more or less long tubercles, which is not harmful for wool quality. Several ecotypes of *M. polymorpha* from Kamaraj, Kazaroon and Lali (Masjad Solyman) should likewise be bulked for farmers in Iran.
8. The excellent performance of Iranian ecotypes indicates the value of further collections. A number of regions have been defined from which no ecotypes are yet available. Collection missions should be organized, preferably in consultation with IBPGR and ICARDA.
9. In the colder areas that have been heavily cropped, *Rhizobium* inoculation could be necessary. Studies should be carried out before any large-scale seeding is attempted to determine whether seed inoculation will be necessary or not. Note should be taken that *M. rigidula* has specific strain requirements.
10. Development of medic-based ley farming requires plenty of good medic seed. Therefore, to maximize yields for pure seed production purposes, installation of seed-processing plants in three regions—Gonbad-Kavoos, Kazaroon and Pol-Doukhtar (Khorram-abad)—should be considered.

These general conclusions and recommendations are derived from a 6-month study period in Western and South Australia and 7 years of experience in Iran.

References

Carter, E.D. 1978. Legumes in the farming systems of the Near East and North Africa region. Report to ICARDA.

Francis, C.M. 1981. Distribution and ecology of annual *Medicago* species in north-west Libya. CSIRO Plant Introduction Review 13:3.

Francis, C.M. 1988. Selection and agronomy of medics for dryland pastures in Iran. FAO consultant report. Project TCP/IRA/6652: Medic dryland farming and seed multiplication of range and pasture species.

Part 2. Ley Farming in Progress

Nitrogen Fixation by Medics and their Role in Rotations and in Marginal Areas in Cyprus

I. Papastylianou
Agricultural Research Institute, Nicosia, Cyprus

Abstract

This paper discusses recent research on the medic system and the possibilities of introducing it on a large scale in Cyprus. Medics, depending on indigenous *Rhizobium*, fix up to 70% of their nitrogen. Cereal yields after medic are higher than after cereals. In marginal areas, the system is functional if proper grazing management is applied. The possibility of introducing medics in marginal areas is higher than in the cereal zone owing to the existing farming system and policies.

Introduction

Medics are leguminous plants that grow naturally in the Mediterranean region. They were deliberately introduced in Australia for screening and improvement in the early 1940s, and suitable cultivars adapted to the environmental conditions were promoted as part of the new farming system of medic/cereal rotation in the 1950s (Puckridge and French 1983). The system has proven to be successful on the large farms of south Australia, where both cereal and animal production fit in with the socioeconomic situation of the local farmer (Webber *et al.* 1976).

In the early 1970s, there was an attempt to transfer the Australian medic/cereal system to countries of the Mediterranean region (Carter 1978). Although it was realized that in each country the system should be modified to match the particular needs and factors involved in the cereal/animal production system of the country (Webber *et al.* 1976), several factors, particularly management of the system, were not followed, which resulted in marked lack of success (Papastylianou 1987c).

In recent times the medic system was placed on a new basis by the search for cultivars to match the climatic and soil conditions, by management appropriate to the animal system, and by selection of rhizobia for particular cultivars (Abd El Moneim and Cocks 1986; Cocks 1988 a,b; Cocks and Ehrman 1987; Materon 1988; Materon and Cocks 1987). In the framework of this new effort, studies were conducted in Cyprus. The results of these studies and the possibility of adopting the system in different zones in Cyprus are presented in this report.

Farming Systems in the Rain-fed Areas of Cyprus

Soils in most of the rain-fed areas of Cyprus are calcareous with pH around 8. Soils have low phosphorus (1-5 ppm, bicarbonate-extractable P), low N (less than 0.1%) and high K (exchangeable greater than 250 ppm). Annual rainfall ranges from 200 to 400 mm, with an average of 250-300 mm in most seasons.

In the cereal zone the dominant farming system is continuous barley. This system is encouraged by the existing subsidies provided to the farmers by the government. The legume/cereal rotation system is applied in less than 10% of the area, mainly by farmers who raise animals as their main source of income. Farmers without animals are in the majority and they see no reason to produce legume forages because N fertilizer is available at relatively low prices and the market for leguminous products is not organized.

However, recent studies in Cyprus (Papastylianou 1989; Papastylianou and Samios 1987) gave encouraging results for modifying the continuous barley system and introducing the legume component. These studies used legumes for hay production only, so legumes for grazing should be further evaluated.

Marginal areas are mainly hilly sites that cannot be cultivated with cereals. No improvement of vegetation or management of these sites is carried out. Shepherds are free to graze these areas. Productivity of the natural vegetation is low, but it might be improved by fertilization and the introduction of new species if management of grazing can be controlled.

N_2 Fixation by Medics

Medics were compared with other legumes for N_2-fixing ability with the existing indigenous rhizobial populations. The N-15 methodology was used to quantify the amount of N_2 fixed. The percent and total amount fixed are shown in Table 1. Nitrogen fixed by medics was at the same levels as the rest of legumes compared. The range of 50-70% is relatively low, possibly due to the low rainfall conditions during the 1982/83 and 1983/84 growing seasons, 200 and 260 mm, respectively. However, the low N_2 fixation might be an indication that there is room for improvement by selecting and testing different *Rhizobium* strains.

The first *Rhizobium* strain x medic cultivar interaction experiment was conducted in the 1988/89 growing season. The results of this experiment (Table 2) showed that all four medic cultivars used responded to *Rhizobium* inoculation with 8-14% yield increases.

Table 1. Nitrogen fixed (Ndfa percentage and amount) by legumes in the two seasons using the A-value and the difference method (DM) with barley as the reference crop.

	1982/83				1983/84			
	Ndfa (N, kg/ha)		% Ndfa		Ndfa (N, kg/ha)		% Ndfa	
Crops	A-value	DM	A-value	DM	A-value	DM	A-value	DM
Medic	92.3	101.4	50.3	54.9	90.0	84.8	70.0	64.6
Ochrus vetch	50.6	37.1	47.1	33.3	105.1	88.3	78.6	63.0
Bitter vetch	30.5	4.8	32.8	-9.2	105.4	98.2	70.3	67.1
Faba bean	93.3	110.8	48.5	58.0	175.7	169.7	79.7	78.3
Tick bean	-	-	-	-	179.8	163.6	84.1	76.0
Woolypod vetch	-	-	-	-	151.0	144.1	79.1	72.9
Chickpea	-	-	-	-	24.9	14.7	41.1	22.3
SE	16.03	18.1	6.5	14.2	24.6	24.5	4.6	5.3

Source: Papastylianou 1987a.

Table 2. Effect of *Rhizobium* strain on dry matter yield (kg/ha) of medics of pod formation stage, Cyprus 1988/89.

	Medicago				
Rhizobium strain†	Barrel medic	*polymorpha*	*rigidula*	*rotata*	Mean
Control‡	6870	6390	5040	4640	5740b
3	7430	6430	5270	5260	6100a
15	7470	6130	5956	5190	6180a
29	7210	6540	5130	5430	6081b
53	7170	6630	5430	5050	6071b
254	7380	6430	5490	5480	6190a
Mean	7260a	6420b	5390c	5170c	

† ICARDA *Rhizobium* strain number.
‡ Control was a non-inoculated treatment.

Medics in Rotation with Cereals

The first experimental data on the role of medics in rotation with cereals in Cyprus came from barley sown after the legumes (Table 1). Grain and nitrogen yields of barley after these legumes are shown in Table 3. The performance of barley after medics was comparable to barley after the other legumes in the study and was better than barley after cereals. Nitrogen yield of barley after medics was 14 kg/ha in 1983/84 and 40-48 kg/ha in the 1984/85 season, higher than barley after cereals.

Table 3. Grain (t/ha) and nitrogen yield (kg/ha) and nitrogen concentration (%) of barley as affected by the preceding crops in two separate cycles.

	Growing season 1983/84			Growing season 1984/85		
Preceding crop	Grain yield	N yield	N conc.	Grain yield	N yield	N conc.
Barley	1.72	28.1	1.63	1.58	24.9	1.58
Oat	1.80	29.5	1.65	-	-	-
Ryegrass	-	-	-	1.04	16.5	1.57
Medic	2.08	42.1	2.05	3.92	63.8	1.62
Ochrus vetch	2.54	45.7	1.81	3.52	54.6	1.55
Bitter vetch	2.38	44.6	1.86	3.49	71.0	1.57
Broad beans	2.32	41.3	1.77	4.72	79.7	1.66
Tick beans	-	-		3.49	71.0	1.57
Woolypod vetch	-	-	-	4.84	83.6	1.72
Chickpea	-	-	-	2.91	45.5	1.54
SE	0.133	2.88	0.076	0.378	7.55	0.055

Source: Papastylianou 1987b.

The above results were obtained from small plots (2 x 4 m) on which the management of medics could not be the one that should be applied in practice. Thus, an experiment was initiated in the 1987/88 season with large plots (0.1 ha). Each plot is fenced and grazing management can be applied. The treatments in this experiment are: (a) continuous barley, (b) continuous medic pastures and (c) medic-barley rotation. Each barley plot is divided into two areas for N fertilizer treatments of 0 and 60 kg/ha. The first results will be available in June 1989.

Medics in Marginal Lands

The possibility of introducing medics in marginal lands was tested in contrasting areas on the coast and inland. A characteristic of the inland areas is the possibility of temperatures around 0 to -2°C during December or January, while in the coastal areas such low temperatures are a rare phenomenon.

The first noteworthy effort to introduce medic in marginal areas was carried out by the Department of Agriculture (Extension Services). Two demonstration pastures of 16 ha each in the coastal and inland areas were used for the period 1978-86. Both areas were hilly marginal sites, but scarification of the soil was possible. Soils were shallow and stony. These pastures were opened for grazing when medics were at the flowering to pod formation stage. The land was communal so all shepherds were allowed to graze their flocks, grazing management was not possible and no seed setting occurred. The pasture was reseeded every year with medic and ryegrass at the rate of 30 and 20 kg/ha, respectively.

The second effort, also by the Department of Agriculture, was begun 4 years ago in coastal areas in farmers'/shepherds' fields in marginal areas owned by farmers with flocks. There are now pastures in the fourth, third, second and first years. The size of the pasture is related to the size of the flock, at the ratio of 10 sheep per 0.13 ha. The pastures are located near the animal sheds. Shepherds take their animals to the pasture for 2-3 hours a day during the period between the end of December and the end of March. The pasture is then left to set seeds. Although pod setting was very successful, shepherds reseeded their pastures (15 kg/ha) and added superphosphate (0-48-0) every year at the rate of 80 kg/ha. This system has been very successful, judging by the shepherds' enthusiasm to continue (Extension Services, pers. comm.).

Discussion

Marginal Areas

The Cyprus experience shows that medic crops can be introduced in marginal areas on land owned by shepherds. The system has been demonstrated in the coastal areas, but not in frost-prone areas. The successful cases have two characteristics: better climatic conditions for medic growth and proper management of the pasture. Establishment of the system in all areas could be possible with due regard to these two factors. Climatic conditions cannot be changed, but selection of cultivars adapted to lower temperatures could solve this problem. Further research will be done if it is justified by the country's needs.

Lack of improved management of the pasture is probably the main factor responsible for failure of the system to continue year after year without reseeding. Correct management is a matter of educating the flock owners to understand how the system operates. Educating the shepherds to manage their own pasture seems an easy task. The difficulty is to control grazing in communal pastures, because each shepherd tries to get maximum benefit out of the pasture without caring for the future of the pasture. The management problem can be overcome by government laws and policy, which will be a very difficult task, and their introduction could only be justified with the economics of the system.

It must be decided whether the substitution of natural vegetation with improved medic pasture is desirable and justified by its economics in order to expand livestock production or to sustain the existing production. It is, therefore, important that the system be further carefully and critically studied and experimental results are provided on which a policy will be formed.

Cereal-growing Areas

Adoption of medics in the cereal-growing areas in Cyprus is less easy because the cereal growers usually do not have animals. If they are going to follow a legume/cereal rotation system they will prefer a legume like vetch, which can be easily harvested for hay and sold to animal owners. The present system of continuous barley cropping, subsidized and covered by insurance in case of failure, does not seem amenable to the unprotected legume/cereal system.

A minority (10%) of farmers growing cereals own animals. They follow a legume/cereal rotation system with preference for legumes suitable for haymaking. Hay is stored and used during pregnancy and lactation periods when demand for quality roughage is high. Shepherds use natural vegetation during winter and spring and stubble during summer and autumn. Adoption of medics in the cereal zone will be possible only if changes in policy modify the existing farming system.

Inoculation of Medics

The N_2-fixation status of medic under the indigenous *Rhizobium* population (50-70%) can be improved. If the system is to be promoted and new cultivars introduced, it is essential to search for more efficient strains. As is shown in Table 2 in the first attempt to see the response of medics to introduced inoculants, it is possible to increase productivity with new strains.

References

Abd El Moneim, A.M. and P.S. Cocks. 1986. Adaptation of *Medicago rigidula* to a cereal-pasture rotation in northwest Syria. Journal of Agricultural Science, Cambridge 107:179-186.

Carter, E.D. 1978. A review of the existing and potential role of legumes in farming systems of the Near East and north African region. A report to ICARDA, Aleppo, Syria.

Cocks, P.S. 1988a. Seed production and seed survival under grazing of annual medics (*Medicago* spp.) in north Syria. Journal of Agricultural Science, Cambridge 110:455-463.

Cocks, P.S. 1988b. The role of pasture and forage legumes in livestock-based farming systems. Pages 3-10 *in* Nitrogen Fixation by Legumes in Mediterranean Agriculture (D.P. Beck and L.A. Materon, eds.). Martinus Nijhoff Publishers, The Netherlands.

Cocks, P.S. and T.A.M. Ehrman. 1987. The effect of geographic origin on frost tolerance of pasture legumes in Syria. Journal of Applied Ecology 24:673-683.

Materon, L.A. 1988. Maximizing biological nitrogen fixation by forage and pasture legumes in semiarid areas. Pages 33-40 *in* Nitrogen Fixation by Legumes in Mediterranean Agriculture (D.P. Beck and L.A. Materon, eds.). Martinus Nijhoff Publishers, The Netherlands.

Materon, L.A. and P.S. Cocks. 1987. Constraints to biological nitrogen fixation in ley farming systems designed for west Asia. *In* Microbiology in Action (W.C. Murell and I.R. Kennedy, eds.). Research Studies Press, John Wiley and Sons, NY.

Papastylianou, I. 1987a. Effect of preceding legume or cereal on barley grain and nitrogen yield. Journal of Agricultural Science, Cambridge 108:623-626.

Papastylianou, I. 1987b. Amount of nitrogen fixed by forage, pasture and grain legumes in Cyprus, estimated by the A-value and a modified difference method. Plant & Soil 104:23-29.

Papastylianou, I. 1987c. Efforts and limitations of adopting the medic cropping system in Cyprus. Paper presented at the Experts' Consultation Meeting on Medic Cropping, 23-26 March 1987, Tunis, Tunisia.

Papastylianou, I. 1989. Land and rainfall use efficiency and nitrogen balance of rotation systems under rainfed conditions in Cyprus. *In* Proceedings of an International Workshop on Soil and Crop Management for Improved Water Use Efficiency in Rainfed Areas, ICARDA, Ankara, 15-19 May 1989 (in press).

Papastylianou, I. and Th. Samios. 1987. Comparison of rotations in which barley for grain follows woolly pod vetch or forage barley. Journal of Agricultural Science, Cambridge 108:609-615.

Puckridge, D.W. and R.J. French. 1983. The legume pasture in cereal-ley farming systems of southern Australia: a review. Agriculture Ecosystems & Environment 9:229-267.

Webber, G.D., P.S. Cocks and B.C. Jefferies. 1976. Farming systems in south Australia. Department of Agriculture, Fisheries, Trade, Development Division, Premiers Department.

Management - the Critical Factor for the Success of the Ley Farming System

P. Beale
7 Hemaford Grove, Gawler East, SA 5118, Australia

Abstract

For ley farming systems to be successful, it is necessary to have the right environmental conditions, the correct species and appropriate management. The ley farming systems works well in Australia because the environmental conditions are suitable, the correct species have been introduced and the overall system of land use lends itself to utilizing ley farming systems. In West Asia and North Africa there are areas where the environmental conditions are suitable and appropriate species occur naturally. Ley farming systems work well in lowland Morocco when appropriate management systems are utilized. However, the difficulties of overcoming the problems of high stocking intensity due to a large population of cattle, sheep and goats, exploitive grazing of pasture, weeds and a continual reduction in the size of holdings are considerable. The socioeconomic conditions on small farms are not conducive to a change to an annual legume-based ley farming system. It is concluded that if unproductive weedy fallows are to be changed to legume-rich pastures in a ley farming system, the issue of management as the critical factor must be addressed.

Introduction

For ley farming systems to be successful it is necessary to have the right environmental conditions, the presence of the correct species and appropriate management. The ley farming system works well in Australia because the environmental conditions are suitable, the correct species have been introduced and the overall system of land use lends itself to utilizing ley farming systems.

In West Asia and North Africa there are areas where the environmental conditions are suitable and appropriate species occur naturally. Ley farming systems work well in lowland Morocco when appropriate management systems are utilized. However, the difficulties of overcoming the problems of high stocking intensity due to a large population of cattle, sheep and goats, exploitive grazing of pastures, weeds and a continual reduction in the size of holdings are considerable. The socioeconomic conditions on small farms are not conducive to a change to an annual legume-based ley farming system.

If unproductive weedy fallows are to be changed to legume-rich pastures in a ley farming system, the issue of management as the critical factor must be addressed.

Requirements for Success of Ley Farming Systems

Correct Climatic and Edaphic Conditions

In many parts of West Asia and North Africa (WANA) we have suitable climatic and edaphic conditions for ley farming systems based on annual legumes. In fact, many of the annual legume species in use in Australian ley farming systems originated in the WANA region.

Presence of Appropriate Genera/Species/Cultivars

Appropriate species occur naturally throughout the region and, in particular, *Medicago* and *Trifolium* are abundant throughout WANA.

In a recent survey in Morocco, for example, Bounejmate and Beale (unpublished) sampled 161 sites and were able to find annual legume pods at almost all sites. *Medicago* was found at all but 15 sites and *Trifolium* at 73 sites. Ehrman and Cocks (1990) found that annual legumes also were abundant in Syria.

Appropriate Farming System and Management

The annual legumes in use in Australia are principally species of *Trifolium* and *Medicago*. The annual growth pattern of these legumes is as depicted in Figure 1a. Basically, this is seed germination and plant establishment in the autumn, followed by a period of slow growth during the winter and then a period of rapid growth during the spring when the plant flowers and sets seed. By the end of the seed-setting period, moisture becomes limiting and the plants mature and die, leaving a mass of dry material and seed. This seed is then available to continue the life cycle with the opening rains of the next season.

The system of set stocking in Australia allows the annual legumes to go through this life cycle. Although a lot of the herbage is consumed as green matter during the growing season, the grazing pressure is not sufficiently high during the spring to prevent the plants growing faster than the animals can consume them and the legumes are able to flower and set seed (Fig. 1b). In addition, grazing in the autumn and winter is often beneficial to the annual legumes as the animals usually prefer the grasses and some broadleaf weeds during this period, thus reducing weed competition for the annual legumes during the spring.

It is worth noting that the ley farming systems that are used in Australia are successful because they fit easily into the overall system of land use in these areas of Australia. In fact, it is a system that has evolved out of necessity owing to the scarcity of labor. To keep stock it is essential to use fences, and with fenced fields the simplest system is to

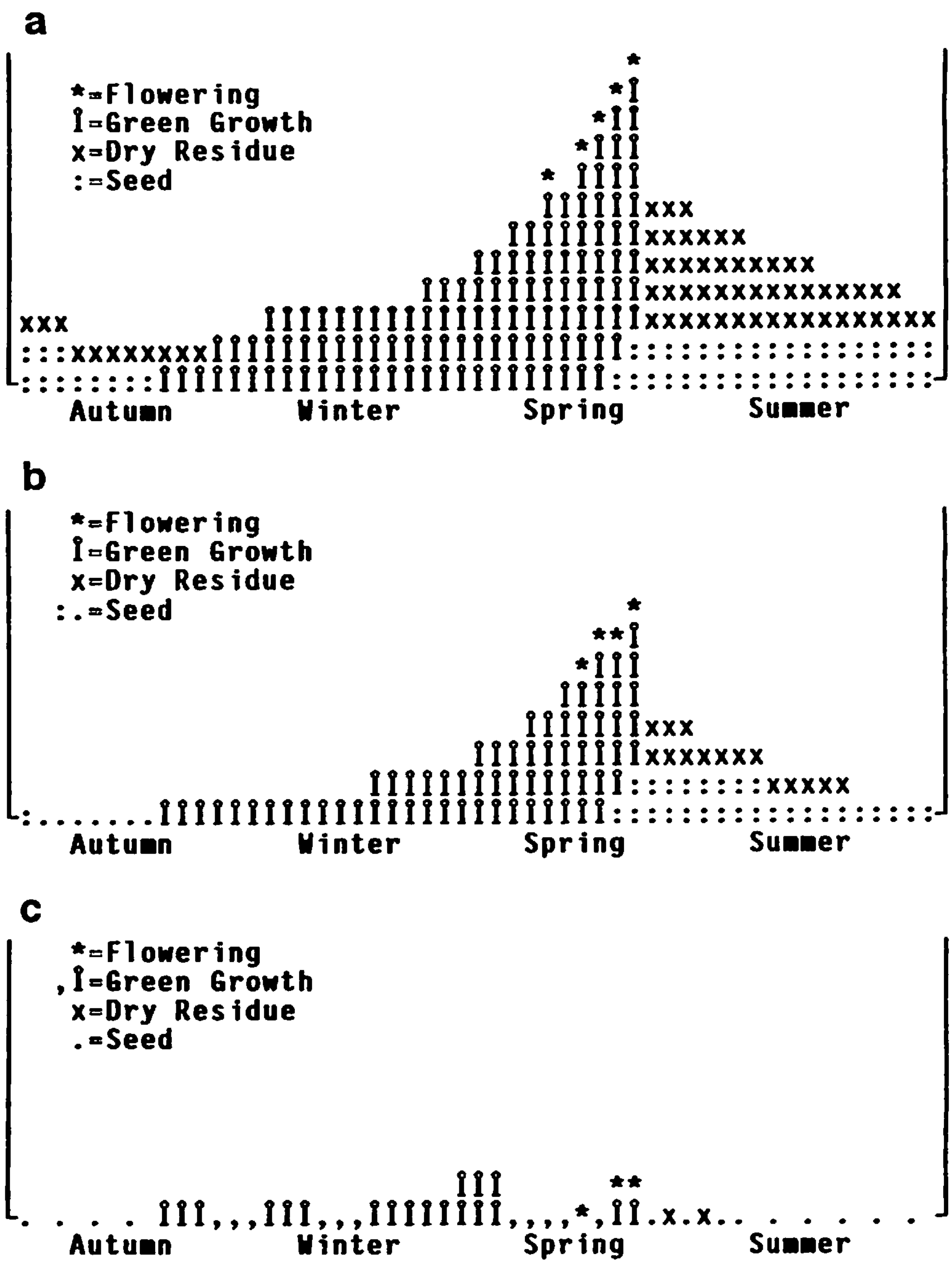


Fig. 1. Schematic diagram of annual growth cycle of annual legumes, ungrazed and under two contrasting grazing regimes: (a) ungrazed; (b) grazed/set stocked, common practice in Australia; (c) grazed/exploitive, typical pattern in WANA.

put stock in the fields and leave them there. Hence the grazing system in use in Australia is one that lends itself to the use of annual legumes, with the simple management strategy of regulating the stocking rate to suit the prevailing conditions. In addition, the Australian farming system is oriented to an export market so there is no intrinsic need to stock land at other than an economic optimum level.

Annual legume pastures in WANA are usually subjected to exploitive grazing from time to time and during the spring there is often very heavy stocking. This results in almost total defoliation either before or during flowering and almost no seed set (Fig. 1c). Where some seed is set, continued heavy grazing can deplete what little seed reserve there is. This tradition of very heavy grazing in the spring is a means of reducing weed populations and is therefore often carried out when a field is to be cropped in the following year.

Effect of Land Use on Natural Populations of *Medicago* in Morocco

Bounejmate and Beale (unpublished) found one site at Kasbah Tadla near Beni Mellal in Morocco with reserves in May 1988 of 160 kg/ha of medic seed, a mixture of *Medicago aculeata* (93 kg/ha), *Medicago truncatula* (31 kg/ha), *Medicago polymorpha* (21 kg/ha) and *Medicago orbicularis* (14 kg/ha).

This site had a density of 250 medic plants/m^2 in December 1988 and the pasture composition in April 1989 was 56% *Medicago* spp. (28% *M. truncatula*, 22% *M. aculeata*, 6% *M. polymorpha* and a trace of *M. orbicularis*), 38% weeds and 6% bare ground.

The site belongs to an Agricultural School and is not cropped or grazed by the school. It is, however, used by local graziers on an opportunity basis although this is discouraged by the school. Consequently, the area is only lightly grazed all year round, which allows the naturally occurring medic population to grow, seed and regenerate.

In contrast, a nearby field that has been very heavily grazed has no medic plants or seed in it, although it appears to be very similar except for the system of land use. Clearly, the different management of these two parcels of land, especially the grazing management, has had a dramatic effect on the naturally occurring flora.

Introduction of Ley Farming Systems into North Africa

It is quite clear that in lowland Morocco the ley farming system based on annual medics works well with appropriate management. Jaritz and Amine (this volume) have conducted a number of broad-scale demonstrations that show convincingly that this is the case.

What then is the problem?

The systems of land use that have evolved in Morocco, in particular the techniques of using grazing land, do not suit the ley farming system. The solution is of course to demonstrate that the system improves overall productivity and then hope that farmers will adopt the system. This, I think, is possible on some of the larger farms, but for small farms it is questionable whether this is achievable within the socioeconomic conditions and traditions that prevail.

Animal Population

A large population of cattle, sheep and goats lives in the areas where the ley farming system could be utilized. There are sufficient animals to put high grazing pressure on all weedy fallows, including those improved with medics. The animal population tends to increase with good seasons and decrease, because of high mortality, following poor seasons and feed shortages. Any significant increase in animal feed availability resulting from the use of ley farming systems is therefore likely to be reflected in an increase in the animal population and the maintenance of a high grazing pressure.

Grazing Control

Where an individual landowner has complete control over the grazing of his land, he can choose to limit the grazing pressure to a density that suits the ley farming system. However, in practice he has a lot of pressures that act against this, not the least being a long tradition of using weedy fallow in an exploitive manner.

A full understanding of the system of grazing rights in Morocco is, it seems, impossible to achieve, but it appears that in some regions fallow land will be grazed by third parties either following a tradition that the land is open to "common grazing" or without consent or the right to graze.

Weeds

Weeds are a severe problem in Morocco and spring is one time when they can be controlled by very heavy grazing to prevent seed set. This is of course detrimental to a system that is trying to encourage seed production of annual legume species. Management to encourage seed set of annual legumes in Morocco may precipitate a large weed problem in the following crop and discourage further attempts to use the ley farming system.

Size of Holdings

As land is passed from generation to generation, farm size is being continually reduced. As has already been mentioned, it is on larger farms that the ley farming system can be introduced most easily. This trend means that it will become progressively harder to introduce ley farming systems to ICARDA's main target group, the small farmer.

Conclusion

I believe it is vital that if we are to continue to try and improve the productivity of weedy fallow in Morocco and, indeed, in WANA, we must address the issue of management as the critical factor. Weedy fallows can be changed from very unproductive land carrying weedy species to legume-rich pastures, providing much increased animal feed production and enriching the soil with nitrogen. This does, of course, need the selection and multiplication of appropriate species of annual legumes, but it is my belief that the most critical factor is finding and implementing an appropriate system of land use and management that will allow the annual species to grow and express their potential for dry matter and seed production.

References

Ehrman, T.A.M. and P.S. Cocks. 1990. Ecogeographic survey of annual legumes in Syria. 1: Distribution patterns. Journal of Applied Ecology 27:578-591.

Progress of Ley Farming in Morocco

S. Christiansen[1] and B. Boulanouar[2]
[1] *ICARDA, Aleppo, Syria*
[2] *Institut National de la Recherche Agronomique and Mid-America International Agricultural Consortium (INRA/MIAC), Centre d'Aridoculture, Settat, Morocco*

Abstract

The fact that Australia has developed successful ley farming practices over the past 50 years does not mean that the system is exportable without major modification to other areas possessing Mediterranean climates. The government of Morocco initiated a large-scale operation in 1985 which has continued to the present, seeding more than 47 000 ha to annual medics (*Medicago* spp.) or subclover (*Trifolium subterraneum*) distributed among 250-500 mm zones throughout Morocco. The Ministry of Agriculture and Agrarian Reform operation was followed by a survey completed by 326 of the program participants. Results focused attention on the regions of Morocco best suited for adaptation to ley farming and identified some major constraints to implementation. The coordinated efforts needed to change agricultural practices take time to implement. Thus, the focus of this paper will be to analyze the history, present work and future directions for ley farming in Morocco and identify the most relevant biological, sociological and institutional constraints impeding further progress. It concludes with a call to organize a Phase II operation and team of scientists from teaching, research and extension institutions in Morocco with the objective of delivering an improved and successful ley farming management package to farmers.

Introduction

Agriculture in Morocco has always been a dominant sector of the Moroccan society. In the early 1960s about 60-70% of the population lived in the rural areas and agriculture alone provided half the jobs in the country. Presently, 40% of the country's 23 million people are active in the agricultural sector (FAO 1987). Along with migration of people to the cities there are decreases of agricultural contributions to the Gross Domestic Product: from 22% in the late 1960s to 15% projected for 1990.

Urban population increased from 29% in 1960 to 43% in 1982 and Morocco has a population growth rate of 2.6%, with over 50% of the population under the age of 20. An influx of rural citizens into Moroccan cities has challenged the Moroccan government who, in 1979, undertook land reform measures to consolidate farmers' scattered holdings, limit the partitioning of land to a minimum size and create private holdings from collective lands.

On an arable land surface of approximately 8 million hectares, the area left to weedy fallow varies annually between 1.6 and 2.6 million hectares and is more prevalent in the drier zones. For example, on average it is possible to find 12% of the land as weedy fallow in the north and 25% in the more arid southern zones. Yearly variations of 10-30% (1985/86 and 1980/81, respectively) in the area of weedy fallow are common, with more land left as weedy fallow in drier years. In addition, rangelands occupy about 20% of the total 71 million hectares in Morocco but population growth and grazing pressure are degrading this resource. Thus, better use must be made of weedy fallow lands, especially in dryland zones.

Morocco began importing corn and wheat grains in the 1960s; after abnormally dry conditions in 1979-1985, imports rose considerably. It is expected that basic food grains will be imported throughout the 1990s. Unreliable rainfall, fragmented land ownership patterns, poor integration of crop and animal operations, insufficient technology, lack of cultivated forage crops and inadequate management have been the major impediments to improved agricultural production. Slow infusion of technology has resulted from many factors. The most important are inefficient research services, inadequate transfer of knowledge to farmers and inability of farmers to buy improved seed, fertilizer, herbicides and machinery.

In Morocco, it is common to invest in livestock as a source of savings to buffer against crop failure. Livestock products represent about one-third of the agricultural production. In 1982, after drought conditions in the late 1970s and early 1980s, the total number of cattle, sheep and goats had decreased by 22, 35 and 25%, respectively. In 1983, Morocco had about 2.4 million head of cattle, 12.6 million sheep and 4.9 million goats. By 1987, the inventory had recovered to 3.2 million cattle, 16 million sheep and 5.8 million goats (MARA 1988). Coexisting with the cattle, sheep and goats in 1987 were 180 000 horses, 470 000 mules, 820 000 donkeys, 52 000 camels, 37 million chickens and 9 000 pigs (FAO 1987). For small farmers, animals of all kinds are important as a source of food, income, by-products and manure. Eighty percent of the farmers own less than 5 ha each, yet they own more than 60% of the cattle and almost 50% of the sheep on only 25% of the cultivable land.

In the 1980s the government devoted attention to rain-fed areas because of the considerable social benefits that could be achieved for the rural population that lives on these lands. In addition, large investments in irrigation projects had not yielded the expected returns in terms of production. Total agricultural investment in the dryland zones rose from 2% in 1975-1980 to 18% in 1981-1985 (Estefan 1986).

As part of the interest in the rain-fed zones and the need to improve utilization of weedy fallow lands, Moroccan agricultural planners, who saw active development programs to evaluate ley farming in neighboring countries, adopted the ley farming model used in South Australia. It seemed a logical and appealing conclusion to assume that pasture plants originating in the Mediterranean region, the basic component of a multi-billion dollar farming system in Australia, could be transferred back to the Mediterranean Basin.

Many optimistic reviews were written in the 1970s extolling the virtues of the ley farming system for North Africa. Unfortunately, these excellent reviews focused narrowly on the convincing biological, ecological and climatological evidence that ley farming should work in North Africa but incompletely understood the considerable sociological and institutional constraints that would ultimately impact the success of the system.

Thus, Morocco moved forward with an evaluation of ley farming through the Ministry of Agriculture and Agrarian Reform (MARA 1989a) for a combination of reasons. By 1989, approximately 47 000 ha had been seeded to annual pasture legumes and the first government analysis of the operation has been published. The operation touched nearly all regions of the country and included small, medium and large farms from private and cooperative sectors. Many additional Moroccan research studies have documented various portions of the ley farming system in the 1980s. These combined experiences will permit follow-up studies by agricultural researchers to fine tune ley farming in Morocco. It is the objective of this review to further analyze ley farming in Morocco and indicate problems to be overcome to better coordinate efforts within Morocco and among North African countries.

MARA's Ley Farming Operation (LFO)

Implementation

Moroccan agricultural planners considered ecological differences between Morocco and South Australia when they began a major LFO initiative in autumn of 1985. It was recognized that edapho-climatic differences could cause adaptation problems for the commercial Australian medics in North Africa; however, it appeared that Morocco would not be obstructed because of unsuitable Australian germplasm, as was found at ICARDA in Syria. Seed supply of local germplasm did not exist; therefore, it was concluded that ley farming could be tested in Morocco using the imported cultivars.

The LFO program was undertaken by MARA through the numerous districts of the Direction Provinciale d'Agriculture (DPA), the Office Régional de Mise en Valeur Agricole (ORMVA) and their regional Centres de Travaux (CTs) and Centres Mise en Valeur (CMV). The DPA and ORMVA offices that participated in the program represent approximately 55 CT or CMV provincial centers that carried out the operation.

The LFO was implemented over diverse geographic and rainfall zones. Medics and subclovers were distributed according to detailed cultivar recommendations from South Australia (modified for Morocco) and in most cases mixtures with differences in cultivar maturities were used to increase potential biomass production while assuring adequate seed yields for regeneration. Certain zones were eliminated because of unfavorable precipitation or low winter temperatures at high elevations.

Potential problems in transforming traditional farming techniques to accommodate ley farming principles were anticipated. Farmers had no experience with these forages as crops, even though they recognized medic or subclover plants as a component of their permanent pastures and weedy fallows. For the ley farming system to function correctly, farmers would need to understand the biology and carefully follow recommendations, or at least understand the consequences of their management decisions.

At the beginning of the program, technical staff from MARA were trained in a series of seminars. Several of the primary concerns were potential difficulties with weed control, deep plowing after the medic and integration of crop and livestock enterprises. Sound forage and livestock management was required of the farmer with only periodic guidance from MARA personnel.

To encourage participation, 60 and 40% of the seed costs were subsidized for cooperatives and individual farmers, respectively. This was made uniform to a 50% subsidy in 1988/89. Importation taxes were suspended. The government imported a total of 950 tonnes of medic and 118.5 tonnes of subclover seed until 1989. The medic plantings far surpassed those of subclover in overall area.

Initially, MARA had ambitious sowing quotas, which were reduced as the program got underway. Regardless of the training efforts and anticipation of problems, some difficulties were encountered in the field: quotas were overestimated because of dry conditions and lack of weedy fallows in heavy cropping zones. It was difficult to recruit small landowners. Land tenure and animal management problems also were encountered: for example, when land was leased or share cropped, farmers were unlikely to invest in land improvements. Some cooperatives were committed to following certain cropping patterns and could not participate. Livestock associations also could have lowered potential involvement in the LFO because initiatives that require financial inputs are not easy to agree upon. Finally, the human resources needed to achieve the goals set out by MARA were underestimated. Nevertheless, across all years and rainfall zones, the area seeded was over 47 000 ha.

Three years after the start of the LFO, a survey was conducted to assess farmers' perceptions of the new system. Farmers representing 326 farms within the service districts of 3 ORMVAs and 30 CTs were surveyed. Eighteen different regional offices of the DPA were involved in administering the questionnaire. The sample was stratified into four land-size categories to give a sample with the following characteristics: 193 respondents having farms greater than 20 ha in size (59% of total); 79 between 10 and 20 ha (24%); 41 between 5 and 10 ha (13%), and 13 less than 5 ha (4%).

Results and Discussion

General

The LFO conducted in Morocco provides a base of information that could lead to a refinement of ley farming development efforts in the future. The MARA results represent the most comprehensive data collected to date concerning ley farming, permitting the opportunity to judge the potential of the system in Morocco. This paper attempts to look at the major concerns impacting the ley farming system, as identified in reviews such as Carter (1975) and Puckridge and French (1983). The LFO survey results were extensive and available in French (MARA 1989a); however, only the most relevant elements of the survey results are discussed in this paper. Whenever possible, corroborating studies from Morocco were discussed as a part of the review.

It is often said that it is difficult to find information that covers the agricultural community and farming systems in Morocco. This is partially a problem of language. An example of scholarly studies whose results are found in Moroccan libraries but rarely in international journals are training modules for students (e.g., Stage de Ruralism, Stage en Exploitation, Stage de Développement) in which students are sent into the countryside according to the guidelines of multidisciplinary committees assembled at the Institut Agronomique et Veterinaire (IAV)-Hassan II. These teams of students study a wide range of topics that are reduced into reports during the course of their studies at the university. A second example of literature not often published in English-language outlets are the theses of sixth-year or 'troisième cycle' students at IAV and fourth-year studies at Ecole Nationale d'Agriculture (ENA) at Méknes. Numerous studies of this type relate directly to the ley farming experience in Morocco.

Farm Size and Crop Rotations

Many farmers who participated in the LFO extended their plantings of annual legumes after their first year of involvement. However, farm size affected their level of interest: 47% of farms bigger than 20 ha increased the size of their ley farming rotation compared with 23% for farms less than 5 ha in size. However, the LFO sample was skewed away from small farms; 13 of the 326 informants had farms smaller than 5 ha and only 23% of them increased their annual legume hectarage. For farms larger than 20 ha, 47% of those farmers increased their annual legume hectare and this was based on a large sample (91/326).

Soil type, climatic conditions and farm size influence crop rotations in Morocco. Jouve and Papy (1983) studied these relationships in arid and semi-arid areas and results from the LFO survey corroborated closely their analysis of cropping systems. Of the farmers who began the ley farming system in 1985/86, 62% followed the rotation recommendations of allowing annual legumes to regenerate in the third year. Of farmers in areas adapted to subclover, 15% allowed pastures to regenerate for three consecutive years. Farmers who changed the crop rotation from annual legume in the third year represented 18% of the sample. Most farmers who dropped out of the LFO were from districts with favorable soil and/or rainfall conditions.

In regions with better soils or higher rainfall, farmers grow crops that demand more water such as durum wheat, food legumes or maize because heavier or deeper soils can be managed to profit from their water-holding capacity (Jouve and Papy 1983). According to the LFO report, farmers from these districts are more likely to own cattle and provide cut and carried green feed or hay. These farmers favored snail medic (*Medicago scutellata*) for its dry matter production and easily harvested upright growth. However, it was often found, not surprisingly, that use of medics as a hay crop removes a large portion of the potential seed production and affects the regenerative capacity of the annual legume in the pasture.

On big farms with deeper soils, the weeds are grazed out early and fields cultivated as soon as practicable to save water. These farmers own animals as a means of diversifying their operations and spreading risk; however, they have come to compromise between clean and weedy fallow to maximize crop production (Jouve and Papy 1983). Ley farming was not a significant improvement to the farm operation in areas favorable for crop production unless a farmer was interested in sacrificing some of his cropped lands to pursue an objective of raising more animals (MARA 1989a).

Decision-making in semi-arid areas is based upon obtaining dependable levels of production with a minimum of risk. Sheep and barley (*Hordeum vulgare*) production are integrated as buffering agents to better control the consequences of variable rainfall in less favorable climatic zones (Jouve and Papy 1983). Sheep are more flexible as units of sale than cattle and it is relatively easy to move flocks a reasonable distance on foot to meet their daily feed requirements. Barley has traditionally been used as a double purpose (forage and/or grain) crop and is well known throughout North Africa as the most durable of the cereals in harsh agricultural zones.

In the areas with shallow soils or less rainfall, adapted annual legumes are a good alternative to weedy fallow if they can be properly managed for satisfactory forage production and regeneration. Unfortunately, because of the diminishing contribution of rangeland to farm feeding systems, these dryland regions are undergoing structural changes, characterized by an increase in cereal hectarages relative to weedy fallow and a near absence of forage crops, especially on the numerous small holdings. These lands are suitable for ley farming, but much needs to be done to provide adapted germplasm and proper grazing management to successfully sustain the system.

On larger farms in the less favorable zones, weedy fallow is still very important, especially if there is little or no access to rangelands or 'free' grazing, such as along roadsides. Farmers minimize labor costs by avoiding spring crops that require the use of hand labor. Since they live under conditions of high cropping risk the weedy fallow represents the most reliable source of pasture for animals. Large farms have a higher proportion of land in weedy fallow than smaller farms and they are perhaps able to experiment with a substitution of forage for weedy fallow. For example, Jaritz (MARA 1989b) summarized data from a subsample of farmers in the LFO and reported that medic plantings as a percentage of farm size were 15.4% for farms smaller than 10 ha but 4.6% for farms larger than 160 ha.

Interaction of Agricultural Zones

Carter (1975) described three major agricultural zones in Algeria: the higher rainfall (> 600 mm), cereal (350-600 mm) and steppe zones (200-350 mm) in which he observed the movement of surplus lambs and older ewes. These animals move from the pastoral steppe lands to the higher rainfall zones to allow fattening before slaughter, or to rear another lamb or two under more favorable conditions with a more regular feed supply. The same inter-relationships undoubtedly occur in Morocco; however, few detailed studies are available to identify how these husbandry and marketing patterns can be better integrated.

Adaptability and Distribution of Legume Pasture Species

Jaritz (MARA 1989b) summarized seed sample data from 108 LFO farms growing medic in nine different regions. Almost two-thirds of the plantings were successful based upon the following plant establishment standards: < 100 plants/m^2 (failure), 101-200 plants/m^2 (conditional success) and > 200 plants/m^2 (successful). These data indicate that method of establishment, and possibly germplasm adaptability, were not technological constraints to success of the LFO.

Although the LFO used Australian cultivars of seed because of their availability, there have been dozens of reviews, annual reports and personal views forwarded by ley farming experts that countries of the Mediterranean basin should develop adapted local germplasm (Cocks 1986; Doolette 1975). For some reason, this has not yet occurred to a great degree in Morocco. Abd El Moneim and Cocks (1986) and Cocks *et al.* (1988) have demonstrated the success of developing local medic ecotypes in Syria and these forages have been adopted by farmers.

Numerous plant collection trips have occurred in Morocco and ecogeographical maps of annual legume germplasm are now better defined (Bounejmate and Beale 1989). Several forage research groups in Morocco have produced small quantities of native medic seed and now that the MARA-LFO has focused attention on areas best suited to ley farming, large-scale seed production could be better targeted for specific zones.

A pragmatic proposal would be to encourage farmers to increase their own seed by developing small-scale vacuum and threshing machines. The development of adapted annual legume pasture mixes for farmers will no doubt recapitulate the same logic that called for mixtures of pasture legumes in the LFO. In this case, it may be developmentally sound to encourage local seed production to assure adaptability and generate additional on-farm income.

Sowing Methods

Two types of seed bed preparation were found in the LFO survey: 58% deep plowed, followed by cover crop, and 42% cover cropped alone. It was concluded that farmers were following land preparation habits that they used for cereals; thus, future extension efforts might explain that deep plowing is not necessary. More research is needed because many farmers and agricultural workers are still unconvinced.

Thirty percent of the LFO survey respondents seeded the annual legume between early September and the end of October; 52% seeded in November and 17% in December and January. Those that seeded late possibly did so because of a higher priority given to the sowing of cereals. Early planting dates need to be stressed in future extension efforts if any autumn or winter grazing is to be expected.

The annual legume seed was covered by farmers as follows: 5% with a traditional simple plow; 39% used the cover crop in a fashion so the disks would not turn much soil and 47% used superficial implements such as harrows or branches dragged behind the tractor, followed in some instances with a roller. Most farmers followed the recommended seeding rate of 20 kg/ha; however, the rate was higher in regions where large-seeded species such as snail and gama medic (*Medicago rugosa*) were included in the seed mixture. Across the entire sample, 5-50% of the respondents mixed barley or oats (*Avena sativa*) with the annual legume at establishment, especially in colder areas; however, rates between 25 and 80 kg/ha also were used. Obviously the higher rates may have caused competition between cereal and annual legumes, negatively impacting the successful establishment of the latter.

Zahir (1987) surveyed 55 participants of the LFO in the Méknes and Safi regions and identified the following problems associated with establishment of medics: seedbed preparation was inadequate and plantings were too late, resulting in retarded emergence and forage growth due to low temperatures. He expressed the view that many farmers could have difficulty in amortizing seed investment costs over many years, unless they correctly managed the medic so it regenerated. Some additional problems should be anticipated: for example, it will be hard to assess the additional income that could be generated by the annual legume and very difficult to convince farmers of increases in cereal production, improvements in soil structure and organic matter content, or that they will find fewer lamb mortalities because of better ewe conditioning during breeding or milk production after lambing.

Annual Seed Production

Residual seed in the annual legume pastures is an important criterion for successful re-establishment in the next ley phase. For medics, a recommended minimum of 200 kg/ha of residual pure seed allows for 180 kg/ha hard seed and 20 kg/ha soft seed for eventual regeneration. Jaritz (MARA 1989b) showed that extension efforts should be directed toward grazing management since 47% of the LFO parcels sampled had less than 100 kg/ha of medic seed on the ground in May. A second sampling from the same farms in September showed that 72% of the pastures had less than 100 kg/ha residual seed, suggesting a decline due to seed consumption by animals. It would be worthwhile to return to LFO farms to study the seed bank dynamics after several cycles of the ley farming rotation and to provide grazing management guidelines to preserve a minimum quantity of seed in soil.

Germination of Seeds in the Crop Year and Use of Herbicides

Zahir (1987) found that snail medic and gama medic (*M. rugosa*) regenerated in the cereal phase. This reduced the seed bank of these species by 80% and caused serious weed problems. The smaller seeds of strand medic (*Medicago littoralis*) and barrel medics (*Medicago truncatula*) did not germinate during the crop phase to a similar extent. Grain yields of cereal were depressed the most by gama and snail medic which gave cereal yields of 2600 and 2900 kg/ha, respectively, compared with the strand and barrel medics (3200 kg/ha). Hardseededness of the medics, sampled in late summer, varied between 78 and 100%, harvested from mixtures or pure stands.

In the LFO, the MARA staff learned that 28% of the farmers surveyed had serious problems with annual legumes regenerating as a weed in the cereal year. This qualitative information does not lend itself to further analysis because the differences among species and regions were not discussed. However, the LFO questionnaire did identify that 40% of the farmers used herbicide in the cereal after medic. Zahir (1987) found that use of 2,4-D increased cereal yields in the crop phase by 200-300 kg/ha following strand and gama medics and 600-700 kg/ha for snail and barrel medics. Many development workers in Morocco feel that better weed control is the simplest, most effective way to increase cereal yields in Morocco. For example, Mazhar (1987a) found that when weed control was practised in continuous wheat rotations, wheat yields increased by an average of 24%. Weed control in the cereal year must be a major focus for successful management of ley farming systems in the future.

Regeneration

The LFO survey showed that 43% of the farmers did not cultivate at all prior to regeneration of annual legumes, 35% superficially scratched the soil and 22% worked the soil deeper with implements such as the cover crop. In the latter case, deep plowing buries the seed too deep. Extension efforts must strive to eliminate this type of mismanagement before it happens so that it does not generate client disinterest. The solution lies in continuing dialogue with trained, readily accessible personnel who circulate regularly to visit program participants.

A high proportion (69%) of those surveyed were satisfied with the regeneration of the annual legume. A portion of farmers who were not satisfied had used a haying operation that reduced the amount of seed available to sustain the system. Many farmers from the zones that used haying were also those who most frequently abandoned the ley farming system, possibly as a result of their inability to sustain adequate seed reserves.

Method of Cereal Planting after Annual Legumes

Forty percent of respondents plowed deep after the ley phase. A regular channel of communication with trained extension people could have prevented this disappointing result. The survey also asked whether those who cultivated superficially were respecting the LFO recommendations or following normal management practices. Results showed that, on average, one-third of the farmers (and in some regions up to two-thirds) changed habits to accommodate ley farming requirements for shallow cultivation. This demonstrates the willingness on the part of some farmers to accept new principles of management.

Another problem certain to occur in the practical application of ley farming in the future is the communication of appropriate guidelines to tractor drivers who generally work soils for cereal plantings much deeper than recommended for annual pasture legumes. The use of custom hired plowing is very common in Morocco and the driver will not share the landowner's concern about shallow cultivation of pastures containing annual legume seed.

Fertilizer Application

Great improvements could be made in fertilization management in Morocco. There are 21 billion metric tons of rock phosphate in Morocco (Leeuwrik 1975), more than in any other country on earth. A phosphorus fertilization subsidy could be encouraged to help add momentum to the LFO because there is a clear need for increased phosphate fertilization. The recommended phosphate addition of 45 kg/ha (Barrow 1985) was subject to tremendous regional variation. In 6 of 18 regions more than 40 kg/ha phosphate were applied, while none at all was applied in 3 regions. When adequate fertilizer was applied, usually 14-28-14 was used. A complete fertilizer containing N, P and K is not always necessary. Potassium is not often limiting in most Moroccan soils and nitrogen fertilizer turns off atmospheric dinitrogen fixation in the legume.

Nitrogen fertilization was continued in the cereal phase by 77% of the survey participants. This practice may indicate that farmers did not understand or were not confident in the ability of legumes to fix atmospheric nitrogen. Great advances could be made in the future if soil fertility status could be quickly and objectively demonstrated. A soil-testing program in Morocco would help farmers to follow and understand fertility changes in the soil over time, but at present the possibility of testing soils through government or commercial channels is rare or nonexistent.

Effect of Annual Legumes on Cereal Yields

Overall, 75% of the LFO informants perceived that there was an increase in grain yield after medic in relation to a system of cereal/weedy fallow. In four regions, every respondent (100%) felt that cereal yields were improved.

Mazhar (1987a), in more detailed and quantitative studies of ley farming rotations, found that wheat rotated with clean fallow was superior to wheat rotated with weedy fallow for yields of wheat straw and grain, mostly because of greater water-use efficiency in the clean fallow treatments. With data averaged over 1984-1987, Mazhar (1987b) compared wheat/weedy fallow with wheat/medic rotations and he reported total yields of 1263, 2894 and 2658 kg/ha vs 1419, 2990 and 3962 kg/ha of cereal grain, straw and forage (medic or weeds), respectively. The grain and straw yields were not greatly different under the two systems; however, the forage yields represented a significant increase in dry matter production compared with weedy fallow. Mazhar's rotations did not include animals and the results from ICARDA (Cocks *et al.* 1988) suggest that the real advantage of the ley farming system is the increased profitability associated with the integration of animal and crop production.

Grazing Methods and Forage Utilization

Farmers who completed the LFO survey used the forage as grazed feed in 82% of the cases. Surprisingly, only 12% of the respondents thought that grazing was difficult to manage, which contrasts with the more detailed remarks of Zahir (1987), who identified problems due to early underutilization and/or late overutilization of the forage.

Those who thought that management was difficult probably lacked clear grazing management recommendations. For example, farmers were advised to remove animals from pasture at flowering, yet this is inconvenient because alternative pastures or feed may not be available. It is clear that management of annual legumes is more complicated than management of weedy fallow.

The remaining 18% of LFO farmers used cutting management of the medic pasture. This was done at various stages of growth: 8% in the vegetative stage, 31% during flowering, 19% during pod filling and 42% when mature. Farmers must understand that regenerating pastures require a seed source and the consequence of cutting the annual legume may be the necessity of reseeding the pasture to reestablish the plants.

Across all categories of management in the LFO survey, 60% of the informants thought annual legumes were as good as, if not better than, other forage crops grown in the rain-fed areas. On the other hand, 17% thought medics were less desirable. Nine percent of the returned questionnaires indicated some problems with bloat.

Animal Production from Annual Pastures

Animal production was not addressed by the LFO. Much more needs to be accomplished regarding animal husbandry and health care to improve productivity. Since the farmer sells animals by head and not by weight, there is very little incentive to improve animal nutrition at the expense of decreased numbers of animals. In addition, selection, culling of unproductive animals or controlled breeding are rarely practised on countryside farms.

A general problem related to animal management during bad times is what to do with a large flock when little feed is available. Normally this is achieved through purchase of concentrate feeds or selling of animals to reduce flock size. Government subsidies on concentrate feeds, coupled with the tradition of keeping livestock as a banking account, have encouraged farmers to hold on to animals in bad times. Availability of cheap concentrate feed encourages higher inventories of animals, meaning more animals than the land base can support on a resource that is already overstocked. Recently, free market rules have been applied to the cost of certain concentrates and this may boost on-farm forage production (Boulanouar 1988).

Land Tenure

The LFO sample of farms was composed mostly of private landowners. The number of private land owners within each land size category was as follows: 11/13 of the respondents with less than 5 ha; 25/41 with 5-10 ha; 52/79 with 10-20 ha and 140/193 with more than 20 ha.

There are some renters of private land but sharecropping is more common and sharecropped farms are managed in one of several ways: 1) the sharecropper receives one-fifth of the crop in return for his labor; 2) the farm is owned by an absentee landlord and several sharecroppers work the farm and divide the crop in a fixed proportion; or 3) the sharecropper acts like a labor foreman, providing a reliable work force for a share of the crop (Hartley 1986).

The LFO survey did not describe whether the owner, the renter or the sharecropper was responsible for completing the questionnaire. However, it was clear that private landowners found the LFO most appealing and the landowner who had more than 10 ha was more interested than those with less than 10 ha.

Division of lands into smaller and smaller parcels has been due to traditional patterns of inheritance in Morocco. The LFO operation indicates that participants in the survey had approximately 5-10 pieces of land per farm; however, the farms with > 20 ha were only half as partitioned as farms with < 5 ha. Division of land through inheritance is governed by traditional rules. If five children are to receive their share from three pieces of land that constitute the farm, each person will receive a piece of the original three pieces because of differences in slope, soil depth, structure, aspect or access to roads or water.

Extension and Institutional Constraints

Of those questioned, 96% thought they received sufficient advice concerning the ley farming system; however, this figure is questionable because the CT agents who were responsible for initiating the LFO also were charged with distributing and collecting the surveys. Agents of the CT do not have the means to visit all areas under their jurisdiction and as a result the amount of on-farm diffusion of specific ley farming expertise is limited.

Within the administrative hierarchy of MARA, the CTs are the main contact between government programs and the farmer. The CT agent visits farmers, organizes meetings and manages on-farm trials. Farmers also can be assisted by the CT in obtaining agricultural loans or title to their lands. For these reasons, the CTs are critical factors in agricultural development in the rain-fed areas.

In Morocco, the CT also provides farmers with seed and fertilizer, the justification being that a farmer can then be offered a complete package of inputs and management advice. The CTs have much control of the sale of selected and treated seed, which is subsidized by the government and obtained from SONACOS, the national seed company. Although their favorite cereal cultivars can be found in local markets at less cost as uncertified seed, the seed is not treated and farmers recognize improvements in stand when using treated seed. Seed supplies of popular SONACOS cultivars are not always available and some farmers have better access to the CT agent than others. With ambitious LFO planting targets, agents could use popular cereal cultivars as a means to induce participation in MARA special operations, such as the LFO.

The CTs and CMVs are strongly influenced via directive from MARA to carry out special programs such as the LFO and improvements could be made in providing constructive feedback mechanisms to reflect their views. There are obvious advantages in hearing the opinions of these people, who are working directly with farmers. Finally, there are few incentives for extension agents and salaries are low. In 1988, an extension agent earned 1200-1500 Dh per month (USD 138-173). There is no reward system for doing a good job, nor a penalty for doing a bad one.

There is insufficient communication among the research, extension and teaching units operating as functional parts of Morocco's agriculture. Many redundancies could be eliminated if the work load were defined by consensus and divided according to the resources available. It will take time before good collaboration is created between the agencies through joint projects and mutual organizational trust.

If the LFO is to overcome the problems that have been so adequately pinpointed by its report, it is time to follow a path of work much closer to the farmer so that researchers, development agents and decision makers can discover why he is having difficulties. This is the methodology recommended by ICARDA (Cocks *et al.* 1988; Nordblom *et al.* 1985) and it seems to be working. It would make good sense to develop a ley farming extension team, cutting across the various research, extension and training organizations, that could now fine tune the LFO for those regions with the most promise.

Summary and Recommendation

It has taken a century to evolve ley farming in Australia. It happened not as a conscious advancement; it developed on enormous hectarages of land when it was realized that introduced pasture legumes were more than just adapted weeds. In North Africa, the introduction of ley farming is an alternative to inefficient traditional production systems. Fortunately, in Morocco and the rest of the Mediterranean, a growing local data and literature base may be coupled with Australian findings to provide research directions and hypotheses to test.

If it is concluded that ley farming is indeed biologically feasible, then ley farming teams could be assembled to cut across institutional boundaries to integrate efforts of planning, research, training and extension and to give all institutional units a voice in the adoption of ley farming. The experiences in Morocco from the 1980s have identified some expected problems but those findings must now be shared and an organized approach for the future synthesized. If resources must be allocated and directed at the highest priority problems, then it follows that we must first agree upon the priorities.

Acknowledgements

We wish to thank Ms Maria Amine and Mr Abderrahim Benyassine, Division des Céréales, Fourrages et Légumineuses, Direction de la Production Végétale, MARA, for their generosity and cooperation in this critique of the MARA-LFO report. We hope our approach is viewed as constructive, pointing out directions for future work. As such, the views expressed in this paper are those of the authors, who take full responsibility for the interpretations made and the opinions expressed.

References

Abd El Moneim, A.M. and P.S. Cocks. 1986. Adaptation of *Medicago rigidula* to a cereal-pasture rotation in North-West Syria. Journal of Agricultural Science, Cambridge 107:179-186.

Barrow, P. 1985. Farming in Morocco. Report to the Ministry of Agriculture and Agrarian Reform, Morocco. Ministry of Agriculture, Rabat, Morocco, 22 p.

Boulanouar, B. 1988. Description de l'élevage ovin dans la Chaouia. Rapport de stage à INRA. INRA-CRRA, Settat, Maroc, 40 p.

Bounejmate, M. and P.E. Beale. 1989. Distribution of annual *Medicago*. 1. Species and their abundance. INRA, Station Centrale des Plantes Fourragères, Guich, Rabat, Maroc (in press).

Carter, E.D. 1975. The potential for increasing cereal and livestock production in Algeria. Centro Internacional de Mejoramiento de Maiz et Trigo (CIMMYT), Mexico City, 54 p.

Cocks, P.S. 1986. The need for seed production of pasture and seed production in and for Mediterranean countries. ICARDA-114 En. Aleppo, Syria.

Cocks, P.S., H. Sawmy-Edo and B. Mawlawi. 1988. Adapting the ley farming system to conditions in West Asia and North Africa. Pages 11-29 *in* Annual Report of the Pasture, Forage and Livestock Program. ICARDA, Aleppo, Syria.

Doolette, J.B. 1975. The strategy of establishing a crop rotation programme using annual forage legumes. Pages 243-251 *in* Third Regional Wheat Workshop, Tunis, Tunisia.

Estefan, F.E. 1986. Chapter 3. The economy. Pages 161-232 *in* Morocco, a Country Study (H.D. Nelson, ed.). The American University, Foreign Area Studies. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C.

FAO. 1987. Production Yearbook. Vol. 41. FAO Statistics Series No. 82. Statistics Division of the Economic and Social Policy Department, Basic Data Unit. FAO, Rome, Italy.

Hartley, J.M. 1986. Chapter 2. The society and its environment. Pages 95-160 *in* Morocco, a Country Study (H.D. Nelson, ed.). The American University, Foreign Area Studies. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C.

Jouve, P. and F. Papy. 1983. Les systèmes de culture dans les zones semi-arides et arides du Maroc Occidental. Revue Géographique du Maroc, No. 7 (Nouvelle Série):3-20.

Leeuwrik, D.M. 1975. The relevance of the cereal-pasture legume rotation in the Middle East and the North African region. Pages 266-290 *in* Proceedings of the Third Regional Wheat Workshop, Tunis, Tunisia.

MARA (Ministere de l'Agriculture et de la Réforme Agraire). 1988. Direction de la Planification et des Affaries Economiques. Enquête Elevage. Rabat, Maroc, 27 p.

MARA (Ministere de l'Agriculture et de la Réforme Agraire). 1989a. Direction de la Production Végétale, Service des Légumineuses et Fourrages. Evaluation de l'opération ley farming. Rabat, Maroc, 96 p.

MARA (Ministere de l'Agriculture et de la Réforme Agraire). 1989b. Direction de la Production Végétale, Service des Légumineuses et Fourrages. Rapport sur l'analyse des questionnaires "Observations agronomiques sur la parcelle de Medicago-Trèfles". (Summarized by G. Jaritz, INRA-GTZ, Station Centrale des Plantes Fourragéres, Guich, Rabat, Maroc, 10 p.)

Mazhar, M. 1987a. Effects of crop rotation on wheat and herbage yield, evapotranspiration and water use efficiency in Morocco. Ph.D. dissertation, University of Missouri, Columbia, Missouri, USA, 188 p.

Mazhar, M. 1987b. Results of crop rotations with forages. Pages 237-242 *in* Annual Research Report 1986-1987. Centre Regional de la Recherche Agronomique, B.P. 290, Settat, Maroc.

Nordblom, T.L., E.K.H.A. Awad and G.R. Potts (eds.). 1985. Research methodology for livestock on-farm trials. IDRC-242e: 311 p. IDRC, Ottawa, Canada, K1G 3H9.

Puckridge, D.W. and R.J. French. 1983. The annual legume pasture in cereal-ley farming systems of Southern Australia: A review. Agriculture Ecosystems & Environment 9:229-267.

Zahir, H. 1987. Contribution à l'étude du système ley farming par essai et enquêtes dans trois zones céréalières du Maroc. Mémoire du 3ème cycle agronomie. Option: Productions végétale. IAV, Hassan II, Rabat, Maroc, 139 p.

Constraints to the Ley Farming System in Algeria

M.E.H. Maatougui
Station Experimentale de l'ITGC, Sidi Bel Abbes 22000, Algeria

Abstract

The ley farming system continues to frustrate many Algerian scientists and farmers. Poor adaptation of Australian cultivars has limited its expansion. This is especially true for the high-plateaux regions characterized by severe winters and where most of the fallow land is concentrated. In favorable zones, the major constraints encountered are poor establishment of the medic pasture, weed competition, overgrazing, poor levels of seed production to ensure acceptable regeneration, and bad seedbed preparation for the wheat crop due to the lack of adequate tillage implements. The current lack of commercial seed production limits the use of frost-tolerant ecotypes selected from local and introduced germplasm. With all its benefits, the ley farming system has been resisted by farmers because of the radical changes it imposes and the complexity of its management.

Introduction

Annual species of *Medicago* used skillfully in south Australia are the key factor to a successful agricultural system integrating cereal and livestock production. As well as increased soil nitrogen levels, significant increases in yield of wheat, wool and meat were achieved. This is not so for Algeria.

The fact that medics are native to the region was not considered by those who decided upon massive introductions of commercial Australian cultivars that were not well adapted to all agroclimatic conditions in Algeria. The medic system was intended to address the issues of optimum land use (replacement of weedy fallow) and increased livestock production, particularly in the high-plateaux regions, which carry a flock estimated to be around 6 million sheep and goats and comprise on average about 2 million hectares of weedy fallow annually.

The feed strategy most commonly practised relies on hay forage, hay crops, stubble, straw, weedy fallow, barley grain and supplementation from the steppe region during the winter. The consequences of this strategy are extreme degradation of the steppe and low cereal production due to poor soil fertility and heavy infestations of noxious weeds.

In the past 20 years, the ley farming system failed to have positive effects in the high plateaux. Although some success has been demonstrated in other regions, the effects are still not very encouraging to farmers.

The following is a review of the main constraints that limit the ley farming system in Algeria.

Constraints in the High-Plateaux Zones

Adaptation of Commercial Cultivars

Winter survival of sown medic cultivars is limited by low and often freezing winter temperatures. In western Algeria, survival of plant stands decreased with increasing elevation (26% at 1-500 m a.s.l., 17.4% at 500-800 m, 3.8% at > 800 m) (Bakhtri 1977; CIMMYT 1975; Maatougui 1978; Saunders 1978), elevation being a reflection of winter temperature regimes, which are usually more extreme with increasing elevation throughout Algeria.

That elevation affects survival was expected. A survey carried out on naturally occurring medic plants, grasses and broadleaf plants (Maatougui 1978) showed the same trend (Table 1), although it is noted that grazing pressure (usually more acute in high elevation zones) can influence the data.

Table 1. Botanical composition as a percentage of natural vegetation in high plateaux of western Algeria.

Elevation (m a.s.l.)	Botanical composition (%) Medic	Other grasses	Broadleaf	Legumes
		1975		
0 - 500	54.2	5.3	12.9	27.6
500 - 800	35.6	8.6	10.8	47.8
> 800	1.7	-	6.0	92.3
		1977		
0 - 500	38	53	9	
500 - 800	31	26	43	
> 800	13	55	32	

Source: Bakhtri 1977.

The relationships among medic seed rate, survival and dry matter production were studied in the high-plateaux region by Saunders (1978) and Maatougui (1978). The data (Table 2) show that increasing seed rates from 12 to 24 kg/ha did not significantly increase dry matter production at Telagh (elevation 1100 m) or Ain El Hadjar (elevation 1000 m) and that higher seed rates did not compensate for poor cold tolerance of the cultivars studied (Jemalong, Snail, Harbinger and Borung). On the other hand, increasing the seed rate to 24 kg/ha significantly increased dry matter production for all four cultivars at Sidi Bel Abbes (elevation 600 m).

This study clearly identifies regions of lower elevation as the most favorable for Australian cultivars in Algeria pending selection of frost-tolerant material for the high plateaux.

Table 2. Dry matter production of four medic cultivars as influenced by seeding rates and location in western Algeria, 1977.

Cultivar	Seeding rate (kg/ha)	Dry matter production (kg/ha) Sidi Bel Abbes 600 m†	Telagh 1100 m†	Ain El Hadjar 1000 m†
Jemalong	12	930	28	21
	24	1790	47	63
Snail	12	1820	102	228
	24	2840	231	200
Harbinger	12	1690	16	13
	24	2210	28	22
Borung	12	2490	76	49
	24	3970	136	120

† Elevation above sea level.

Constraints in Favorable Zones

As stated earlier, the introduction of the ley farming system in Algeria was not successful. Simply said, it is a complex system for most Algerian farmers because it requires careful management of two integrated production systems: cereal and livestock.

A reflection of the first attempt and failure to establish the system during the 1970s is illustrated by Table 3 (Maatougui 1978). Of the 15 000 ha sown to medic in western Algeria from 1973 to 1978, only 5342 ha were in medic in the 1978 crop year. By 1980, not a single hectare was a medic pasture. Following an additional establishment program of 3000 ha sown to medic in 1987, very few fields can still be called medic pastures.

Table 3. Evolution of sown medic areas (ha) from 1973 to 1978 on State Farms in western Algeria.

Wilaya province	Cropping years						Total
	1973	1974	1975	1976	1977	1978	
Oran	-	120	280	579	1060	260	2299
Mostaganem	15	10	190	130	100	125	570
Sidi Bel Abbes	25	391	866	1273	1458	3602	7615
Mascara	10	150	350	648	398	745	2301
Tlemcen	-	149	325	610	340	500	1924
Saida	-	90	110	121	116	110	547
Tiaret	34	99	98	-	10	-	241
Total	84	1009	2219	3361	3482	5342	15497

Although many extension efforts were deployed, the potential of the ley farming system has not yet been fully exploited at the farm level. The main reasons for failure in the implementation of the system can be summarized as follows:

- lack of long-term planning in the management of the system,
- poor establishment of medic pastures (rough seedbed and deep sowing),
- poor grazing management and overgrazing,
- progressive infestation of weeds (especially *Bromus* spp.),
- deep plowing,
- lack of adequate tillage implements (chisels, cultivators),
- reduction of cereal yields after medic (compared with fallow),
- poor medic regeneration due to poor seed production,
- lack of capacity for local seed production, and
- lack of conclusive extension at the farm level.

Although the negative effects of all these factors combined have been addressed with the data of Table 3, the effects of most importance can be substantiated further.

Grazing Management

Grazing management is the key factor in the system, especially during pasture establishment. Grazing influences weed control and medic seed production, from which regeneration is expected. Careful monitoring of stocking rates is therefore of prime importance.

The influence of stocking rates was studied with a survey carried out in May and July in farmers' medic fields and Ministry of Agriculture demonstration fields. The average number of sheep per hectare in demonstration fields was 7.2 and 6.5 in zone 1 (0-500 m elevation) and zone 2 (500-800 m elevation), respectively, compared with 9.1 and 12 sheep/ha in farmers' fields (Table 4). This clearly indicates overgrazing of medic (Table 5). As grazing is excessive in either May or July, chances of good seed production are mediocre and subsequent regeneration is compromised.

Table 4. Stocking rates in demonstration and farmers' fields in western Algeria, 1977.

Elevation (m a.s.l.)	Stocking rate (ewes/ha)			
	Demonstration fields		Farmers' fields	
	Range	Average	Range	Average
0 - 500	5.0 - 10.0	7.2	3.5 - 17.8	9.1
500 - 800	4.0 - 12.0	6.5	5.0 - 20.0	12.0

N.B.: This survey was conducted with 42 State Farms and 2 demonstration fields.

Table 5. Level of grazing recorded in a survey of 42 State Farms in western Algeria, 1977.

Grazing level	Grazing situation (%)	
	End of May	End of July
Excessive	27	77
Good	29	5
Insufficient	26	-

Medic Seed Production

Reaching a good seed production level (200 kg/ha and more) is an important achievement during the first medic year to ensure regeneration after the cereal crop. It is the first-year seed level and subsequent tillage management that ensure the installation of the ley farming system in a medic/cereal rotation system.

The levels of seed obtained in farms that introduced the ley farming system are one of the major causes of failure. Most of the farms surveyed in western Algeria achieved poor yields of medic seed because of overgrazing and heavy weed infestation.

Weed Control

The importance of weed control in the system is vital to its survival and to obtaining high yields for the cereal crop. The relationship between weed infestation, stocking rates and medic seed production is illustrated in Figure 1. Saunders (1979) pointed out that when grazing is not optimum, weed infestation is dominant. This dominance is expressed by grasses at the beginning and broadleaf weeds later, with a resurgence of *Bromus* after full flowering of the medic pasture.

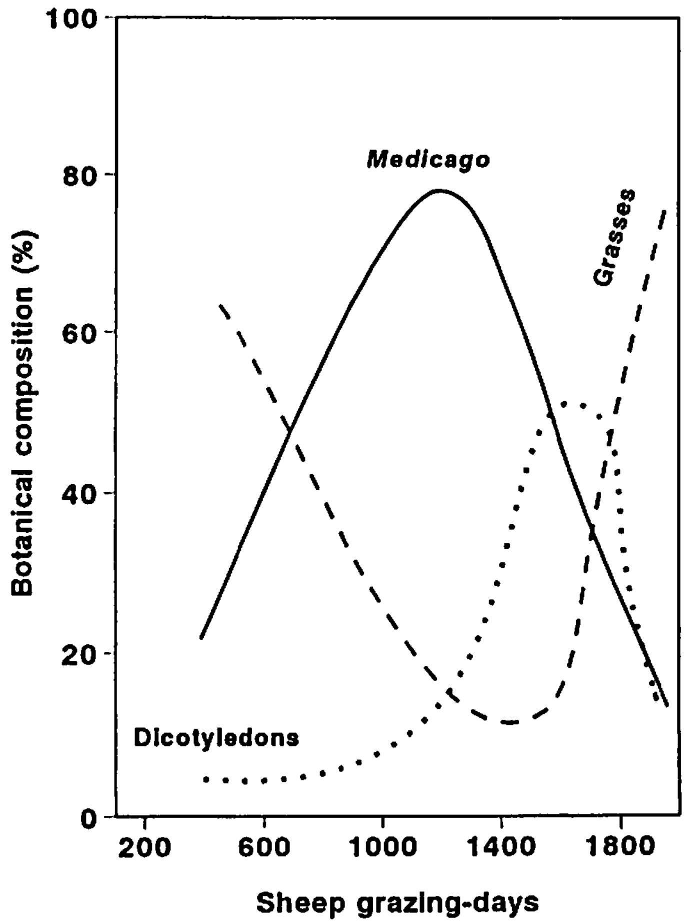


Fig. 1. Relationship between botanical composition and grazing pressure, Western Algeria, 1975/76.

Although it sounds easy, weed control with grazing pressure is not easily mastered and is still a major obstacle to the adoption of the ley farming system.

As chemical control is not yet used on medic pastures, the yield of wheat after medic is usually lower than after fallow or food legumes (Table 6).

Table 6. Wheat yields (t/ha) following various crops in Algeria.

Preceding crop	Eastern Algeria 1974/75	Western Algeria 1974/75	Western Algeria 1975/76
Fallow	1.66	2.87	3.22
Hay	1.15	2.49	2.52
Food legume	0.57	2.27	2.82
Medicago pasture	0.38	2.36	2.75

Source: Saunders, D.A. (1979)

Investigation into effective herbicides that can be used on medic will greatly help weed infestation problems. Mowers with hydraulic height control could play an important role in clipping upright weeds and limiting their proliferation in the pasture phase. Clipping would thus decrease the negative effect of weeds on wheat yield.

Other Areas

Successful ley farming requires the management of a medic system as a farming system that integrates cereal and livestock and not as medic replacing fallow (Maatougui 1987; Zeghida 1987).

The method by which sheep production is now managed must be changed. The steppe region is degraded and flock movement north and south has to be reduced. Research proved that with medic it is possible to adequately feed 7 sheep/ha in favorable zones compared with 1 sheep/ha for weedy fallow (Maatougui 1987).

Because of the high prices of forage hay and straw, it is possible that medics like *Medicago scutellata* could be viewed as an economical forage crop and will be adopted with all the care they require. Another important component for success is availability of adequate tillage equipment (chisels, cultivators, harrows). Deep plowing with disks or moldboard plows usually destroys the ley farming system.

Nevertheless, with commercial seed of local varieties available, farmers may eventually recognize the flexibility and potential of the ley farming system. It may be possible to achieve the introduction of medics on 3 million hectares in Algeria as Carter (1975) optimistically pointed out.

Acknowledgements

I would like to thank ICARDA for financial support to attend the Perugia workshop. Also, I would like to express my gratitude to Dr D.A. Saunders who introduced me to the wonderful world of medic. Finally, my sincere thanks to Drs P.S. Cocks and L.A. Materon for assistance and encouragement.

References

Bakhtri, M.N. 1977. Wheat-forage legume rotation and integration of crop and sheep husbandry in the Near East and North Africa. Pages 520-538 *in* Proceedings of an International Symposium on Rainfed Agriculture in Semi-arid Regions, UCR/OSU/CALI, 17-22 April 1977. Riverside, California, USA.

Carter, E.D. 1975. The potential for increasing cereal and livestock production. A report for CIMMYT.

CIMMYT (Centro Internacional de Mejoramiento de Mais y Trigo). 1975. Report on wheat improvement.

Maatougui, M.E.H. 1978. Le système d'assolement medic-blé. Seminaire Evolution des Assolements, 27 et 28 Mai 1978. Oran, Algerie. 22 p.

Maatougui, M.E.H. 1987. Installation et conduite du système medic-blé. Cerealiculture 16:46-51.

Saunders, D.A. 1978. Report on recent *Medicago* research. IDGC, Direction Regionale d'Oran. 16 p.

Saunders, D.A. 1979. The role of rotations in weed control. Pages 52-59 *in* Proceedings of a Cereal Workshop, MARA/ICARDA/CIMMYT, 5-9 May 1979, Vol. II. Algiers, Algeria.

Zeghida, A. 1987. Possibilités et limites du materiel végétal d'introduction. Resultats d'experimentation des écotypes locaux. Cerealiculture 16:58-62.

The Use of Annual Medics in Pasture Systems in Algeria

A. Abdelguerfi
Departement de Phytotechnie, Institut National Agronomique, El-Harrach 16200, Algeria

Abstract

Algeria is one of the largest countries in Africa, with a diverse array of land forms. This contribution inventories the potential of each of these areas in Algeria with the goal of accounting for the potential feed resources that are or could be exploited on each. Annual medics are a rich source of germplasm in Algeria that should be exploited to reduce feed deficits, hold down the soil and improve fertility.

Introduction

Algeria faces a chronic deficit in animal products, which is increasing under the pressure of a rapid rise in population and changes in the consumer's food habits.

The importation of animal products for human consumption (dairy products, meat, eggs and honey) rose from 200 to 290 million USD between 1980 and 1984. During the same period, non-food animal products (skin, leather, wool, hair and horse mane) also were imported at a cost increase from 10 to 25 million USD. Concurrently, ovine, caprine and bovine livestock increased in number from 13.40, 2.72 and 1.36 million head in 1980 to 15.66, 2.80 and 1.40 million head in 1984. Over a longer term, the total number of livestock in Algeria was 10.35 million head in 1967 and reached 20.00 million head in 1986.

Attempts to increase livestock numbers and import animals with high genetic potential have not improved the importation problem. This is due to the deficit in quantity and quality of animal feed. This inadequacy of feed leads to periodic, large-scale decimation of the national livestock inventory due to extreme climatic adversity. Moskal (1983) estimated the annual feed deficit at 3 billion animal feed units [1 feed unit (FU) is equivalent to about 1 kg of barley grain]. Laib (1986) has mentioned a deficit of 3.5 billion FU and 224 million kg of digestible protein.

Natural vegetation from extensive areas of range, marginal land, weedy fallow and 'maquis' form the predominant source of Algeria's forage resources, providing the feeding foundation for the national livestock inventory. Relatively small areas are reserved for the production of introduced forage plants. According to Lapeyronie (1982), it is a characteristic of all Mediterranean countries.

Annual medics can play a role in ley farming rotations or as annually regenerating plants on native grasslands.

Saharan Steppe

Saharan steppe covers an area of 20 million hectares that receives annual rainfall between 50 and 100 mm. Forage production can reach about 400 million FU (Le Houerou 1971). It consists of spontaneous vegetation existing mainly along oueds in areas where only goats and camels (dromedaries) can be grazed.

Oases play an important role in supplementing livestock with forages. Animals of this region regularly consume agricultural by-products (straw, residues of dates, etc.) produced in these small areas.

At the level of some oases, forage species such as alfalfa, berseem, oats, green barley and barley grain play an important role and constitute a component of livestock feed essential for maintaining the Saharan livestock base. Forage is often marketed in part in small green sheaves in oasis markets.

Livestock are maintained on 'drinn' (*Aristida pungens*), inflorescences of 'retam' (*Retama retam*) and other spontaneous species (Siga 1989). These practices are denuding an already sparse vegetative cover. According to Siga (1989), drinn is now rare around El-Menea. Desertification is accelerating due to uprooting of perennial vegetation for sale or firewood.

In these difficult areas, annual medics occur but are rare. Ozenda (1980) indicated that *Medicago laciniata* is common in the Sahara while *Medicago littoralis* is confined to its north limit.

Annual medics can easily be developed at oasis level and thanks to market exchanges with the north (wool, seeds) they have been introduced accidentally and are considered weeds that often are sold as feed after hand weeding. Medics also could be sown along subdesert stream beds to provide intermittent grazing in the wet season (Gachet and Elmir 1972).

Rangeland Zone

The rangeland in Algeria covers an area of 15 million hectares and is demarcated by rainfall isohyets of 100-400 mm. Production is very low (100 FU/ha, i.e., 1.5 billion FU), but this is sheep country par excellence. Unfortunately, over the last decade overgrazing and cereal cultivation have increased the degradation of this rangeland zone.

Overgrazing is exacerbated by an excess of sheep that are maintained on the land, even in bad years, by feeding them barley grain. According to Le Houerou (1985), price supports for barley are speeding up range and steppe degradation.

Pressure to feed the population and more widespread access to farm equipment explain the extension of cereal cultivation to areas that receive as little as 250 mm of rainfall (Pouget 1980). Cultivation of cereals in these risky areas is opportunistic and is carried out irrespective of microclimate, soils or existing vegetation. The major criterion to cultivate is based solely on topography and the absence of rocks and stones on the soil surface.

Outputs are low with a high probability of failure. The consequence is frequently range degradation, provoked by the destruction of perennial species and reduction or elimination of the seed bank of native plants.

Spontaneous annual medics on rangelands (*Medicago polymorpha, M. truncatula, M. minima, M. laciniata* and *M. littoralis*) are less and less common. Bourahla and Guittonneau (1978) used regeneration techniques that were associated with an increase in the presence of legumes including *M. laciniata.*

The cultivation of cereal on the fringe of the range (300-400 mm annual rainfall) should be prevented and this area revegetated with annual *Medicago* species to increase existing forage production and reduce the grazing pressure on the remaining steppe.

We can think about a pasture system which is based on rangelands improved by using, among other species, adapted annual medics in association with barley in certain areas, established using low- or no-till techniques so that the small-seeded native species that provide the annual vegetation are not buried. Shrub species also could be established in plantations and the time is right to enact and enforce legislation to protect renovation measures. Rangeland condition is declining beyond its ability to be easily revegetated. A rational use could be made of this resource, as in the past, when it was part of an animal feeding system integrated across several agroecological zones.

Miscellaneous Range, 'Maquis' and Forests

This land resource grouping accounts for about 4 million hectares associated with an annual production of nearly 300 FU/ha.

In Algeria, some forest and scrubland vegetation (maquis) plays an important role in feeding livestock. In the north, livestock spend most of the year in these areas

(Abdelguerfi-Berrekia and Abdelguerfi 1986). Overgrazing is extreme, but the thicket nature of the vegetation, often on steep hillsides, provides many areas that are inaccessible to animals. This maintains a diverse supply of medic and other native species.

According to Bourbouze and Donadieu (1987), lawn vegetation in North Africa often consists of gramineae, labieae, cistaceae and legumes of the genera *Medicago*, *Lotus* and *Trifolium*. These and other enclaves in forests, firebreaks and 'matorrals' are environments in which medics play a useful role. However, the landscape is often hilly and risks of erosion are great. Often these sites are rather degraded and would benefit from an immediate oversowing of medics. Here a mixture of species is advised to allow for differences in microclimate and soil type. In areas where a base of naturalized medics remain, broadcasting rock phosphate would stimulate their production.

There are many extreme problems that need to be addressed. Much of the scrubland has been cleared and plowed, often straight up and down the slope of the hills. Soil erosion is immense, cereal outputs are low; destruction of the watershed and silting of rivers and dams are the result. Drastic measures are needed to protect these areas and reverse the damage.

Domestic herbivores have a direct impact on the management of botanical composition on the land. In regions where the soil can no longer be plowed, grazing by livestock represents a method by which the land can be revegetated (Jarriage 1979). Using proper grazing management, livestock can disperse small-seeded species where seed has been plowed too deep, or has been washed or blown away.

Permanent Meadows or Pastures

Meadows represent nearly 20 000 hectares in Algeria. They are used for hay production and as pastures after reaping. Permanent pastures or meadows are heavily used in autumn and early winter before animals are removed, but some meadows are grazed throughout the year.

On the sublittoral low plains and interior plains, permanent natural meadows have decreased in area since the beginning of colonization. During the colonial period nearly 90% of the permanent meadows were cleared and used for cereals, vineyards, gardens and building lots (Ducellier 1933; Laumont 1960). The interior plains diminished in area for various reasons: poor agricultural financing, cropping, vegetable farming, development of orchards, greenhouses and increase in water pollution (Abdelguerfi and Hakimi 1988). This disappearance has been documented over the years (Ducellier 1933; Laumont 1960), yet the trend continues unabated. Ducellier (1933) indicated the presence of *M. polymorpha*, *M. ciliaris*, *M. truncatula*, *M. intertexta* and *M. geatula* in hay and Laumont (1960) explained that permanent meadows produced a high quality of hay. Even now, the hay of the remnant meadows is better appreciated than oat hay as feed for livestock.

Cereal Zone

The cereal zone is found on the Algerian high plains and its northern border. Precipitation ranges between 300 and 600 mm in which we can distinguish two subzones. The cereal zone is well suited to rearing and breeding sheep (Laumont, 1948).

Areas of the High Plains Receiving 300-400 mm

This zone contains lands that are so fragile that their best use would be as they were used in the past: as a sheep-rearing/cereal zone (Laumont 1948). The same could be said of areas with slightly higher rainfall that have poor soils, steep slopes or where the plow destroyed pastures and ancestral rangelands.

We can complete or modify in part some of the actions proposed by Laumont (1948):

1. Reconstitute or revert to natural pasture. One of the only options to do so would be to use annual medics on these calcareous soils.
2. Re-establish permanent natural meadows in the most favorable locations. This alternative would appear difficult to undertake because of the expansion of greenhouse culture in these areas, which is assumed to be more profitable.
3. Use the better locations for a rotation of barley grown for grain in rotation with annual medics.
4. If it is possible, grow irrigated forages to stock a maximum reserve for difficult periods and for sale to herders with flocks on the steppe.

Areas Receiving 400-600 mm

In this zone, cereals are rotated with different kinds of fallow:

Worked fallows

Plowed in autumn or spring, the total area of worked, clean fallow amounts to 1 million hectares. This practice makes the land the most prone to erosion and provides no feed for animals in the fallow year. The justification for this system was the superior cereal yield or for control of weeds, but to accomplish the latter, many cultivations usually are needed.

Cut and harvested fallows

A yearly surface area devoted to this form of land use averages from 120 000 to 130 000 ha. In dry years the surface is reduced to 70 000 ha, while in moist years it can reach 160 000 ha.

Cut and harvested fallows are used as pasture until December. They are later cut as good quality hay composed of annual grasses and legumes. These areas are somewhat special because they are highly fertile or the soil is deep. Phosphate fertilizer could be used judiciously for these reserved areas to increase forage output.

The most frequent annual medic species found in harvested fallows are *M. polymorpha*, *M. orbicularis*, *M. truncatula*, *M. ciliaris* and *M. intertexta*. The frequency and diversity of species on cut fallows can change depending on the soil, climate and cultural conditions used during the cereal year. After hay-making time, these fallows can be pastured to utilize the remains of the hay crop and vegetative regrowth.

Pastured fallows

These weedy fallows cover between 1.5 and 2 million hectares and are common because of the need for forage or the lack of time and equipment to work the soil.

Until 1965 to 1970, pastured fallow gave considerable forage production. These fallows play an important role in livestock feeding. Their forage production is low, and sometimes extremely low (100-200 FU/ha), because of a degradation in the frequency and diversity of spontaneous flora. Several elements are responsible for this phenomenon:

- deep cultivation using moldboard and disc plows because alternative, more advanced equipment is not developed or available;
- excessive use of herbicides, particularly 2,4-D;
- overgrazing;
- impoverishment, degradation and erosion of soils.

In some cereal-growing regions where adjacent marginal land or maquis vegetation is rare, lambs are maintained from November to the beginning of May on pasture fallows. The weak production of pasture in fallows can result in inadequate sheep nutrition and the loss of 10-15 kg of liveweight per head. They remain undernourished until July-August when they can make compensatory weight gains on cereal stubble. Lambing generally occurs in the fall or winter when the lack of forage is most acute and this results in a high level of lamb mortality.

This necessitates an improvement in forage production on these fallows. In remote regions where mechanization and use of herbicide are absent, fallow flora is rich in annual medics. The cereal/*Medicago* system has always existed on land where cultivation of soil is not mechanized (Abdelguerfi and Abdelguerfi-Berrekia 1987).

This system should not be considered new in Algeria or in any part of the Maghreb. It is simply a return to an old tradition of grazing indigenous annual medics and other native legumes. Several elements are necessary to revive the system: adapted legume seed stocks; proper cultivation of soil, and proper flock management.

Adapted plant material must be found. A mixture of several species is essential in regions known for erratic climatic conditions. Changeable microclimatic and edaphic conditions are buffered by a diversity of adapted species (Abdelguerfi *et al.* 1989a,b). Collection, evaluation and exploitation of local populations of annual medics began in 1971/72 (Abdelguerfi 1989).

Cultivation of the soil must be studied based on three points:

- an evaluation of appropriate cultural conditions for optimum wheat production;
- the stock of medic seed necessary for regeneration of medic with enough excess to allow for some mismanagement;
- weed control, especially of brome.

Flock management is connected to extension. However, complementary forage systems will help make the medic system succeed. For example, green barley could be introduced alongside annual medics. In effect, cereals (particularly barley) always have been used as a substitute for forage in autumn and particularly in winter.

These feed deficit periods are very difficult for farmers and medics alone cannot satisfy them. Medic is limited by low rainfall conditions in autumn, slow growth or death due to cold conditions and overgrazing. Barley does not compensate for any of these problems; however, the farmer can adopt a strategy according to the conditions of the year. For example, barley can be grazed once or several times during winter (Lelievre 1981), but when other forage is available (fallows, rangelands) and/or the year is good, the farmer can grow barley to maturity. Triticale also can be treated in this way.

In other respects, medics do not constitute the only alternative for increasing forage production of fallow and marginal zones. For example, some vetches grow spontaneously in rotation with cereals. *Hedysarum*, particularly *H. coronarium* and *H. flexuosum* in the north and *H. carnosum* and *H. spinossissimum* in the south, also can be exploited. Other reseeding annual legumes include *Scorpiurus*, *Lotus*, *Trifolium* and *Onobrychis*. Importantly, some of these species can be used efficiently for protecting soils against erosion on sloping ground, a major problem in Algeria.

Littoral Zone and North Tellian Zone

In these two zones, rainfall is generally higher than 600 mm and bovine rearing is the most dominant livestock enterprise. Annual medics are common in these regions; *Hedysarum*, *Trifolium*, *Scorpiurus* and *Onobrychis* are associated species.

Conclusion

Algeria is a country with a rich tradition of sheep rearing. Unfortunately, the attempt to remain self-sufficient in cereal production without proper agronomic practices and management has degraded the soil and resource base over a large area of the country.

Rangelands, steppe and permanent pastures are decreasing in area because of plowing and sowing of cereals. Even marginal zones have been affected. Erosion is ubiquitous and the silting of dams an extreme consequence. Wind erosion is accelerating, especially in the southern zones of Algeria. This past management has caused a decrease in the forage base for feeding livestock, an increase in grazing pressure and degradation on remaining surfaces.

Furthermore, government subsidies for barley have artificially elevated the number of livestock per unit of land which has exacerbated what was already a horrendous degradation of the land.

In addition, agricultural intensification has caused a net reduction in the spontaneous flora having forage value. Vetch/oat mixtures cannot be used in all areas. Neither can medics, but medics could be used to rebuild soil fertility, organic matter and cover in degraded zones. Using medics in fallows or on land not suitable for cereal will help reduce the national forage deficit and improve agricultural output. The reintroduction or recovery of this traditional grazing resource will return the land to a stable pattern of use and possibly diminish the national feed dependency.

References

Abdelguerfi, A. 1989. Les ressources phytogenetiques d'interet fourrager: état de la recherche a l'Institut National Agronomique. Annales de l'Institut National Agronomique, El-Harrach 12(1):95-111.

Abdelguerfi, A. and R. Abdelguerfi-Berrekia. 1987. Le systeme blé/*Medicago*: pourquoi, ou et comment? Cerealiculture 16:44-45.

Abdelguerfi, A. and M. Hakimi. 1988. La regression des milieux naturels en Algerie: Cas des prairies permanentes. Premier Seminaire International sur la Gestion de l'Environnement. Constantine, 27-30 Nov. 1988 (sous presse).

Abdelguerfi, A., J.Y. Chapot and A.P. Conesa. 1989a. Contribution a l'etude de la repartition des especes spontanees de luzernes annuelles en Algerie, selon certains facteurs du milieu. Fourrages 113:89-106.

Abdelguerfi, A., J.Y. Chapot, A.P. Conesa and R. Roseau. 1989b. Contribution a l'etude des especes spontanees du genre *Medicago* L. en Algerie: I. Repartition des especes en fonction des facteurs du milieu. Annales de l'Institut National Agronomique, El-Harrach 12(1):304-328.

Abdelguerfi-Berrekia, R. and A. Abdelguerfi. 1986. Valorisation des ressources phytogenetiques locales d'interet fourrager dans l'amenagement des zones de montagnes. Annales de l'Institut National Agronomique, El-Harrach 10(2):1-11.

Bourahla, A. and G.G. Guittonneau. 1978. Nouvelles possibilities de regeneration des nappes alfatieres en liaison avec la lutte contre la desertification. Bulletin de l'Institut Ecologie Appl. (Orleans) 1:19-40.

Bourbouze, A. and P. Donadieu. 1987. L'elevage sur parcours en regions mediterraneennes. Option Medit. IAM. Montpellier: 1-93.

Ducellier, L. 1933. La production fourragere en Algerie, Imp. Vollot, Alger:1-52.

Gachet, J.P. and A. Elmir. 1972. Etude monographique des *Medicago* annuelles. Annales de l'Institut National de Recherche Agronomique, Tunisie 45(1):1-45.

Jarrige, R. 1979. Utilisation des paturages des milieux defavorises: essai de conclusion. Pages 541-565 *in* Utilisation par les Ruminants des Paturages d'Altitude et Parcours Mediterranéens. 10e journées du Grenier de Theix, 1-3 Juin 1978. INRA, France.

Laib, M. 1988. Evaluation des bilans fourragers à travers les differents plans de developpement et leurs impacts sur le cheptel national (bovin-ovin-caprin). Thèse Ing. INA, Alger.

Lapeyronie, A. 1982. Les productions fourrageres mediterranéenes. Ed. Maisonneuve et Larose, Paris:1-425.

Laumont, P. 1948. Le probleme de l'affouragement du cheptel algerien. Imp. Gulauchain, Alger:1-31.

Laumont, P. 1960. Les prairies naturelles en Algerie. Documents Rens. Agric. 5:1019.

Le Houerou, H.N. 1971. Les bases ecologiques de l'amelioration de la production fourragere et pastorale en Algerie. 1ère partie: bioclimatologie, cultures fourrageres. FAO Rome:1-58.

Le Houerou, H.N. 1985. La regeneration des steppes algeriennes. Rapport de mission de consultation et d'evaluation 18/11 au 2/12/85:1-45.

Lelievre, F. 1981. L'appoint fourrager par deprimage des cereales au Maroc: differentes situations et premières études experimentales. Fourrages 88:73-94.

Moskal, L. 1983. Bilan fourrager en Algerie du nord. I. Bilan energetique. INA, El-Harrach:10-49.

Ozenda, P. 1980. Flore du sahara. Ed. CNRS, Paris:1-298.

Pouget, M. 1980. Les relations sol-vegetation dans les steppes sud-algeroises. ORSTOM 116, Paris.

Ley Farming in the Mediterranean from an Economic Point of View

T.L. Nordblom
ICARDA, Aleppo, Syria

Abstract

Several important socioeconomic contrasts can be noted between conditions in Australia, where ley farming was developed, and conditions in countries of the WANA region: (1) large vs. small land holdings, (2) large vs. small flocks of sheep, (3) high vs. low wage:sheep price ratios, (4) fences vs. shepherding for control of grazing, (5) wool vs. milk and lamb production, and (6) simple diets of sheep in sedentary operations vs. complex diets achieved through mobility of flocks. Because of the high costs of fencing the small, narrow strip fields typical in the WANA region, this technology will not be useful to most farmers. Grazing control by shepherd has the disadvantage that pasture is left vulnerable to grazing by others' flocks. These socioeconomic conditions do not favor introduction of ley farming on the great majority of farms in the WANA region. Extension work on ley farming should be targeted toward those farms with suitable land, labor and management conditions (i.e., larger farms facing high labor costs and with round-the-clock ability to protect and manage their pasture).

Introduction

Economics is about constrained choices of alternative means for satisfying multiple objectives. This paper highlights the economic issues that farmers, villages and governments in the Mediterranean Basin face with regard to the introduction and maintenance of ley farming systems.

Ley farming refers to an integrated crop/livestock/pasture system in which crops are grown in rotation with self-regenerating annual pastures. Australian ley farming systems combine rotations of dry-farmed cereal crops with annual *Medicago* spp. or subterranean clover pasture grazed by sheep on mechanized farms with large fenced fields. In his classic description of farming systems in the tropics, Ruthenberg (1980) gave a broader definition, distinguishing between types of ley systems:

> The word 'ley' is used wherever several years of arable cropping are followed by several years of grass and legumes utilized for livestock production. A distinction is then made between unregulated and regulated ley systems. Unregulated ley systems in the tropics are characterized by a natural fallow vegetation of various

grass species, a certain amount of bush growth on the pasture, communal grazing and a lack of pasture management, all of which make such systems often more akin to short-term fallow systems than to regulated ley systems. Individual grazing, fencing, pasture management and rotational use of grassland are the usual characteristics of regulated ley systems.

Australian ley farming systems are clearly identified as 'regulated leys,' according to Ruthenberg's typology. The socioeconomic prospects for introducing some form (not necessarily the Australian form) of regulated ley farming with annual pasture legumes in the Mediterranean Basin are examined in this paper. Issues of grazing access, property rights and land-use management are touched on first. Discussion on the economies of scale in shepherding and fencing raises distinctions among countries of the Mediterranean Basin and with the USA and Australia. Information from various sources on flock sizes, economic purposes and forms of management allows further contrasts among countries. Finally, the requirements for economic success of ley farming are outlined in terms of balances of crop, pasture, feed, sheep, labor and cash. Much work remains to be done and this is outlined here.

Transhumant Shepherding

Let me begin with some recollections from my boyhood some 40 years ago in Antelope Valley, the western part of the Mojave Desert of California. The area has much in common with the marginal and steppe lands of Syria (i.e., the same north latitude, elevation and Mediterranean climate). I remember the arrival of large flocks of sheep in the valley at the beginning of winter, brought down from their summer pastures in the California mountains when the snows began to fall. Their transhumant shepherds were attracted to the grain and alfalfa stubble which could be negotiated for grazing at low cost from local farmers.

The shepherds were Basques, from northern Spain, who had been contracted for this work by commercial Basque/American sheepmen. They were equipped with water-tank trailers and troughs, small trailer houses, pickup trucks, trained dogs and great rolls of wire sheep fence. The latter could be quickly erected as a barrier to separate the sheep from the paved roads and fast traffic. Even as a boy, I remember being surprised at the mobility of these flocks—appearing one day, several hundred sheep grazing a stubble field, with fence and trailer camp established—then disappearing to a new location.

I recognized that being a shepherd, like those Basques, was serious business. They were with the flock continuously and it was a 24-hour-a-day, 7-day-a-week job. They had to have the ability to follow the feed wherever it was available cheapest and best, given the condition of their flocks.

In those days, the valley was widely covered with irrigated alfalfa fields and considerable areas of rain-fed cereals; many sheep flocks wintered there. Today, the pumping of groundwater has become so expensive, the water table having been drawn down over the years, and land taxes have gone so high that many of the irrigated farms have gone out of business. Flocks still come in the winter but their numbers have dropped. Few people want to be a shepherd anymore; it is a rigorous life and filled with trouble. There are more people wherever one goes in California today. With them have come pet dogs running wild, more roads, more laws, less open space and less free access to pasture.

Transhumant shepherding has a vastly longer history in the WANA region but is facing difficult problems and rapid change today (Chatty 1986; Lewis 1987). I have related my personal observations from home in Mediterranean California because the economic categories of factors of production (land, labor, capital and management) that need to be considered in the establishment of ley farming are the same in Mediterranean West Asia and North Africa (WANA). Also, many of the same forces causing the disappearance of transhumant grazing in California are at work in the Mediterranean Basin. There are trends toward greater sedentarization of livestock production.

Management of Grazing Lands

Property Rights

Property (access) rights are human institutions created by the society that defines and enforces them. These vary from country to country and are subject to change by gradual evolution and by revolution.

Usufruct (the right of using and enjoying the fruits or profits of something belonging to another) has been observed by some pastoral groups with regard to the crop residues and weedy fallows of sedentary farmers. Tactical might and mobility of pastoralists have contributed to the perpetuation of such 'access' rights in some parts of the region. Farmers face obvious economic losses if their crop stubble and fallow lands cannot be protected from grazing by the livestock of others.

The transaction costs of prosecuting a minor offence, such as the wrongful grazing of one's pasture, are high relative to the satisfaction that may be gained by the plaintiff and the chances of conviction are low. This is more the case if the pasture is small, its boundaries are poorly marked and the condition of the pasture is poor. The defendant (shepherd) may claim innocence based on lack of notice or on false charges, because bare ground cannot be damaged by sheep. Because of this, village-wide agreement to limit trespass accidents is essential if ley pastures are to be successfully managed as the enterprises of individual farmers.

According to Hardin's (1968) article on the "tragedy of the commons," as long as an individual benefits from increasing his own offtake from a common property renewable resource (by increasing the size of his own flock in a common grazing area, for example), he will have an incentive to do so. The combined effect of many individuals doing the same thing is to destroy the resource or reduce its productivity to a very low level. The cultivation of barley in the common grazing lands of the Syrian steppe can be cited as an example of destructive exploitation of resources (Manners and Sagafi-Nejad 1985).

Similar depletions of forest, groundwater and ocean fishery resources provide other important examples of the "tragedy of the commons." Each user of the resource has an incentive to ignore the social costs of his behavior for fear that others will take the benefits before he does. Grazing of native pastures and of fallows in the Mediterranean region often has such characteristics. Individual farmers cannot afford to unilaterally invest in improving a common pasture because free riders will take the benefits.

Land-use Management

Collective agreement and action on land-use management for the benefit of the community (a hallmark of civilization) are certainly not unknown in villages of the Mediterranean and elsewhere. Wade (1987) points out that collective action at the village level may include setting and observing a rule of restrained access to a common resource with the desired result of sustainable exploitation. An example from India is given of arrangements by which village guards and privately hired guards monitor the day and night grazing of fallows and field boundaries by village animals, preventing them from damaging standing crops and thievery of trespassing animals.

Examples where arable lands of a village are divided into two or more large contiguous blocks of smaller private fields for the purpose of economical separation of crop and livestock grazing activities have been noted in Syrian history by Lewis (1987). Each family would have fields in the two blocks; cropping and fallow grazing are then rotated between blocks from year to year. This author has noted this form of land-use management in the village of Cukurbag in the Toros Mountains of Turkey. These are forms of regulated ley farming systems, which operate with communal grazing of the village flock, but productivity of the weedy fallow grazing is low.

Islamic Sharia law decrees that land owned by an individual passes to his inheritors after his death. Although the number of inheritors may vary as years go by, it does increase, leading to land fragmentation (Qasem 1984). Sometimes the division of land among heirs is made vertically on slopes so that all recipients receive equal proportions of good bottom land and poorer stony land on the hilltops and this leads to accelerated soil erosion. This, combined with the effect of reducing farm sizes to uneconomic scales, causes land fragmentation to be considered one of the major constraints on agricultural development in the rain-fed lands of Jordan and elsewhere in the region (Duwayri 1985).

According to Lewis (1987), block rotations of crops and fallows by agreements within a village serve to minimize the problem of combining the two fundamentals of the farming system, grain-growing and shepherding, since it is easy to keep the sheep on the uninterrupted areas of fallow land and off the blocks that are under crop. In the context of conflicts between farming villages and nomadic tribes of central Syria in the 1800s, Lewis noted that such a land-use plan also gave the security advantage that most farmers plowed and harvested within sight and sound of one another.

Villages throughout the transitional zone of central and northern Syria still organize their farming operations so that big blocks of crop-bearing land alternate with similar areas of fallow (Lewis 1987). Although less common today than in the past, the Musha system of communal ownership, land allocation and reallocation for farming among members of village communities provides another example of agreements that serve common interests (Rafeq 1984). Seeden and Kaddour (1984) assert that this system of land distribution and use "is clearly of peasant origin" and that villages with such systems were extremely robust, healthy and balanced social and economic organizations. Small irrigated tenancies of the Gezira Scheme in Sudan have for many years been managed under government authority in large contiguous blocks for the economical delivery of inputs such as canal water and aerial sprays for insects in cotton. These and the above examples show how, through agreements on land use among members of a community, desirable outcomes such as crop protection, grazing control and security can be achieved economically (i.e., without the costs of protecting each field separately).

Springborg (1986) argued that while the transfer of ley farming technology is easiest where the target group is comprised of large private farmers, considerations of equity and the fact that most farmers in the region have small holdings raise serious doubts about the appropriateness of this. The possibility of targeting the custom equipment contractors who perform much of the tillage work for small farmers was raised because the right equipment and understanding on their part may be necessary to sustain ley farming. Springborg reported that agricultural cooperatives have generally not been successful targets for ley farming technology because of failures at organizational and operational levels; the one exception he named was the Jordanian Cooperative Organization, particularly in its equipment operations.

The prospect of establishing ley farming systems with proper pasture management on a whole-village basis suggests itself, particularly where there are traditions of village-level agreements on organizing the management of small plots in block-wise rotations of crop and fallow (or other crops). Participation in the costs and benefits of the grazing will likely be the thorniest issue to resolve, but there seems to be no good reason why this cannot be done. More discussion on this is needed, but several other points should be covered first.

Protection of Livestock

Perhaps wherever sheep are raised they face hazards of harassment and injury by dogs and wolves and of theft by people. The potential economic losses from these threats are the inspiration for remarkable investments in protective measures. These include, among others: (1) the famous 'dingo fence', which cordons off the southeastern third of Australia for sheep, separating them from the wild dogs beyond; (2) the fortress-like sheep-fattening houses of Aleppo; and (3) the 24-hour-a-day watch by the Basque and Bedouin transhumants of California and WANA, respectively.

While there is no doubt of the existence and purpose of the dingo fence in Australia, nor doubt that it is the longest fence in the world, there is disagreement among sources as to its exact length: the Guinness Book of World Records (1988) reports that it stretches 3437 miles (5500 km) and Christmas (1986) states that it runs 6000 miles (9600 km), but indigenous workers give it a mere 2208.6 km (Webber and Nash 1980). These three sources come close to agreement on the height of the dingo fence, however: about 1.8 meters. Discrepancies regarding its length may be partly due to the fact that successions of dingo fences were built over the years, enclosing ever larger areas, as human settlement pushed further inland from the coast (Don Walsgott, personal communication). Whatever its exact length, one may be impressed with the scope of the investment and community agreement undertaken to exclude the dingo from the main sheep areas of southern Australia.

The high labor costs in North America and Australia preclude close herding of livestock. According to Doyle (1980), all livestock in Western Australia can be run in open paddocks throughout the year, with no shepherding and minimum handling. The costs of establishing fences, watering points and salt licks for grazing animals are balanced against labor costs, which are high relative to the value per unit of the resulting livestock products.

In contrast, lower opportunity costs for labor and higher relative values of livestock products in West Asia and North Africa mean that the movements of livestock are usually guided by herdsmen. Without the aid of fences, they are able to concentrate on patches of high quality or underutilized grazing, thereby making the best use of available feed (Sandford 1983). Sheep are thus given access to a wide and changing smorgasbord of feed throughout the year.

"Schools are the enemies of sheep" was the comment made to the author by a Syrian farmer who was making the point that life has changed from the days of his youth when boys spent much of their time shepherding. There was only mock remorse in this farmer's emphasis on the loss to sheepraising when the shepherds are sitting in school rooms; he was clearly pleased that all his children were in school, hoping to become engineers or doctors. A few farmers still see the need to keep some of their children (especially the girls) out of school to help with the farm work, particularly shepherding.

Economies of Scale in Shepherding and Fencing

It is worth noting the effects of the number of sheep and the shepherd's daily wage on the cost of controlling the daily grazing by sheep (Fig. 1). A quick look at daily wage rates for farm labor around the Mediterranean Basin reveals contrasts in opportunity costs for shepherds. In the Maghreb countries of Morocco, Algeria and Tunisia, daily

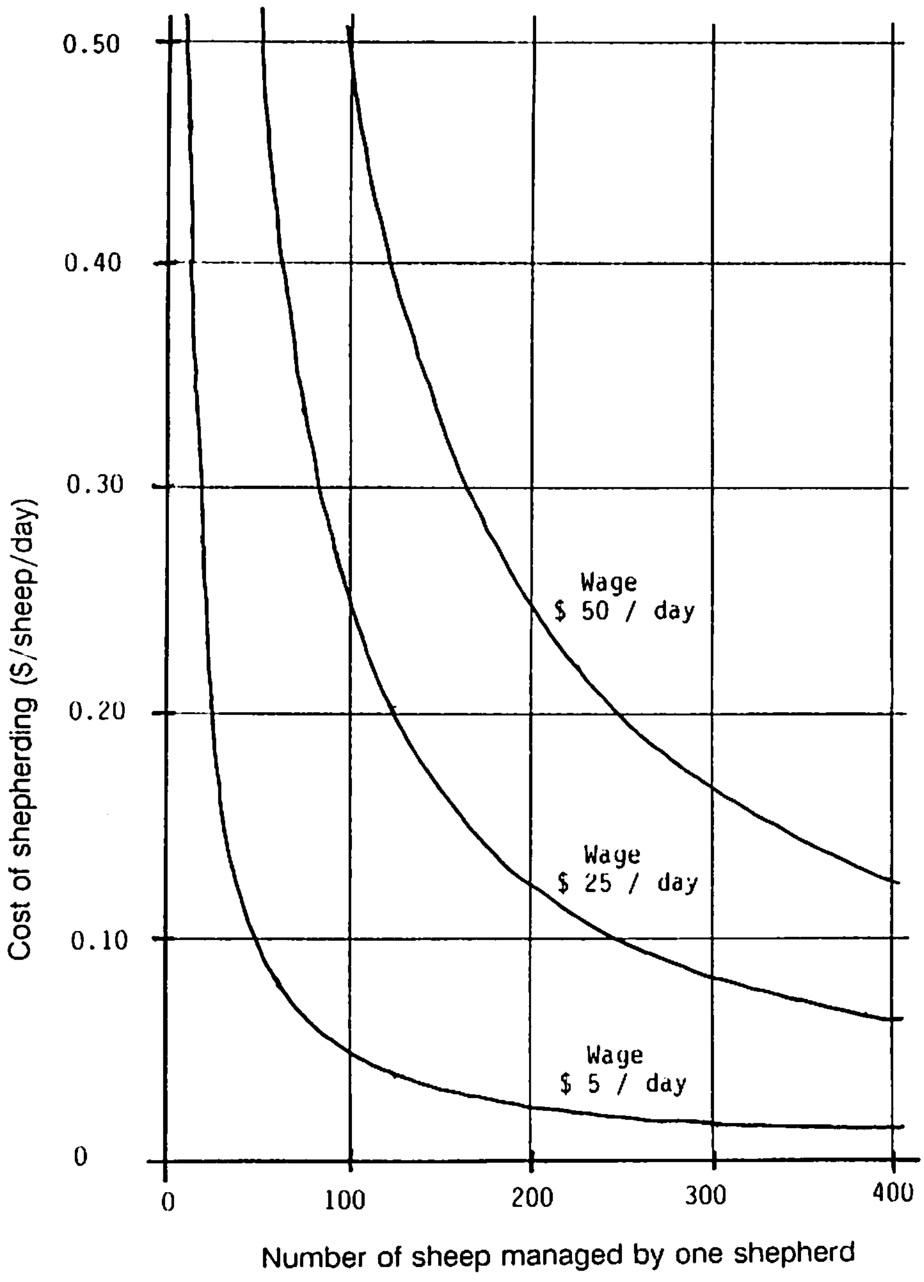


Fig. 1. Cost of shepherded control of sheep as a function of daily wage and sheep numbers per shepherd.

wages are about USD 4; in Egypt, USD 5; Jordan, USD 6; Syria, USD 4; Cyprus, USD 10; Turkey, USD 8; Italy, USD 50; France USD 30 and in Spain, USD 30. Daily wages average USD 45 for farm workers in the USA and Australia. The point is that shepherding a small number of sheep is far more expensive on a per head basis than shepherding a larger number, but the daily wage of the shepherd is of pivotal importance in determining costs of grazing.

Only some of the roles of the shepherd can be replaced by capital investments in fencing. A fence merely contains the sheep in a given field, but will usually not on its own protect the animals from predators or thieves. Provision of watering facilities within the fenced paddock also will be necessary if sheep are to graze with low labor inputs. Otherwise, sheep must be trekked to water, which requires so much labor that the original justification of fencing (saving labor) is sharply diminished.

A shepherd moving with a number of sheep may direct them to different grazing areas each day or move them gradually across a given grazing area from one day to the next. This great flexibility to move sheep wherever the cheapest good feed is found would perhaps be impossible to achieve with a system of fences. Sheep diets in the Mediterranean Basin vary through the course of an annual cycle, comprised chiefly of hand-fed materials in winter and shifting to various grazing sources in the spring, summer and fall, as they become available (Cocks and Thomson 1988; Nordblom 1987; Nygaard and Amir 1988).

The degree of control the shepherd exercises over a flock is remarkable to western eyes: disciplined movement of sheep across roads, down country lanes between standing crops and a sort of precision grazing of one plot without disturbing the crop in the adjacent plot. Sheep in the Mediterranean region are typically tame because of daily handling. They are often seen following their shepherd as they are trekked from their village to the day's grazing area and back again.

However, the shepherd's attention occasionally may lapse, intentionally or otherwise, and sheep wander to forbidden plots wherein promiscuous or accidental grazing may take place. Because such promiscuity is so difficult to prevent and to prove on a practical basis, one finds some districts (especially those with valuable tree crops) where grazing is simply banned altogether.

Fences give excellent protection from accidental grazing but only fair protection from promiscuous grazing by another's sheep. The distinction between these two sorts of wrongful grazing exists because most shepherds would never intentionally damage what is known to belong to another; on the other hand, the sheep will follow their own appetites if allowed to do so in an unfenced area and there are temptations for some shepherds to take advantage of the ease with which a fence can be cut (or stolen) if left unattended.

Where fences do stand, however, they are more effective than a shepherd in clearly showing the borders of a plot that is being managed in a way that limits (or prevents) grazing at critical times in a production cycle (i.e., at flowering or in late summer when a minimum amount of seed pods must be left on the ground to allow future regeneration of the pasture). It is neither easy nor cheap (on a per hectare basis) to post a continuous guard for the prevention of grazing of a small unfenced field that appears to contain little more than bare ground. Fences serve such passive sentinel roles well.

Two minor problems with a fence are that it may interfere with traditional freedom of movement of flocks and that it interferes with mechanized tillage operations, thereby creating a niche for unwanted flora and fauna along the base of the fence. However, the greatest problem with a fence is its high establishment cost. Further, small fields are much more costly (on a per hectare basis) to fence than large fields and long, narrow fields are far more costly to fence than square or circular fields; the latter will contain the largest area for a given length of fence.

The total perimeter length (P) in meters and cost (C) of establishing a fence around a rectangular field are a function of the field's length (L) and width (W). Assuming a field length of 500 m,

$$P = 2(L + W) = 2(500 + W)$$

Assuming each meter of sheep fence, including fence posts and labor, will cost USD 1, the total cost of the perimeter fence will be:

$$C = (\text{USD } 1)P$$

Given a field length of 500 m, the area (A) of the enclosed field, expressed in hectares (1 ha = 10 000 square meters) is:

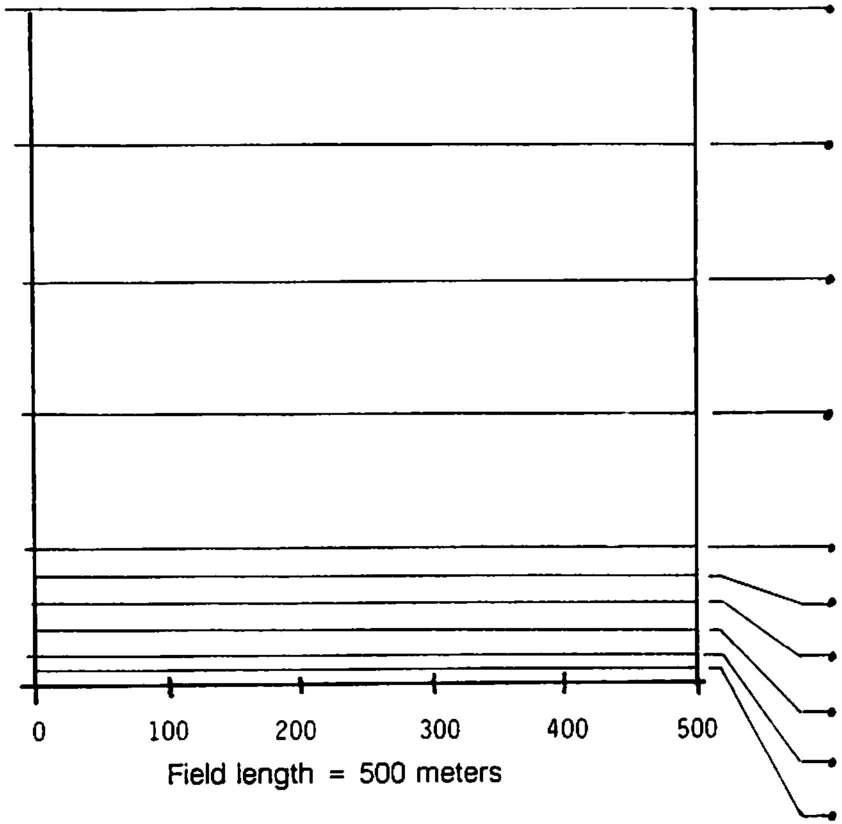
$$A = (L\ W) / 10\,000 = (500\ W) / (10\,000)$$

Finally, the cost per hectare of enclosing a 500-m-long field will be inversely related to the width of the field (i.e., the wider the field, the less cost per hectare), as shown by the following formula:

$$\text{Cost per hectare} = C / A = \frac{(\text{USD } 1)\ 2(500 + W)}{(500\ W) / (10\,000)}$$

Fence costs per hectare are illustrated in Fig. 2. It is shown that a 0.5-ha field, 10 m wide and 500 m long, would cost the equivalent of USD 2040/ha to fence. Fields of such awkward dimensions are, unfortunately, common in the Mediterranean Basin because of fragmentation caused by inheritance and policies inimical to aggregation of larger holdings. A field 20 m wide, just 10 m wider than the first, although costing only half as much per hectare to fence, will still be very expensive. The reader can see, in Fig. 2, that subsequent widening of the field dramatically reduces the cost of fencing per hectare.

Fig. 2. Fence establishment costs per hectare for fields 500 m in length and of different widths.



Field width	Area	Establishment cost/ha
500 m	25 ha	$ 80
400 m	20 ha	$ 90
300 m	15 ha	$ 107
200 m	10 ha	$ 140
100 m	5 ha	$ 240
80 m	4 ha	$ 290
60 m	3 ha	$ 373
40 m	2 ha	$ 540
20 m	1 ha	$ 1040
10 m	0.5 ha	$ 2040

A 25-ha square field, 500 m on each side, would cost only about USD 80/ha to fence. It is significant that a field of this size would be considered a relatively small paddock in Australia, but an unusually large field in Syria.

The decision on whether or not to fence a field, which is an important investment expense in any country, will depend upon a number of points already mentioned (the costs of shepherding, the cost and probability of losing the regenerative capacity of the pasture through promiscuous grazing by other's livestock, the size and shape of the field, the cost per meter of fence, the security sheep would have from predators or thieves if left unattended in a fenced field overnight, availability of watering facilities in the field) and several other key points:

1. The expected life of the fence (i.e., 10 or 20 years?);
2. The productivity of the fenced pasture (i.e., annual stocking rate or number of grazing days);
3. The timing of pasture availability under different use-options, vis-a-vis the timing and costs of other potentially available feeds and pastures (related to point 2 above).

Even though they are both expressed as 365 grazing days, one sheep grazing for 365 days is not the same as 365 sheep grazing for one day. The reason the two cases are different is that the opportunity cost (or cost of the next cheapest alternative) of grazing one day with 365 sheep will depend very much on which day of the year it is. The same amount of grazing in midwinter may be worth far more than it is in midsummer when abundant cheap alternatives are available.

If the discussion is limited to the consideration of pasture use at a particular time (or times) of the year, its value, in terms of the cost to replace it with other available materials, can be determined. A further assumption is that with either a fence or a shepherd the pasture could be used over the same time period, when it is at its best advantage with respect to other alternative feed sources.

From Figure 1, it is clear that the cost per head per day of shepherding is a function of the daily wage and the number of sheep handled. Given a fixed wage and number of sheep, the cost per hectare for shepherding the grazing of pasture is a linear function of the pasture's productivity. With cost of grazing control per hectare on the vertical axis, and pasture productivity (in terms of grazing days and annual stocking rate) on the horizontal axis, the solid rays from the origin in Figure 3 are shepherding cost functions with different daily wages and sheep numbers. These may be compared, at any stocking rate, with the costs of fenced control for pastures of 500-m length and various widths, assuming a 10-year life for the fence.

The dashed rays from the origin of Figure 3 represent the values of the pasture at different levels of productivity. One important aspect of this value (in addition to replacement cost, as mentioned above) is that it is derived from the value of the sheep products. By halving the value of sheep products from the pasture, the value function can

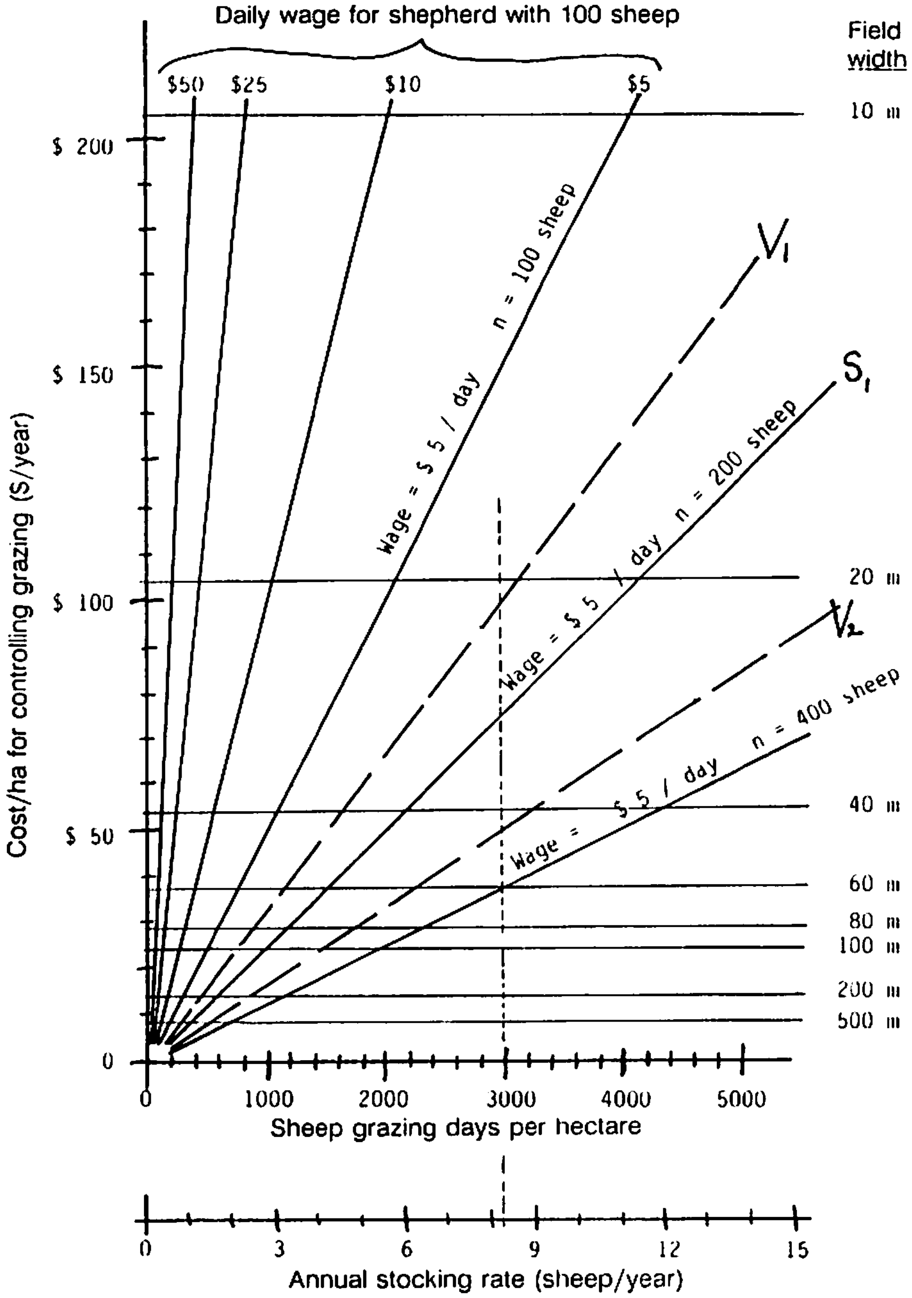


Fig. 3. Comparisons of shepherding and fencing costs per hectare for a field 500 m in length, at different widths and different wages and numbers of sheep per shepherd, as a function of annual stocking rate and assuming 10-year fence life.

shift from V1 to V2, for example. This would be sufficient to make shepherding at the level of S1 (with wage = USD 5 and 200 sheep per shepherd) no longer economical. At an annual stocking rate of just over 8 sheep/ha (3000 grazing days), however, the establishment of a perimeter fence of 60 or more meters in width remains economical. Note that the opportunity cost of the capital (expressed as interest or otherwise) required to establish the fence is ignored here with a simple focus only on depreciation costs. Likewise, salvage values of fence posts, etc., are ignored here.

Figure 3 contains the briefest summary of why we do find shepherding a common practice and fenced pastures almost unknown in the WANA region, and the reverse in Australia and the USA.

The trend toward greater levels of education (i.e., investment in human capital) and greater opportunities for off-farm employment is general across the WANA region. Literacy levels and other measures of education vary among countries of the region, as do the rates of change in these measures. Increases in the efficiency of lamb production and greater quantities marketed (which are among ICARDA's goals) will reduce meat prices, the value per head of sheep and the value of pasture. The point is that a trend toward higher opportunity costs for labor, and lower sheep values, will inevitably result in a trend away from shepherding as a means for controlling livestock movements.

Averages of the author's 1965 and 1985 estimates of crop residue use, as percentage of dry matter in ruminant diets, for the rain-fed farming countries of the Mediterranean region (Nordblom 1988) are: Algeria, 18; Jordan, 21; Libya, 7; Morocco, 20; Syria, 35; Tunisia, 23, and Turkey, 23. Crop residues are complemented in ruminant diets chiefly by grazing of rangelands and fallows and to a lesser extent by feed grains and by-products of agricultural processing. An independent estimate for Syria in 1977 (USDA *et al.* 1980) indicated that 39% of dry matter in livestock diets was from crop residues (reasonably close to the author's 35% estimate) and another 39% was from grazing sources (of which rangelands contributed 34%, fallows 4% and sown pastures 1%). Livestock in the other named countries of the region appear to depend more on rangeland and fallow grazing sources than those in Syria. In all these countries today, the capture of grazing value from rangelands and fallows is accomplished chiefly by shepherding.

Flock Sizes, Purposes and Management

In the USA, according to Scott (1982), small flocks of 10 to 100 ewes often are poorly managed, mechanization is not feasible and return per hour of labor is not great. Since the major income to these producers is derived from other sources, adequate attention may not be given to selection, nutrition, reproduction and animal health. At the other extreme of flocks that are too large, additional labor must be hired and sheep are not under constant surveillance of the manager. Labor requirement per ewe declines, but production per ewe also may decline. Scott indicated that sheep production may be most profitable where it is the major source of income to the producer and where the commercial flock size is 1000 to 2000 ewes; this allows economic use of buildings, corrals and feeding equipment, and more intensive management practices. In the cereal and sheep areas of Western Australia, most farms carry sheep for wool production and typical flock sizes are from 2000 to 3000 head, with a range of 500 to 5000 or more (Doyle 1980).

Wool and lamb sales are the chief sources of income from sheep flocks in Australia and the USA. The milking of sheep is practically unknown. Goats, in far fewer numbers and managed separately from sheep, are milked for home use and a minor market for specialized dairy products. Sheep grazing is controlled by fence in large paddocks, with strategically placed watering points. Shepherding of small flocks without the aid of fences is rare indeed. Community and government action achieves fair protection of sheep from predators and theft, through control programs (including dingo fences) and effective law enforcement, respectively. The value of one sheep often may not reach the level of the daily wage of an ordinary farm worker. These observations are in contrast to what is found in the WANA region.

Several reviews of livestock/crop/rangeland balances in the WANA region are available and these provide information for future research directions (Carter 1978; Faulkner 1978; Gurdon 1985; Leewrik 1975; Jaradat 1988; Tully 1986). These are complemented by a number of local surveys.

Dairy sheep and goats in Turkey are often in small family flocks of 3 to 10 animals for home consumption of yogurt and cheese. In some cases these small flocks are brought together into medium-size groups of 200 to 300 head for grazing common pastures under the care of shepherds. Single-farm flocks of 100 to 400 head are found where large farms are adjacent to grazing lands. Less commonly, large flocks of 500 to 2000 ewes under the care of herders follow a migratory system, moving from the plains, dry pastures and crop residues to upland grazing areas from season to season. These large flocks, consisting of both sheep and goats, are sometimes owned by people living in a village or may be owned by tribes of people not settled in villages (Sonmez and Ozkan 1983).

A survey of 156 barley farmers in southeast Turkey in 1984/85 found that livestock holdings of an average household included 25 sheep, 7 goats and 2 cattle (Yurdakul *et al.* 1987). Tully's (1984) survey of farmers nearby in the Al Bab area, north of Aleppo, Syria, found a similar average flock size of 25 sheep and goats per household.

In a survey of 48 sheep-owning farmers in southern Idleb Province, 100 km south of Aleppo (Nordblom 1987), 44 reported having ewes, two farmers said they had 500 head or more, another seven reported having 150 or more while among the remaining 35 farmers the average number of ewes was 41 head (standard deviation of 33 head).

Another survey in the same area, but covering 119 sheep-owning farmers, found similar flock sizes and described the composition of the value of sheep production as 5% from wool, 28% from dairy products, 63% from the sale of lambs and ewes and 4% from the production of meat (Sting 1987). These 'share-of-sheep-income' figures are comparable with the estimates of 5% from wool and 20% from dairy products, given by Thomson and Bahhady (1983) for Aleppo province.

The ratio of income share from wool to that from dairy products is 0.18 according to the above estimates of Sting, and 0.25 according to those of Thomson and Bahhady. Wool and dairy income figures for Al-Fadl and Al-Hassanna Bedouin flocks in Syria, as reported by Chatty (1986) for 1963 and 1973, give ratios of 0.18 and 0.21, respectively, which match well with the other indications. Wool thus gives only a fifth to a quarter the level of income expected from sheep dairy products in Syria.

A survey of 17 semi-nomadic and settled sheep-owning farmers in the cultivated margin of the northwest Syrian steppe, from 1979 to 1981, showed an average flock size of 238 head with a range of 20 to 793 head (Thomson *et al.* 1989).

In a survey of 130 farmers on the northwest coast of Egypt (in the Mersa Matruh and Sidi Barani areas) 126 had small ruminant animals, with average holdings of 117 head (88 sheep and 29 goats); these are typically herded in flocks of 50 to 60 animals under the watch of a single shepherd (Najjar *et al.* 1988).

The common features in the above examples from Turkey, Syria and Egypt are that sheep and goats are typically managed in small mixed flocks; they are tame and handled frequently; they are controlled by shepherds, not fences; the value of one ewe is approximately equal to a month's wages for a farm worker; wool is the least important part of livestock income and dairy products for home consumption and lambs for cash sales are the most important; livestock do not represent or indicate wealth, they *are* wealth. Wealth is measured in sheep, not money. To many of these people, livestock are also a means of social fulfillment and personal satisfaction (Miller *et al.* 1979; Livingstone 1987; Ruthenberg 1980; Sting 1987).

Balancing Feed, Pasture, Sheep, Labor, Cash and Crops

Whenever an intervention or new technology in a farming system has its effects through interactions among several components of the system, which cannot be analyzed with a simple budget, there is a case for whole-farm modeling. Such cases arise frequently where changes in the system affect livestock feed supplies in any way. The introduction of a ley farming system is a prime example.

According to Dillon (1977), five major complexities must be allowed for in any reasonable model of the pasture-livestock complex:

1. The possibility of innumerable systems of grazing arising from the possible combinations of various time sequences of input injections and output harvests; each system will have its own response function (also see Doyle 1987);
2. The multi-stage nature of the overall production process; pasture is one stage and its grazing for livestock production is the next;
3. These two production stages are not independent; livestock influence pasture output and vice versa, so allowance must be made for their simultaneous determination;
4. Allowance must be made for the possibility of conserving some pasture, as hay for example, for later injection into the livestock process;
5. Livestock make decisions and have variable appetites; this raises the importance of information on voluntary intake of the various feedstuffs.

The complexity of the possible scenarios given these facts requires the use of simplifying and limiting assumptions which allow progress toward reasonable solutions within time and budget constraints. Examples of static whole-farm models that have tackled combined rain-fed crop-pasture/forage-sheep systems are Morrison *et al.* (1986) in Western Australia and Nordblom and Thomson (1987) and Sting (1987) in Syria. An example of a stochastic whole-farm model in which crop and forage yields vary over 5-year run sequences, where feed and sheep inventories as well as cash balances are carried over from year to year, is given for an ICARDA study area in northern Syria by Maerz (1989). This study clearly indicates increases and stabilization in farm incomes over time when fallow is replaced with vetch forage crops, which allows increases in flock size.

The element of time needs explicit consideration in modeling a ley farming system in comparison with existing successful crop rotations. This is because higher costs and lower pasture performances are anticipated in the establishment season of the ley pasture than in subsequent regeneration years. Given that other, profitable, crops may be foregone by the adoption of the ley system, and given a positive time-preference for earnings, a 6-year time horizon is proposed for the analysis (Nordblom 1987). This allows comparisons with the existing 2-year and 3-year rotations that characterize the current farming systems in ICARDA's ley farming study areas.

Initial results from on-farm and on-station trials in Syria indicate that *Medicago* ley pastures with locally adapted species are able to regenerate spontaneously in rotation with wheat and to support impressive liveweight gains in grazing lambs and milk production in ewes (Cocks 1988; Cocks *et al.* 1989). Rough calculations of the value of this production indicate the need for completing the economic analysis as proposed and collaborating with the national research and extension programs to plan practical, large-scale, whole-village, pilot trial demonstrations in which all field operations are farmer-managed.

ICARDA and the Syrian national program have considerable experience at on-farm trials with pasture, forage and livestock (Erskine *et al.* 1990; Jaubert and Oglah 1985; Thomson *et al.* 1985; Tully *et al.* 1985). The idea for pilot-village trial demonstrations will require a number of additional considerations beyond what has been done in the past in trials with individual farmers.

Because village-wide agreement on pasture and sheep management, as well as block management of crop rotations, is required for the success of such pilot projects, requests to join the project should come from the villages themselves rather than from outsiders attempting to force the idea upon unwilling participants. Village-wide agreements are more difficult to achieve than finding individual farmers who are enthusiastic or just curious about the new system. However, because of the existing traditions of community agreements in many places, there is reason for confidence that villages with the appropriate conditions can be found that will be willing to give the system a try.

Concerns that medic pasture may reduce the yield of the wheat crop growing in rotation with it are being followed up in studies at ICARDA (A.E. Osman, M.J. Jones, H. Harris and N. Nersoyan, unpublished). However, such effects, if they exist, may easily be outweighed by the value of the pasture production. Comparisons of wheat after fallow with wheat after medic may have little practical economic meaning.

Bakhtri (1978) pointed out that success in establishing and maintaining a ley farming system requires that the system be applied in totality, as a package deal including: (1) suitable varieties, (2) introduction of shallow tillage, (3) use of appropriate numbers of sheep, and (4) use of good management practices.

The last point is the most difficult because the concept of pasture management, for the benefit of the pasture plants, is fundamentally lacking among shepherds. This is in contrast to their sensitivity to sheep response to grazing materials of different quality. The idea of considering the welfare of the pasture plant community is generally missing; weeds and native pasture plants are known to persist and appear spontaneously without any input from man. Part of the remedy to this point of view is effective and informed extension, based on demonstration.

The village-wide trial should be designed to take advantage of existing practices of assembling small family flocks into larger ones under the care of reliable shepherds for daily grazing sorties. These shepherds should be the targets for training on the objectives and requirements of the ley farming system. Because the ley pasture plants have long been known to farmers as local weeds, their image must be upgraded to the status of a valuable crop, which has particular management requirements.

Plans for handling possible invasions of non-village flocks should be decided in advance. The cost of a perimeter fence surrounding the entire blocks of land to be managed in the pilot village would not be prohibitive; fencing of subplots likely will be out of the question.

By having an appropriate grazing flock size within clear pasture boundaries, management units would be identified to both protect the investment in pasture establishment and capture the economics of scale. In addition to close monitoring of the biological aspects by scientists and extensionists there is a need for continuous follow-up on the socioeconomic side. Crises of cash flow and feed provision should be spotted in advance and averted in a way that allows the ley system to persist.

The idea for a village-wide system is predicated upon the likelihood of rising wages and falling sheep prices in future years. On the other hand, the success of a ley farming system on small, individually managed, unfenced plots appears to be predicated on the continuation of very low wages and high-priced sheep. Both formulas require village-wide understanding and respect for the grazing management needs of the pasture plants in order to sustain the system.

A significant point is that for the majority of farmers in the Mediterranean Basin, the Australian mode of managing sheep and pasture in a ley farming system will not be feasible. By Australian mode, I mean the use of large fenced paddocks where sheep may safely be left grazing overnight with minimal supervision and where sheep graze ley pastures all year round.

The reasons are that farms are typically too small for economical fencing, given the stocking rates expected, and sheep are too valuable relative to farm wages to risk leaving them unattended in a fenced area anyway. Given that shepherding will remain necessary, options remain open for using a great variety of grazing sources to complement ley pastures.

References

Bakhtri, M.N. 1978. Wheat/forage legume rotations and integration of crop and sheep husbandries in Algeria. Pages 161-166 *in* Technology for Increasing Food Production (J.C. Holmes, ed.). Proceedings of the 2nd FAO/SIDA Seminar on Field Food Crops in Africa and the Near East, Lahore, Pakistan. FAO, Rome.

Carter, E.D. 1978. A review of the existing and potential role of legumes in farming systems of the Near East and North Africa region. A consultant report to ICARDA. Waite Agricultural Research Institute, Adelaide, SA, Australia.

Chatty, D. 1986. From camel to truck: The bedouin in the modern world. Vantage Press, New York.

Christmas, L. 1986. The ribbon and the ragged square. Viking/Penguin Books, Harmondsworth, Middlesex, England.

Cocks, P.S. 1988. The role of pasture and forage legumes in livestock based farming systems. Pages 3-10 *in* Nitrogen Fixation by Legumes in Mediterranean Agriculture (D.P. Beck and L.A. Materon, eds.). Martinus Nijhoff Publishers, The Netherlands.

Cocks, P.S., H.S. Edo and B. Mawlawi. 1989. Adapting the ley farming system to conditions in west Asia and north Africa. Pages 11-29 *in* Annual Report, Pasture, Forage and Livestock Program 1988. ICARDA-144 En, ICARDA, Aleppo, Syria.

Cocks, P.S. and E.F. Thomson. 1988. Increasing feed resources for small ruminants in the Mediterranean

Basin. Pages 51-66 *in* Increasing Small Ruminant Productivity in Semi-Arid Areas (E.F. Thomson and F.S. Thomson, eds.). Kluwer Academic Publishers, Dordrecht.

Dillon, J.L. 1977. The analysis of response in crop and livestock production. Pergamon Press, Oxford.

Doyle, C.J. 1987. Economic considerations in the production and utilization of herbage. Pages 217-226 *in* Managed Grasslands (R.W. Snaydon, ed.). Elsevier, Amsterdam.

Doyle, R.J. 1980. The farming and pastoral lands of Western Australia. *In* Field Tour Book, International Congress Dryland Farming, Adelaide, SA, Australia.

Duwayri, Mahmud. 1985. Farm systems in rain-fed areas. Pages 126-158 *in* The Agricultural Sector of Jordan: Policy and Systems Studies (A.B. Zahlan, ed.). Published for the Abdul Hameed Shoman Foundation, Amman, by Ithaca Press, London.

Erskine, W., T.L. Nordblom, P.S. Cocks, M. Pala and E.F. Thomson. 1990. The use of on-farm research as a method of extending legume production in Mediterranean farming systems. Pages 273-282 *in* The Role of Legumes in the Farming Systems of the Mediterranean Areas (A.E. Osman, H. Ibrahim and M.A. Jones, eds.). Kluwer Academic Publishers, Dordrecht.

Faulkner, D.E. 1978. Report on livestock husbandry research and development in ICARDA's Programme of Work. Consultant's report, ICARDA, Aleppo, Syria.

Guinness Book of World Records. 1988. Sterling Publishing, New York.

Gurdon, C. 1985. Livestock in the Middle East. *In* Agricultural Development in the Middle East (P. Beaumont and K. McLachlan (eds.). John Wiley & Sons, Chichester.

Jaradat, A.A. 1988. An assessment of research needs and priorities for rainfed agriculture in Jordan. Jordan University of Science and Technology, Irbid. Published in Jordan by USAID.

Jaubert, R. and M. Oglah. 1985. Supplementary feeding of Awassi ewes in the barley zone of north-west Syria. Paper prepared for the International Conference on Animal Production in Arid Zones, held at ACSAD, Damascus, Syria, September 7-12, 1985.

Hardin, G. 1968. The tragedy of the Commons. Science 162:1343-1348.

Leeuwrik, D.M. 1975. The relevance of the cereal-pasture legume rotation in the Middle East and the North Africa region. Pages 266-290 *in* Proceedings of the Third Regional Wheat Workshop, Tunis.

Lewis, N.N. 1987. Nomads and settlers in Syria and Jordan, 1800-1980. Cambridge Middle East Library, Cambridge University Press, Cambridge.

Livingstone, Ian. 1987. The common property problem and pastoral economic behavior. *In* Agriculture and Economic Instability, I.A.A.E. Occasional Paper No. 4, International Association of Agricultural Economists (M. Bellamy and B. Greenshields (eds.). Grower Publishing, Brookfield, Vermont, USA.

März, U. 1989. Farm Classification and Impact Analysis of Mixed Farming Systems in Northern Syria. PhD Dissertation, Institute of Agricultural Economics and Social Sciences in the Tropics and Subtropics, Univ. Hohenheim, Stuttgart, Germany.

Manners, I.R. and Tagi Sagafi-Nejad. 1985. Agricultural development in Syria. *In* Agricultural Development in the Middle East (P. Beaumont and K. McLachlan (eds.). John Wiley & Sons, Chichester.

Miller, S.F., F.E. Bolton, D.E. Booster, J.B. Fitch, T.L. Jackson, R.F. Miller, T.L. Nordblom and A.H. Winward. 1979. Dryland agriculture in winter precipitation regions of the world: Status of the technical art. Dryland Agric. Tech. Comm., Off. International Agric., Oregon State Univ., Corvallis, Oregon, USA.

Morrison, D.A., R.S. Kingwell, D.J. Pannell and M.A. Ewing. 1986. A mathematical programming model of a crop-livestock farm system. Agricultural Systems 20:243-268.

Najjar, S., E.R. Perrier and M. Shykhoun. 1988. Evaluation of farm resource management in the northwest coast of Egypt. Mimeo, ICARDA, Aleppo, Syria.

Nordblom, T.L. 1987. Farming practices in southern Idleb Province, Syria: 1985 survey results. ICARDA-107 En, ICARDA, Aleppo, Syria.

Nordblom, T.L. 1988. The importance of crop residues as feed resources in west Asia and north Africa. *In* Plant Breeding and the Nutritive Value of Crop Residues (J.D. Reed, B.S. Capper and P.J.H. Neate, eds.). Proceedings of a Workshop, ILCA, Addis Ababa, Ethiopia, 7-10 Dec. 1987. ILCA, Addis Ababa.

Nordblom, T.L. and E.F. Thomson. 1987. A whole farm model based on experimental flocks and crop rotations in northwest Syria. ICARDA-102 En, ICARDA, Aleppo, Syria.

Nygaard, D.F. and P. Amir. 1988. Research strategies for development: Improving sheep and goat production in developing countries. Pages 37-50 *in* Increasing Small Ruminant Productivity in Semi-Arid Areas (E.F. Thomson and F.S. Thomson, eds.). Kluwer Academic Publishers, Dordrecht.

Qasem, S. 1984. Agricultural policy formation and administration. Pages 376-411 *in* The Agricultural Sector of Jordan: Policy and Systems Studies (A.B. Zahlan, ed.). Published for the Abdul Hameed Shoman Foundation, Amman, by Ithaca Press, London.

Rafeq, Abdul-Karim. 1984. Land tenure problems and their social impact in Syria around the middle of the nineteenth century. *In* Land Tenure and Social Transformation in the Middle East (Tarif Khalidi, ed.). American University of Beirut, Beirut, Lebanon.

Ruthenberg, H. 1980. Farming systems in the tropics. Third Edition. Oxford University Press.

Sandford, S. 1983. Management of pastoral development in the Third World. John Wiley & Sons, Chichester.

Scott, G.E. 1982. The sheepman's production handbook. Sheep Industry Development Program, Denver, Colorado, USA.

Seeden, H. and M. Kaddour. 1984. Space, structures and land in Shams Ed-Din Tannira on the Euphrates: an ethno-archaeological perspective. *In* Land Tenure and Social Transformation in the Middle East (Tarif Khalidi, ed.). American University of Beirut, Beirut, Lebanon.

Sonmez, R. and K. Ozkan. 1983. Sheep and goat production systems in Turkey. *In* Proceedings of the European Association of Animal Production—International Symposium on Production of Sheep and Goat in Mediterranean Areas, 17-21 October 1983, Ankara, Turkey.

Springborg, R. 1986. Impediments to the transfer of Australian dryland agricultural technology to the Middle East. Agriculture Ecosystems & Environment 17:229-251.

Sting, J. 1987. The economy of the integration of livestock and trees in a dry area of Syria. Unpublished MSc Thesis, Inst. Agricultural Economics and Social Sciences in the Tropics and Subtropics, Univ. Hohenheim, Stuttgart, Germany.

Thomson, E.F. 1987. Feeding systems and sheep husbandry in the barley belt of Syria. ICARDA-106 En. ICARDA, Aleppo, Syria.

Thomson, E.F., F.A. Bahhady and A. Martin. 1989. Sheep husbandry at the cultivated margin of the north-west Syrian Steppe. ICARDA-148 En. ICARDA, Aleppo, Syria.

Thomson, E.F., R. Jaubert and M. Oglah. 1985. On-farm comparisons of milk yield of Awassi ewes grazing introduced forage and common village lands in the barley zone of north-west Syria. Internal Publication No. PFLP-3. ICARDA, Aleppo, Syria.

Tully, D. 1984. Land use and farmers' strategies in Al Bab: The feasibility of forage legumes in place of fallow. Research Report No. 12, FSP. ICARDA, Aleppo, Syria.

Tully, D. 1986. Rainfed farming systems of the Near East region. Discussion Paper No. 18, FSP. ICARDA, Aleppo, Syria.

Tully, D., E.F. Thomson, R. Jaubert and T.L. Nordblom. 1985. On-farm trials in northwestern Syria: Testing the feasibility of annual forage legumes as grazing and conserved feed. Pages 209-236 *in* Research Methodology for Livestock On-Farm Trials (T.L. Nordblom, A.K.H. Ahmed and G.R. Potts, eds.). IDRC-242e. IDRC, Ottawa, Ontario, Canada.

USDA, USAID and the State Planning Commission, Syrian Arab Republic. 1980. Syria: Agricultural Sector Assessment. Vol. 3: Agricultural Production Annex. USDA, Washington, DC.

Wade, R. 1987. The management of common property resources: Finding a cooperative solution. Research Observer, Vol. 2, No. 2. The International Bank for Reconstruction and Development, Washington, DC.

Webber, G.D. and H.M. Nash. 1980. Mid-congress tour, South Australia. *In* Field Tour Book, International Congress Dryland Farming, Adelaide, SA, Aug-Sept, 1980.

Yurdakul, O., O. Erkan, I. Genc, C. Bedestenci, Y. Kirtok and M. Direk. 1987. Economics of barley production in southeast Turkey. Cukurova University Publishing Center, Adana.

Extension of Ley Farming in the Mediterranean Basin

G.D. Webber
South Australian Department of Agriculture, Adelaide 5001, Australia

Abstract

Ley farming in Mediterranean-type climates is based on growing cereals in rotation with annual legume pastures, which increase soil fertility and supply high quality feed for livestock. Ley farming can be adapted to ecologically appropriate areas in WANA if the constraints to extension are overcome: lack of adapted cultivars, inadequate grazing management and insufficient research and extension programs. The successful development and adoption of ley farming will require coordination of national programs and substantial technical and extension effort.

Introduction

Ley farming in Mediterranean-type climates is based on growing cereals (wheat, barley and oats) in rotation with annual legume pastures, mainly medics and subterranean clover (*Trifolium subterranean* L.). The pastures, because they fix atmospheric nitrogen, increase soil fertility for the cereals and supply high quality feed for livestock (mainly sheep).

The system originated in southern Australia in the 1940s (Donald 1981; Macindoe 1975; Trumble 1939; Halse this volume) when farmers observed that the pasture legumes volunteered in the fallows of cereal/fallow rotations, particularly where phosphate had been applied to the previous crop.

In the cereal-growing areas of south Australia, cereal yields rose by 50%, sheep numbers doubled and wool yields more than trebled between the 1930s when legume pastures were first encouraged and the 1960s when their use was widespread (Webber 1975; Webber *et al.* 1976). On some farms, cereal production more than doubled and livestock quadrupled (Puckridge and French 1983).

The basis of ley farming, the self-regenerating annual pasture, is simple for farmers to manage even though the system itself is biologically complex. It depends on dormant seeds surviving through at least one year of cereal and regenerating without resowing in the following year. The main management constraints are that farmers must not cultivate too deeply and must prevent their flocks from overgrazing during flowering and during the summer.

Ley Farming as a Land-Use System

It is important to view ley farming as one of several land-use options. In the Mediterranean region, it is mainly rainfall that determines land use. The cereal-producing zones are placed between the arid zone, where agricultural production is mainly based on low-density grazing of the native steppe, and the humid zone, where lack of moisture is normally not a constraint and land can be used for high-intensity livestock grazing and high-value crops. In southern Australia the three zones are interdependent in that livestock are moved between them so that grazing pressure accords with seasonal variations in availability of feed. This integration benefits the stability of each zone.

Relevance of Ley Farming to West Asia and North Africa (WANA)

There is increasing evidence that there are large areas of land in the Mediterranean region where integrated farming systems could be adopted. The physical and economic conditions in WANA are a mirror image of those that existed in southern Australia in the 1940s when the ley farming system was introduced.

1. Livestock products are in demand and prices are high relative to cereals.
2. There is a shortage of livestock feed.
3. Cereal yields are either declining or have become dependent on the use of nitrogen fertilizer.
4. Soil erosion is widespread and both farmers and governments are becoming concerned about land degradation.
5. Desertification of the marginal areas is rapid.

As it was in Australia, the introduction of legume pastures is a potential answer to these problems. For example, Doolette (1980) postulated that, taking into account environmental constraints and existing patterns of land ownership, there may be 15 million hectares where ley farming could be profitably adopted. Carter's (1975, 1978) estimate was 30 million hectares; if 70% of this land were sown to pasture, approximately 80 million tonnes of herbage would become available, enough to feed 100 million ewes, an increase of 30% over the existing population. Carter also estimated that 1.4 million tonnes of nitrogen would be added to the soil per year. While these numbers of additional sheep may be optimistic (technical evidence suggests that they are not: Cocks 1988), the transfer of sheep into the cereal zone would make possible a reversal of the trend to desertification in the marginal areas and help revegetate huge areas of steppe.

Attempts to Introduce Ley Farming into the Mediterranean Basin

This subject is covered in detailed elsewhere in this volume. I will simply add a few comments on the relevance of the various approaches. The projects described by Halse (this volume) can be divided into two approaches representing our perceptions of what was needed at the time: (1) the information transfer approach, and (2) the technical adaptation approach, concentrating mainly on the modification of the various technical aspects of the system. The emerging approach, which must address farmer needs and the training of national workers who interface with farmers, will be discussed in the next section.

Information Transfer

This approach concentrated on transfer of the ley farming system using Australian pasture cultivars (Cocks *et al.* 1977; Cocks *et al.* 1978), tillage methods and management practices.

The lack of farmer adoption of ley farming as a result of this approach raised the question of the relevance of ley farming and its place on farms in the region. Oram (1977) noted that the Australian system of sowing medics and clovers in wheat rotations, although shown to be technically feasible, has not been widely adopted in the Mediterranean proper. The specific problems of this approach have been addressed by Cocks (1983), who identified that the failures to transfer the Australian technology were due to:

1. Poor performance of Australian medics, which were selected and developed for mild winter environments (Crawford 1962a, 1962b) and which have not been successful in west Asia or the high plateaux of north Africa, where winter temperatures are low.
2. Insufficient emphasis on livestock, yet it was its ability to increase livestock production that made ley farming attractive to Australian farmers.
3. Failure of medics to nodulate because of lack of inoculation or use of inappropriate rhizobia.
4. Limited opportunity to involve farmers.
5. Inadequate grazing management resulting in poor seed.
6. Insufficient follow-up of projects once the initial phase had been completed.

Springborg (1986) strongly agreed with point (2) stating that "the emphasis in many early projects was on the benefits of ley farming to cereals but that the benefits in the short term will be by increasing livestock production and only slowly by improving cereal production."

Technical Adaptation of the System

In this phase, it was recognized that more than transfer was involved (Saunders 1976). It has concentrated on adaptation—transferring the principles into existing technical and social systems. Since 1980, the projects have focussed mainly on the technical constraints to using the system in a new environment. These are as follows:

1. **Climatic and edaphic:** a general comparison of climatic and edaphic conditions of cereal zones in south Australia and areas of WANA reveals that altitudes in the cereal zones of the latter are higher, winter temperatures lower and summer temperatures higher. Alkaline soils are more widely distributed.
2. **Identification of adapted cultivars:** the Australian cultivars are adapted to the climatic conditions of southern Australia; *Medicago truncatula* and *Medicago littoralis* are widespread in WANA only in regions with mild winters. *Medicago rigidula*, *Medicago rotata* and *Medicago aculeata* are common in cold, dry areas with intense frost. Under these conditions they are superior to the Australian cultivar (Cocks and Ehrman 1987), produce more seed and herbage and therefore can be used successfully in ley farming.
3. **Use of adapted rhizobia:** The extent to which inoculation and seed coat pelleting is necessary needs further research although Cocks (1983) found that seed that has been lime coated and inoculated with WSM 244 (a strain isolated in northern Iraq) is normally effective for a number of medics (but not *M. rigidula* and *M. noeana*; see Materon, this volume).

More recently, research has concentrated on taking ley farming to farmers and testing the system under farm conditions using farm resources through:

1. On-farm research programs (Cocks *et al.*, this volume) and on-farm demonstration and monitoring programs (Reeve, this volume);
2. Involving farmers in decision-making about selection of fields and management factors;
3. Recognizing that farmers need alternative sources of forage, and
4. Taking account of, and where possible using, the farmer's mechanical resources.

This has resulted in a more realistic recognition of where ley farming fits; farmers have quickly recognized it has most relevance in areas that do not have other production options: on shallow and stony soils, where rainfall is low, where fallow is not an economic option because of the soil's inability to store moisture, where grain legumes are not economic and where intensive cropping is not economically and environmentally viable owing to the nature of soils, aridity and low production levels.

An Integrated Research and Extension Approach

We are now moving to a place that needs to focus on extension and adoption. For this, a new approach is needed. In southern Australia, ley farming was developed by farmers and scientists working together and was implemented by farmers using advice from skilled extension officers (Webber 1988). In WANA, a similar approach must be used. Scientists and farmers need a clear understanding of all the components, must recognize that most will need to be modified and integrated and that this cannot be achieved without substantial technical and extension effort. At the same time, and in parallel, cultivar evaluation and plant improvement must be continued in close consultation with extension workers.

Extension agents must therefore become committed from the outset of research and development projects and must lead their implementation at local level. They must be involved in problem identification and definition and also in the development of solutions through research. Research workers must assist extension staff in adapting the new technology to local conditions and provide backup to extension agents working directly with farmers.

Research programs and their managers must recognize their responsibilities in relation to technology transfer. Many research organizations are now reducing inputs into production research and are giving priority to technology transfer.

The role and importance of extension staff needs to be more widely recognized. Mortiss (1984) suggests that successful extension workers need to understand their product or technology, promote their product, adapt the technology to existing farm resources, understand their farmers' needs, have high credibility with farmers and enhance self-confidence of farmers.

One major constraint to the rapid expansion of ley farming that must not be overlooked is lack of seed of adapted cultivars. A critical objective of any program must be to make available adequate supplies of seed and to improve seed production within the region. Seed production technology is well known and needs to be seen as a specialized form of technology.

Training for Ley Farming

For the successful development and adoption of ley farming it will be necessary to coordinate the work of national programs based on collective technical data and proven methodologies. The first step toward achieving this end is the development of a training program for national specialists and extension workers.

It would seem logical for one organization (possibly ICARDA) to provide the initial training program in technical aspects of the system and in the methodology of on-farm research and farm monitoring. The starting point is to extend the results of existing research and the methodologies by which they were obtained. This involves three steps: technical training, training in methodology and in-country training and assistance with the planning and implementation of field programs.

The objective of technical training is to develop a clear understanding of ley farming; training would concentrate on four key issues: selection of adapted medics and their field evaluation, selection of appropriate rhizobial strains, development of inoculation techniques, and seed multiplication and seed production technology.

The objective of training in methodology is to enable national specialists to develop skills and experience with the following methodologies: on-farm research and demonstration programs, biological monitoring of the system and management of the system.

The objective of in-country training and assistance with planning and implementation is to develop on-farm research and demonstration programs, involve local staff in monitoring field projects and train extension workers and their managers in the conduct of planned extension programs involving farmers. This step is close to the traditional role of FAO, but to develop a coordinated approach we need to bring these roles and responsibilities together into a joint effort.

It is critically important that all steps must be part of the same program and it is essential that the basic training program be extended to provide guidance through to the in-country adoption stage.

This approach needs to involve a single Research/Extension Program with one organization (possibly ICARDA) coordinating a program and having unified management. Its leader (possibly based in Aleppo) would have specific responsibilities for achieving the following outcomes:

1. Conducting the training programs.
2. Demonstrating on-farm research methodology.
3. Producing a technical manual for trainees.
4. Coordinating and assisting national agencies in the development of their programs.
5. Identifying further research needs.

Conclusions

Ley farming can be adapted to ecologically appropriate areas in WANA but clearly not without modification. The technology has been successful, given the short time involved and the modification of technology that has been necessary. However, developments often have been piecemeal without appropriate attention to all the key technological inputs.

To make the system work a clear understanding of all the technology components, recognition that all components must be integrated and modified as necessary, and that this cannot be achieved without substantial technical and extension effort is needed.

There needs to be greater farmer involvement to ensure long-term acceptance and adoption at farm level.

As was the case in southern Australia, a critical objective of any program must be the availability of adequate supplies of seed and the development of appropriate technologies to produce seed.

Expansion of ley farming needs the technical training of extension specialists and development of extension programs to teach farmers the practical skills of ley farming.

Further development and modification of the system requires a coordinated program across the region involving the International Agricultural Research Centers, development programs and national agencies. This can be achieved with a coordinated training program for technologists involved in national programs, subsequent in-country coordination of research and development, and planned extension programs.

References

Carter, E.D. 1975. The potential role of integrated cereal-livestock systems from southern Australia in increasing production in the Near East and North African region. FAO./UNDP Workshop Report, FAO, Rome, Italy.

Carter, E.D. 1978. A review of existing and potential role of legumes in farming systems in the near east and north African region. Report to ICARDA, Aleppo, Syria.

Cocks, P.S., G.D. Webber, E.J. Crawford and M. Matheson. 1977. Pasture seeds from south Australia. SA Department of Agriculture and Fisheries, Adelaide, SA, Australia.

Cocks, P.S., M. Matheson and E.J. Crawford. 1978. From wildplants to pasture cultivars: annual medics and subterranean clover in south Australia. Pages 569-596 *in* Advances in Legume Science (R.J. Summerfield and A.H. Bunting, eds.). Royal Botanic Gardens, Kew.

Cocks, P.S. 1983. Agronomy Research Report. Agro-Pastoral Development Project, Erbil, Iraq.

Cocks, P.S. 1988. Strategies for improving feed resources in West Asia and North African and their potential impact. Pages 23-33 *in* Tropische Weiden und Futtersourcen (Justus-Liebiz Universitat: Sussen).

Cocks, P.S. and T.A.M. Ehrman. 1987. The geographic origin of frost tolerance in Syrian pasture legumes. Journal of Applied Ecology 24:673-683.

Crawford, E.J. 1962a. Barrel 173: a new strain of medic for the wheat belt. Journal of Agriculture of South Australia.

Crawford, E.J. 1962b. Harbinger medic for the lower rainfall wheat belt. Journal of Agriculture of South Australia.

Donald, 1981. Agriculture in the Australian economy. Sydney University Press, Sydney.

Doolette, J.B. 1980. The Australian ley farming system in north Africa and the Middle East. *In* Proceedings of an International Congress on Dryland Farming. Department of Agriculture, Adelaide.

Macindoe, S.L. 1975. History of production of wheat in Australia. Pages 99-121 *in* Wheat and Other Temperate Cereals (A. Lazenby and E.M. Matheson, eds.). Angus and Robertson, Sydney.

Mortiss, P.D. 1984. Agricultural extension - a practicing manual. Queensland Department of Primary Industry, Brisbane.

Oram, P. 1977. Proceedings of an International Symposium on Rainfed Agriculture in Semi-arid Regions. University of California, Riverside.

Puckridge, D.W. and R.J. French. 1983. The annual legume pasture in cereal-ley farming systems of southern Australia: a review. Agriculture Ecosystems & Environment 9:229-267.

Saunders, D.A. 1976. Proceedings of the Third Regional Wheat Workshop, Tunisia 1976. CIMMYT, Mexico City.

Springborg, R. 1986. Impediments to the transfer of Australian dryland agricultural technology to the Middle East. Agriculture Ecosystems & Environment 17:229-251.

Trumble, H.C. 1939. Barrel medic (*Medicago tribuloides*, Desr.) as a pasture legume. Journal of the Department of Agriculture, South Australia 342:953-958.

Webber, G.D. 1975. The ley farming system in south Australia. Special Bulletin No. 20/75. SA Department of Agriculture and Fisheries, Adelaide, Australia.

Webber, G.D., P.S. Cocks and B.C. Jeffries. 1976. Farming systems in south Australia. SA Department of Agriculture and Fisheries, Adelaide, Australia.

Webber, G.D. 1990. The extension of the ley farming system in south Australia - a case study. Pages 257-272 *in* The Role of Legumes in the Farming Systems of the Mediterranean Areas (A.E. Osman, H. Ibrahim and M.A. Jones, eds.). Kluwer Academic Publishers, Dordrecht.

Part 3. Annual Legumes Research and Genetic Resources Conservation

Selection of Annual Medics for French Mediterranean Regions

J.M. Prosperi
Institut National de la Recherche Agronomique, 34060 Montpellier Cedex, France

Abstract

The aim of the INRA (French National Institute of Agricultural Research) Montpellier forage group (plant breeding, agronomy and root-symbiosis laboratories) is to select useful plants and *Rhizobium* spp. for rangelands improvement, for reseeding perennial pastures or for cultivated lands (grazing vineyards or rotations with cereals) in the dry and cold Mediterranean regions, and to introduce them in farming systems. Priority is given to the genus *Medicago*. This paper presents descriptions of the French Mediterranean regions, the probable role of medics in the different farming systems and the programs of selection for these species. Differences in criteria of selection, depending on ecological environment and farming system, are discussed.

Environmental Conditions

The French Mediterranean area covers 12% of France (around 7 million hectares). It includes the Languedoc-Roussillon, Provence-Alpes-Cote d'Azur (PACA) and Corse administrative regions.

French Mediterranean Climates

The real Mediterranean climate is mainly in the coastal plain, except in Corsica or in the north of extreme southeast France. Some regions, such as the hilly countries north of the littoral plains (see Fig. 1), have a Mediterranean climate with an important winter rainfall and dry summers with relatively hot temperatures; these are included in the Emberger classification, as a cold and humid subgroup of Mediterranean climates.

For example, the Languedoc region includes the Garrigues zone to the north of Montpellier, 10-50 km from the seaside. Other regions, such as the high plateaux called Causses (500-800 m elevation), 50 km north of Montpellier, often are included because they have a very dry summer period; however, winters are typically colder.

One main characteristic of all these regions is the importance of winter rainfall (more than 40% of annual rainfall, with cold temperatures) (Table 1), which reduces the possibilities for vegetative growth. Total annual rainfall generally exceeds 600 mm.

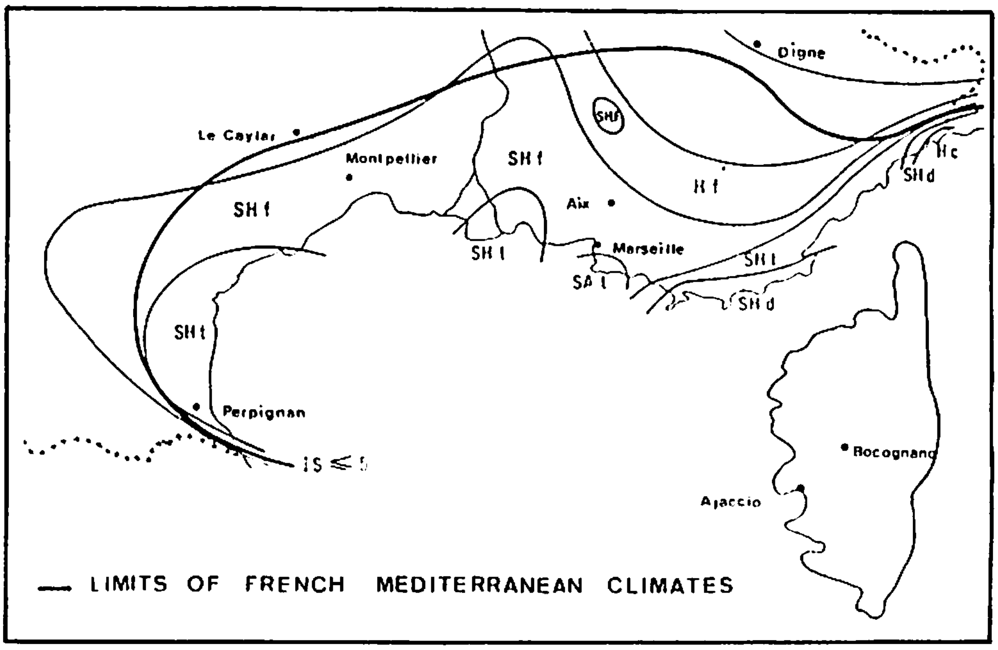


Fig. 1. Limits of French Mediterranean climates (from Thiault 1979). Humid (H), Subhumid (SH), Semiarid (SA), Cold (F), Cool (f), Temperate (t), Moderate (d), Hot (c).

Soils and Natural Vegetation

Most (more than 70% of total area) French Mediterranean regions have calcareous soils, with a basic pH, but some types of soils, such as red soils on calcareous rocks, are slightly acidic (pH between 6 and 7). The other regions—Roussillon (south part of Languedoc) around the town of Perpignan, Maures and Esterel mountains and Corsica—have acid soils. Where soils are built on schist rocks, pH is nearly always above 6.

Three areas, excluding mountains, are distinct:

Coastal region is cultivated with high-income agricultural activities such as fruit trees, vegetables or vineyards. In this area, the animal production is now limited.

Intermediate zone is covered by a dense vegetation called Garrigues on alkaline soils and Maquis on acid soils. Agricultural activities are mainly cereal crops, some small vineyards and extensive sheep or cattle meat production based on grazed rangelands, representing about 1 million hectares. The rangelands constitute a poor quality vegetation of *Quercus coccifera*, *Cistus* spp., *Juniperus*, etc. The herbaceous stratum of these rangelands is limited and mainly composed of *Brachypodium* spp. and other grasses. Legumes are not very common and usually represent less than 10% of total annual forage production.

Table 1. Annual winter rainfall and temperatures of French mediterranean regions. Winter rainfall is the amount of rainfall when the mean monthly temperature is below 10°C.

Town (elevation)	Annual	Rainfall Winter	% of total	M, °C†
Languedoc-Roussillon				
Perpignan (40 m)	570	160	28	3.9
Montpellier (40 m)	700	320	46	1.8
Le Caylar (1240 m)	1240	650	52	2.1
Provence-Alpes-Côte d'Azur				
Marseille (25 m)	550	260	47	2.3
Aix (170 m)	600	270	45	0.5
Dignes (600 m)	780	340	44	1.0
Corse				
Ajaccio (4 m)	660	230	35	3.9
Bocognano (600 m)	1280	760	59	1.7

† M = mean of minima of coldest month (Météorologie nationale).

High plateau or medium mountain zones are mainly assigned to milk production to produce cheese such as Roquefort in the Causses region. Cultivated lands (forage and cereal crops) are intermixed with rangeland tracts composed of short and poor quality herbaceous vegetation and forest.

An important aspect of all these regions is the presence of uncultivated land (Fig. 2).

Livestock and Forage Resources

The French Mediterranean area, limited to the three regions mentioned above and Aveyron, carries less than 3.5% of French cattle (340 000 head), 24% of the sheep (2 860 000 head) and 13% of the goats (about 140 000 head) (SCEES 1988). The most important livestock are located in Provence Alpes, Côte d'Azur region (> 1 million) for meat production and in Causses (> 1 million) for milk production. These livestock systems are well structured in comparison with those of Languedoc-Roussillon or those on Corsica.

For sheep and goats, we can schematically separate the management systems into three different groups (Gintzburger *et al.* 1988; Mansat 1981):

Extensive: located everywhere but Roussillon. The flock size is from 200 to 500 head. Land per flock varies from 300 to 500 ha, with little cultivated land (about 10 ha)

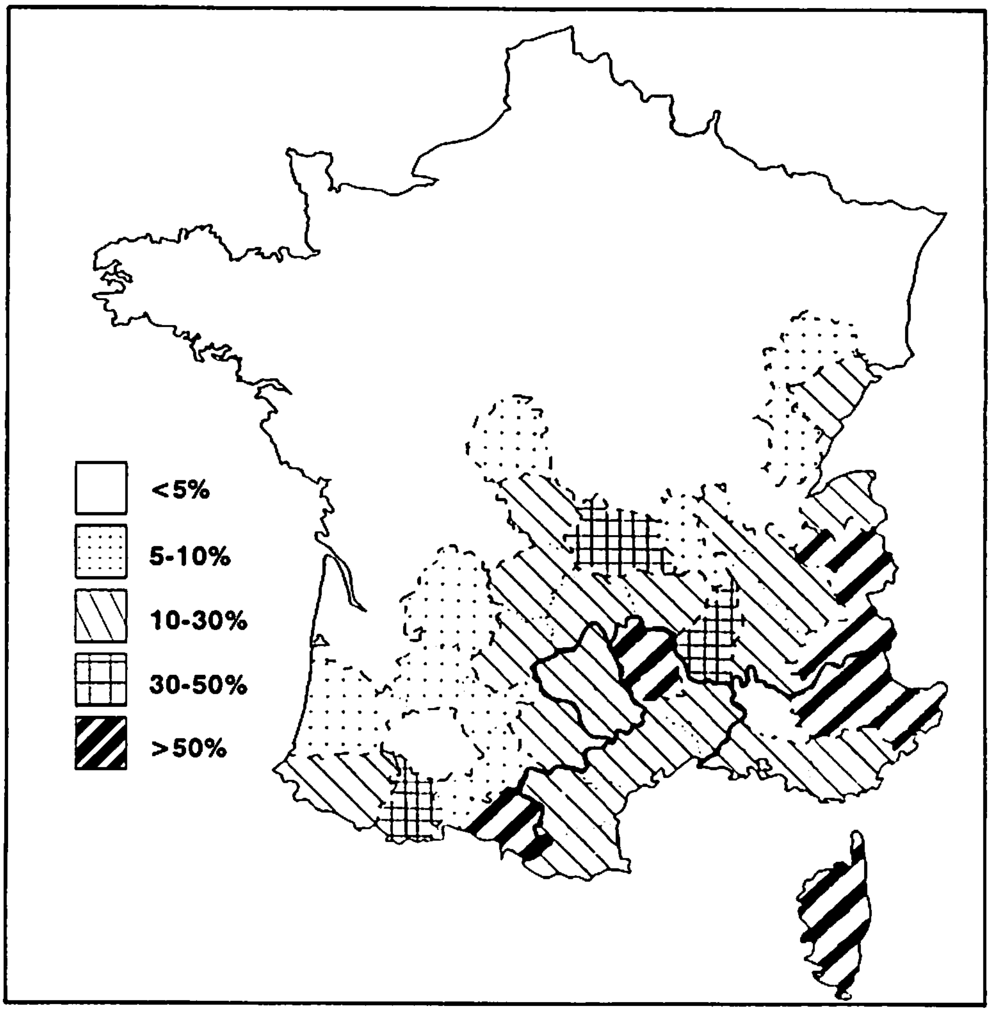


Fig. 2. Importance of uncultivated lands (rangelands, abandoned cultivated lands, etc.) in Mediterranean zones.

reserved for hay and cereals crops for animal feed. The main forage resources come from rangelands or perennial pastures. Level of supplementation of animals is variable but generally low, lower in Languedoc than in PACA. Meat production is most common, with the exception of Corsica where milk production is used to produce local cheese. This extensive system represents about 30% of the flocks, comprising about 40% of the total sheep inventory in the mediterranean area. Few goats are included in this group.

Intensive: mainly located in medium-altitude zones (from 500 to 800 m in Causses and PACA regions) at the limits of Mediterranean zones. The flock size is variable (from 100 to 1500 sheep), with a recent and important tendency to increase the size. Animal production is based on forage crops (lucerne, sainfoin, *Dactylis*, *Festuca*), using marginal lands around the farm, generally limited to spring or autumn use. This group represents about 20% of the flocks and 40% of the total sheep; few goats are found in this type of system.

All other types are difficult to classify, but, in the main, animal production is associated with other enterprises (agricultural or not). Flock size is generally under 100 head. Forage resources are variable, but all these farms have little land. In 1979, this group represented more than 50% of flocks, 20% of sheep and 70% of goats of the French mediterranean livestock (SCEES 1980).

For all these sheep-rearing systems in French Mediterranean regions, the most important issue is the variability of the forage resources used on-farm; there is no main system of production.

What Role for Medics?

Medics: a New Available Forage Resource

The main forage crops in Mediterranean French regions are perennial plants (lucerne, sainfoin and mainly grasses) used in rotation with cereals or other annual crops. Annual forages and especially annual legumes are not used. Medics can be considered new, even if they are common in all rangelands or abandoned cultivated lands. Their importance relative to all other forage resources is a function of forage gaps in the feeding calendar.

When all types of animal-rearing systems in Mediterranean zones are compared (Gintzburger *et al.* 1988; Mansat 1981; Xème Grenier de Theix 1979), there is a noticeable lack of forage resources during the summer dry period and from November to March. Graziers can bridge the summer deficit period, mainly by moving flocks from the lowlands to the mountains. It is more difficult to fill the feed need in winter. Partial compensation is provided by stored hay and cereals, bought or produced on the farm. The winter period also corresponds to the lambing period. A system of storage is a necessity for more productive and intensive livestock (milk producers) and for the coldest regions, such as Causses, where winter growth is greatly reduced by hard frosts.

In most French Mediterranean regions, however, it should be possible to grow medics for direct grazing, especially by those producers who grow sheep for meat in the intermediate or coastal zones.

The Utilization of Medic

For all the Mediterranean regions, the potential use of annual self-reseeding legumes such as medics varies. Ley farming could be the most important use of medics in north Africa or the Middle East, but in European countries their potential use is more diverse (from rangeland improvement to vineyard grazing systems).

In France, the possibility of a ley farming system is now limited because most farmers prefer perennial and known forage crops, mainly used for hay. But in the near future, overproduction of cereals and increase of fallow lands in rotation with cereals with EEC subsidies (now 1000 FF/ha annually for Mediterranean regions) could provide a shift toward fallow land conversion to medic-dominated pasture.

Perhaps the best ways to use medics in France are by improving winter rangeland production and oversowing perennial or degraded natural pastures under dry conditions. Several experiments have been conducted with subclovers or medics to introduce them into marginal lands: with *Quercus suber* forest in Roussillon (Masson and Gintzburger 1987) or in Garrigues area (Prosperi and Soussana 1984), and perennial degraded pastures in Provence and Corse regions or in Roussillon littoral plain (Rochon *et al.* 1988)

The main part of selection activity on medics of our laboratory is assigned to produce cultivars adapted to these conditions (Table 2).

Medics and subclovers also can be interseeded in vineyards to provide grazeable forage and particularly to limit soil erosion on sloping land (Masson and Gintzburger 1986). This second utilization should be applicable to non-Mediterranean regions such as the west of France where winter temperatures are not too cold and would permit an annual legume growth period in the fall and spring. The last possibility is to use them as spring annual forage legume crops throughout France, in place of *Vicia* or *Pisum*. In this case, we need some high-producing, erect species, such as *Medicago scutellata*, to produce hay. In Mediterranean countries, this utilization also is feasible as a forage mixture with grasses or cereals, as a substitute for traditional *Vicia* and *Avena* production.

A very significant use for medic will be in combination with perennial forage legumes, which have their own specific role in these relatively high rainfall zones. Prostrate and rhizomatous types of *Medicago sativa* or *Medicago varia* are being tested and bred for introduction into rangelands.

What Criteria for Selection of Medics?

Medics and subclovers have been selected for ley farming by Australian plant breeders. This system, based on a rotation of cereals and annual self-reseeding legumes, leads to cultivars with very specific characteristics (Crawford 1983; Puckridge and French 1983).

Table 2. Criteria for selection as functions of environmental conditions and farming systems.

	Ley farming for Australia	Improvement of rangelands for France
Selection for environmental conditions		
Frost tolerance		
Leaves	+ †	+ + +
Plants	+	+ + +
Winter growth	+	+ + +
Growing season	4-6 months	8-9 months
Flowering date	Early	Late
Maturation period	Medium to long	Neutral
Resistance to		
fungal diseases	+	+ + +
insect pests	+ + +	+
Selection for farming systems		
Seedling vigor	+	+ + +
Competition with weeds	+	+ + +
Seed production	Important	Neutral
% of hard seeds	> 80%	40 - 60%
Break of hardseededness	After 1 year	Neutral

† Important (+) to very important (+ + +).

In some cases, these cultivars are incompatible with other forms of utilization such as improvement of rangelands (Prosperi *et al.* 1987).

Some selection criteria are directly bound to the type of utilization planned and others to the ecological or climatic environment, such as the length of the growing season or duration and amount of spring rainfall.

Winter Growth and Frost Susceptibility

At INRA, we have a program of evaluation for frost susceptibility and degree of winter growth. These criteria are very difficult to estimate, because frost has three different levels of action:

1. It limits growth of plants with no damage. This effect is related to the average temperature and the range of variation of temperatures from day to night. A large

range of variation allows better growth than a shorter one for the same average temperature, as long as absolute minimum temperatures are above the frost susceptibility threshold. Good nitrogen fixation and strains of *Rhizobium* may play a crucial role in this regard (Gintzburger and Cleyet-Marel, personal communication).

2. It destroys leaves or stems so they are no longer available for animals, but leaving meristems and buds alive for further production. This effect is mainly related to absolute minimum temperature. For us, this characteristic is very important because medics will always be used during winter. The main possibility for interesting growth is in spring so forage production must be kept available and in good quality condition through winter.
3. It kills plants outright. This consequence is a function of the threshold frost susceptibility of the genotype and the level of plant hardening that occurs. This effect is related to the growth stage and density of plants (also linked to sowing date), minimum temperatures and the date and severity of first frosts. Poor nitrogen fixation or winter rainfall that favors diseases like soil fungi at young stages, and all factors that influence general plant health, increase the susceptibility of frost damage.

In fact, these levels of susceptibility are highly correlated; however, some differences among accessions do exist for winter growth and damage to leaves by frost.

Competitive Ability with Weeds

Competitive ability in annual legumes is perhaps more important for improvement of perennial pastures than in ley farming because weeds in a pasture rotation with cereal usually are controlled in the cereal phase. This limits the invasion and seed production of weeds.

It is obvious that control of weeds can only be done by grazing. Use of herbicides is most often out of the question. Weeds are very competitive because we have high rainfall conditions and the rhythm of medic utilization, mainly during winter and summer, favors all types of spring-growing plants.

In addition to density of germinated plants, competitive ability is a function of different characteristics: speed of germination, seedling vigor, speed of ground covering at young stages and after grazing, type of growth (prostrate or erect) and density of stems and leaves.

Very strong differences exist for this criterion among the different species and genotypes of medics tested. For instance, *Medicago rigidula* seems to be more competitive than *Medicago polymorpha* or *Medicago truncatula*. The latter often are more erect and have lower leaf/stem ratios at young stages.

Growing Season, Flowering Date and Maturation Period

The important and quite regular spring rainfall in the south of France allows an 8 to 9-month growing season (compared with 4-6 months in drier areas). This fact benefits long-season genotypes that can respond to late spring rainfall.

In fact, late-flowering genotypes are better suited than earlier ones because they escape late spring frosts during flowering and they can be rested from April to June while the natural forage resources of rangelands are available. Improved rangelands or perennial pastures are generally used in combination with large areas of unimproved rangelands. In this case, it is possible to have a rest period, which allows better seed production than with continuous grazing.

Seed Production, Hardseededness and Regeneration

These criteria are the most closely linked to successful ley farming systems because high seed production and high levels of hardseededness are needed to compensate for pod consumption by animals, germination during the cereal phase and destruction of seeds or seedlings by cultivation.

For annual reseeding in a perennial system, we think that the percentage of soft seeds at the first autumn rains must be over 40%. Total seed production can be lower than in a ley farming system. This is especially true if germinating conditions are favorable; however, seedling density must be kept high enough to allow good winter growth and competition with weeds.

The selection of genotypes with average seed production is possible because seed production is often negatively correlated with vegetative growth and late flowering dates.

Ability to retain water inside the pod, rapid root elongation and seedling vigor are particularly important attributes when pods lie on the soil, as in uncropped systems. Seedling vigor generally increases with seed size, but very large seeds germinate more slowly than smaller ones and need a long, favorable period of germination, as shown by the comparison of *M. scutellata* and *M. truncatula* (Olivieri *et al.* 1989).

Resistance to Diseases and Insect Pests

Our wet conditions in autumn and in spring, when daily temperatures are quite high, favor all types of foliar fungi, like Oïdium (*Erysiphe* spp.), mildew (*Peronospora* spp.) or rust (*Uromyces* spp.). Losses caused by black stem (*Phoma medicagenis*) can be great; this damage can be so important in ungrazed conditions (in nursery rows or dense plots) that it reduces the length of growing season and seed production. Most Australian cultivars and ecotypes from dry conditions such as in north Africa are susceptible; however, strong differences exist between and within species.

Root rot diseases are really important only in nursery experimentation when medics are transplanted. The main responsible fungi are *Rhizoctonia solani* and *Fusarium* spp. (Davet, personal communication). Some damage on seedlings can be observed when using late sowing dates under wet autumn conditions.

Few insect pests or viruses are really virulent, so susceptibility is actually not a problem.

Process of Work

The various research programs of the Montpellier plant breeding laboratory and connections with other laboratories are summarized in Fig. 3. This work can be divided into two steps.

Collection and Genetic Resources

The first step of our work on medics and perennial *Medicago* is mainly based on a general program of collections all around Mediterranean countries. Until 1988, we have collected, in cooperation with national institutes of research of each country concerned, species of *Medicago* in Spain, Portugal and Algeria. Southern France has been collected in phases. Collections of subclovers and medics have been made in Corsica and around Montpellier.

All this collected material (Table 3) is preserved in a germplasm bank and is available for study after a first step of multiplication and evaluation. A computer is used to store and retrieve ecological, morphological and agronomic data and to edit different lists.

Table 3. Plant populations collected from 1986 to 1988.

	France	Spain	Algeria
Sainfoin	33	-	-
Perennial *Medicago*			
Landraces	21	-	-
Wild populations	70	108	6
Annual *Medicago*	673	456	654
Subclovers	51	12	-

Ecological data from germplasm collections are the foundation of research on geographic and ecological distribution of medics and to define the most useful species for each type of environment (Prosperi *et al.* 1989).

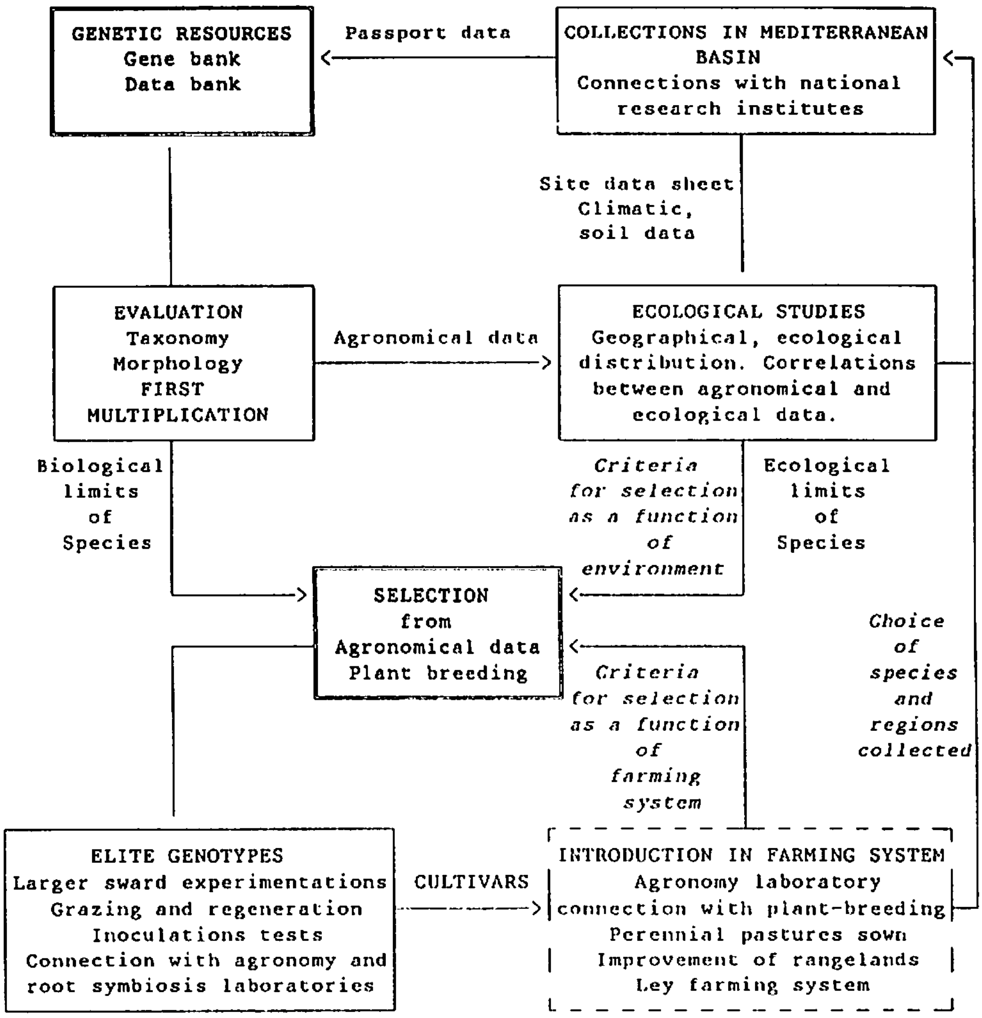


Fig. 3. The different research programs of the plant breeding laboratory at INRA, Montpellier.

Evaluation and Selection

The second step of the work is selection of medics following the scheme described below.

First year

All the collected plants are multiplied and evaluated (botanical and morphological characteristics, classification into earliness groups, scoring of foliar fungi resistance). Every 2 years 200-300 populations are tested. Seeds are sown in nursery rows, 30 seeds/m, two replications of 2-m length. If there are not enough seeds available after collection, populations are first multiplied in the glasshouse. Sowing occurs in spring with irrigation to reduce the chance of frost damage for susceptible populations.

One population represents all seeds of one species or subspecies, collected in one site. Separation between subspecies is based on pod characteristics. In most cases these populations are uniform. One accession in the genebank corresponds to one population, even if this population is not uniform.

Second year

General characteristics such as date of flowering, scoring of vegetative growth, frost susceptibility, general resistance to disease and seed production are measured in the second year. Every 2 years, 100-150 populations are sown in autumn without irrigation in nursery rows, four replications of 2-m length. The selection intensity of the population is about 30-40%.

Third and fourth years

Evaluation of plants occurs in spaced plant nurseries that are sown in autumn without irrigation. After sowing in Jiffy pots, 30 plants are transplanted for each population selected in preceding nursery row evaluations. General characteristics are scored and the different lines from nonuniform populations are separated. Selection intensity of plants is about 10% each year.

Fifth and next years

As a first step, dense sward experiments are conducted in two locations (one with cutting to estimate winter growth, another one under grazing). As a second step, seed of elite genotypes are multiplied in small areas (in a national network with 4-5 locations) to produce seeds for farming experiments and stabilizing morphological and botanical characteristics of the best lines.

During the first 4 years, all seeds or plants are inoculated with a mixture of four strains of *Rhizobium* that includes two local strains, CC169 and a special strain for lines of *M. rigidula* from ICARDA. In sward experiments, we generally compare inoculated and uninoculated medics to test *Rhizobium* specificity of these lines. The selection of the best pair of medics and selected strains of *Rhizobium* is made later in collaboration with the root-symbiosis laboratory.

In the first steps of selection, we do not want to inoculate with a unique strain of *Rhizobium* in order to avoid selection of specific associations of medic and single strains. Medics are found everywhere in the Mediterranean and therefore *Rhizobium* spp. are equally ubiquitous in soils. We think that all selected lines should have a general adaptation to fix nitrogen using local strains, under a range of soil conditions. However, maximum production may be obtained with a specific couple and, in this case, must be recommended.

First Results

These results were obtained in the Montpellier area, at the Plant Breeding Station in the littoral plain or in the Garrigues area, 10 km north of town, on basic soils, with average rainfall of 650 mm in the coastal plain to 900 mm in the hilly zones.

Frost Susceptibility and Winter Growth

The frost susceptibility of medics, scored after hard frosts during the 1986/87 winter, was variable and mainly depended on the species and their origin. All Australian cultivars are very frost susceptible under our conditions (Fig. 4). Some differences exist between species: *M. rigidula* and *M. orbicularis* seem to have good frost resistance, whatever the origins of ecotypes, which differs from what is observed with *M. polymorpha* (Fig. 4). The frost resistance of *M. rigidula* has been reported by Cocks and Ehrman (1987). All French medic ecotypes are more resistant to frost than north African or Spanish ecotypes, with the exception of those from the high plateaux.

Winter growth was scored in a spaced plant nursery, to avoid interaction with plant density. Scores measured in December and January before the hard frosts during the winter of 1986/87 and in December, January and February during the 1988/89 winter showed a high degree of variability within and between species.

Medicago rigidula has the least variable but poorest winter growth, whereas *M. polymorpha* and *M. truncatula* have large variabilities from poor to high winter production. There is no direct relation (Fig. 5) between general origin of populations (north Africa, Spain or France) and the level of winter growth, which is in general negatively correlated with degree of frost at the collection site.

Correlations between winter growth and hard frost susceptibility depend on the species. For instance, no positive correlation exists for *M. rigidula* or *M. orbicularis*; some ecotypes have a good level of winter growth associated with a frost resistance. On the other hand, a positive but nonsignificant correlation exists for *M. polymorpha* (Fig. 6). These results are based on evaluation of 64 populations from different origins and must be confirmed with a larger range of variability.

Australian cultivars have shown good winter growth associated with high frost susceptibility.

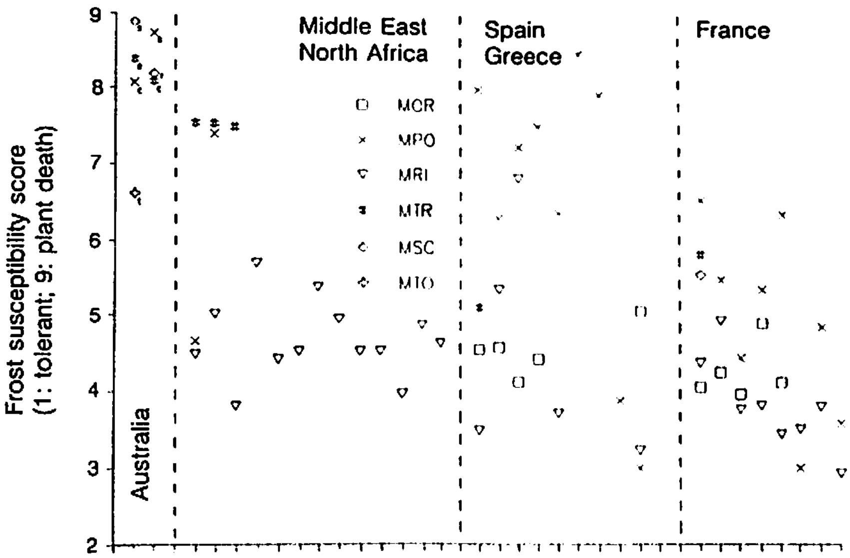


Fig. 4. Frost susceptibility and origin of population. (Scored spaced plants in a nursery: 30 plants per population during the winter of 1986/87. Absolute minimum soil temperature was -17°C; mean temperature, 10-20 January 1987, -3.5°C with 30 cm snow cover.) *Medicago* species: MOR *M. orbicularis*, MPO *M. polymorpha*, MRI *M. rigidula*, MTR *M. truncatula*, MSC *M. scutellata*, MTO *M. tornata*. Control varieties: MPO, c = Circle Valley, s = Serena; MTR, a = Akbar, c = Cyprus; MSC: r = Robinson, s = Sava; MTO: t = Tornafield.

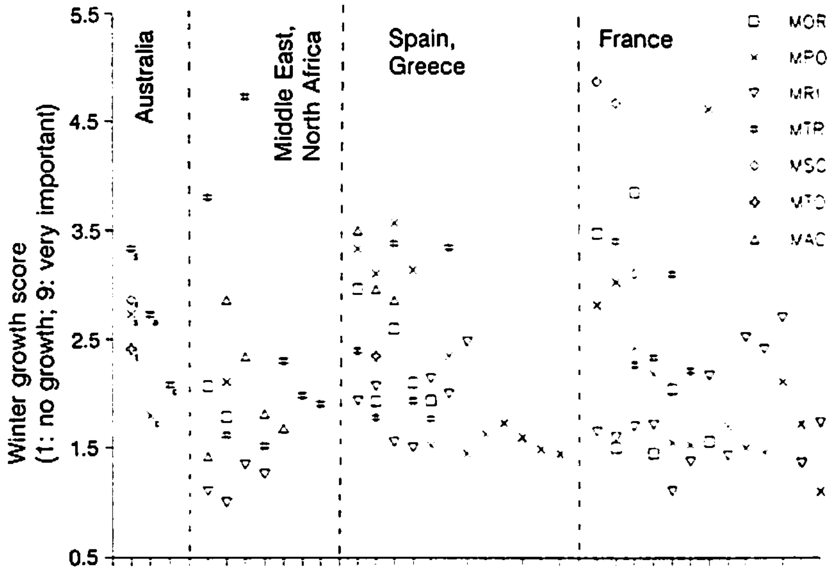


Fig. 5. Winter growth and origin of populations. (Measured in spaced nursery plants with 30 plants per population. Mean of two scores for winter 1986/87 and mean of three scores for winter 1988/89. The data of the two years are adjusted to the performance of the control varieties.) *Medicago* species: MOR, *M. orbicularis*; MPO, *M. polymorpha*; MRI, *M. rigidula*; MTR, *M. truncatula*; MSC, *M. scutellata*; MTO, *M. tornata*; MAC, *M. aculeata*. Control varieties: MPO, c = Circle Valley, s = Serena; MTR a = Akbar, c = Cyprus, s = Sephi; MSC r = Robinson; MTO t = Tornafield.

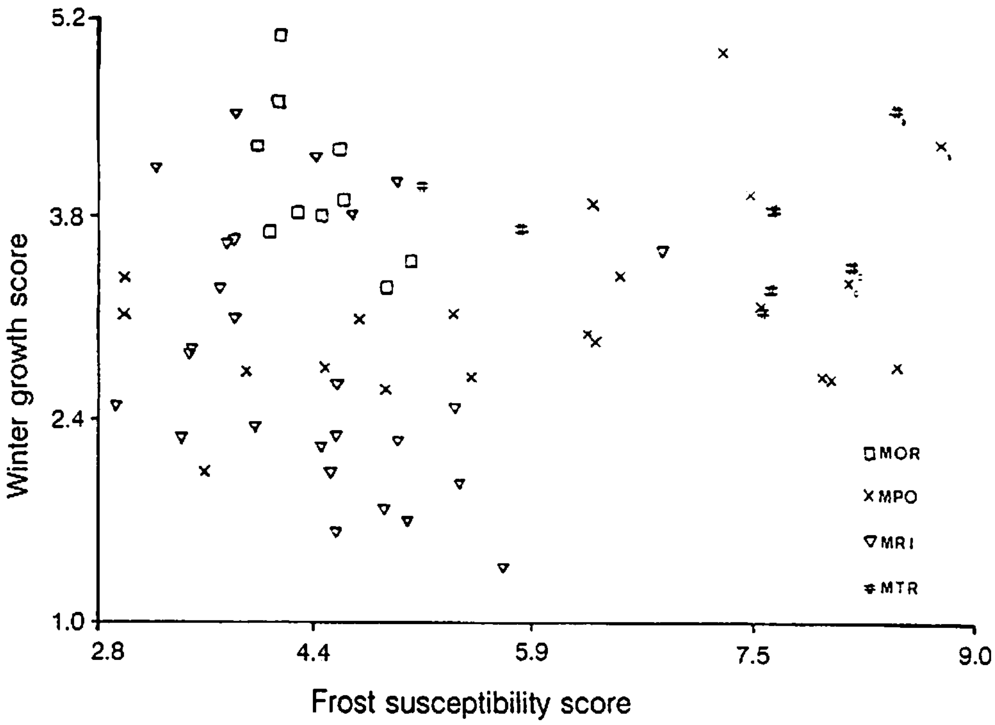


Fig. 6. **Correlation between susceptibility to hard frosts (X axis, cf. Fig. 4) and winter growth (Y axis, cf. Fig. 5) during the winter of 1986-1987: MOR, *M. orbicularis* (10 populations): r = -0.63, prob 0.05; MPO, *M. polymorpha*, s = Serena (21 populations): r = 0.35, prob 0.11; MRI, *M. rigidula* (26 populations): r = -0.27, prob 0.19; MTR, *M. truncatula*, a = Akbar, c = Cypress (7 populations): r = -0.01, prob 0.99.**

Foliar Fungi Resistance

Foliar fungi resistance is mainly estimated by scoring in spring sowings without fungal inoculation. The association of irrigation with no grazing and natural inoculation induces very heavy damage.

No direct relation exists between origin of population and resistance to disease (Fig. 7). Under our conditions, the Australian cultivars and especially *M. truncatula* varieties appear very susceptible to foliar fungi species and particularly to black stem. Differences among species were highly significant (Table 4). *Medicago rigidula* is the most resistant to Oïdium, mildew and black stem but susceptible to rust and *Pseudopeziza* spp.

These observations will be confirmed in future by tests with inoculation in controlled conditions.

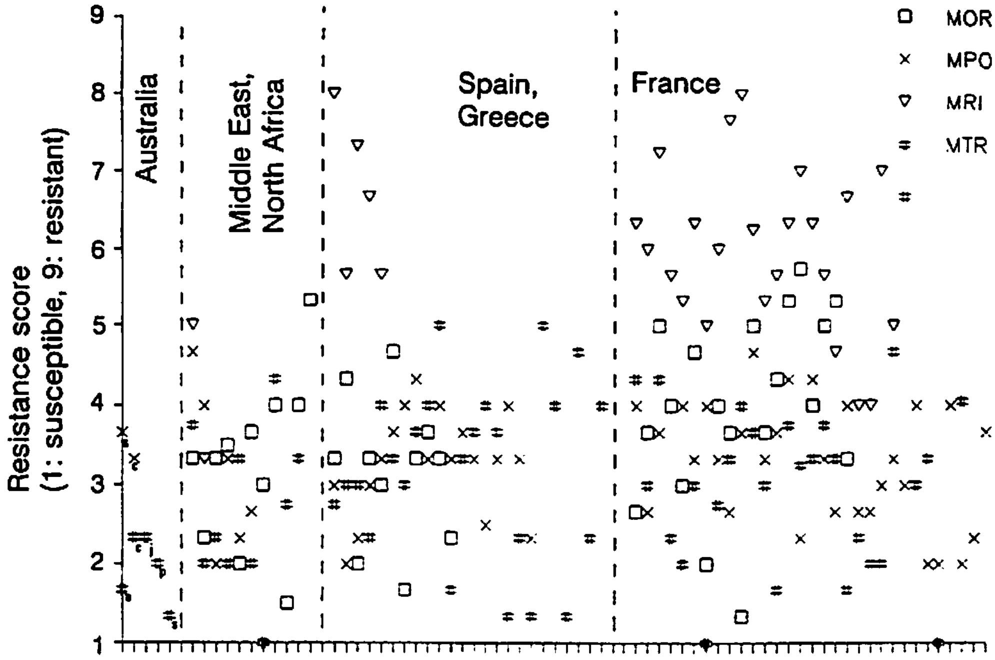


Fig. 7. Foliar fungi resistance and origin of population. (Scored in nursery scoring rows during the springs of 1987 and 1988. Mean of two scores.) *Medicago* species: MOR, *M. orbicularis*; MPO, *M. polymorpha*; MRI, *M. rigidula*; MTR, *M. truncatula*. Control varieties: MPO, c = Circle Valley, s = Serena; MTR a = Akbar, c = Cyprus, j = Jemalong, p = Paraggio, s = Sephi.

Table 4. Foliar fungi resistance of different species from Spain, Algeria and France.

Species	Spring 1987 All fungi	Spring 1988 Oidium	Other spp.†
M. orbicularis	3.58 b	4.46 b	5.1
M. polymorpha	3.28 b	4.81 b	5.01
M. rigidula	5.99 a	6.68 a	5.29
M. truncatula	2.78 b	4.96 b	5.48

Scored in nursery sowing rows, during spring 1987 and 1988: 1 = very susceptible to 9 = resistant Means followed by different letters are significantly different at 5% (Duncan's test).
† Other spp.: other fungi (mildew, rust, black stem, etc.).

Dry Matter, Seed Production and Regeneration

Sward experiments (Table 5) confirmed the frost susceptibility of Australian cultivars that were destroyed by hard frosts during the winter of 1986/87 in the Garrigues area. The

Table 5. **Frost susceptibility, dry matter (t/ha) and seed production (t/ha) from sward experiments. Means followed by different letters are significantly different at 5% (Duncan test).**

		St. Gely† - Garrigues area sown on 22/10/86				Le Chapitre‡ - coastal plain - sown on 2/11/87				
Cultivars/ ecotypes	Frost suscept.	Density 03/86	DM 21/04/86 07/86	SY 87	Reg 88	Reg 02	DM 04	DM 88	SF 88	SY
Paraponto	8.3 f	0.7 d	-	-	0.5	1.0	0.17 cde	2.6 c	109 g	1.12 de
Robinson	8.0 ef	1.0 d	-	-	2.0	2.0	0.41 a	4.8 a	119 f	2.76 a
Serena	7.0 e	0.7 d	-	-	1.2	1.7	0.21 bcd	2.6 c	99 h	2.53 a
Parragio	4.7 d	4.7 c	1.4abc	0.13 c	5.5	4.0	0.25 b	3.1 c	128 de	1.79 bc
Tornafield	4.0 cd	4.7 c	1.0c	0.05 c	3.5	2.7	0.18 bcde	2.5 c	131 de	1.27 cde
Circle Valley	3.3 bc	5.7 bc	1.1bc	0.25 c	2.2	4.0	0.23 bc	3.2 bc	130 de	1.95 b
Jemalong	3.3 bc	6.0 bc	1.0bc	0.17 c	2.7	5.0	0.34 a	4.1 ab	131 de	1.20 de
Sephi	3.0 b	7.0 ab	1.6abc	0.19 c	6.5	6.3	0.36 a	4.6 a	127 e	0.92 ef
Mri 716§	1.0 a	7.7 ab	1.0bc	0.04 c	2.2	2.3	0.23 bc	3.2 bc	133 cd	1.53 bcd
Mri 834¶	1.3 a	7.3 ab	2.3ab	0.48 bc	7.5	8.3	0.14 de	3.0 c	138 bc	0.51 f
Msc Comb¶	2.7 b	8.3 a	1.6abc	1.02 ab	2.0	2.3	0.18 bcde	2.9 c	145 a	0.83 ef
Mor Bart¶	1.0 a	8.3 a	2.6a	1.08 a	1.8	3.7	0.11 e	2.4 c	141 ab	0.66 f

Frost suscept. = frost susceptibility score; density = density on sowing rows; DM 02 = dry matter on 02/02/88; DM 04 = dry matter on 05/05/88; SY = seed yields; Reg. = regeneration in October each year (score: 1 = no regeneration to 9 = excellent); SF 88 = number of days from sowing to first flower.

† J.M. Prosperi, unpublished data.

‡ G. Gintzburger, unpublished data.

§ ICARDA line of *M. rigidula*, without proper inoculation for St. Gely experimentation.

¶ Local ecotypes of *M. rigidula*, *M. scutellata* or *M. orbicularis* from France or Spain.

best cultivar in these conditions was Sephi although it is very susceptible to foliar fungi in ungrazed experiments (Le Chapitre area). Cultivars of *M. polymorpha* that perform well in Le Chapitre have too little seed production and tolerance to frost to regenerate well in Garrigues.

Some local ecotypes have good frost tolerance and adequate spring growth but poor winter growth (December to February) in comparison with Australian cultivars.

Medicago orbicularis regenerated poorly while having had the best seed production in the first year at St. Gely due to a high percentage of hard seed, a characteristic of the species. In contrast, MRI 834 had very good regeneration with quite poor seed production, but possessed the highest percent of soft seeds. This result confirms the possibility of selection of lines that combine average seed production with lower percentages of hard seed.

Conclusion

In French Mediterranean regions, climatic variability (from cold to cool and wet climates) is associated with variability of animal production and forage resources giving rise to multiple livestock production systems. One constant is the use of rangelands, which is generally important in the south of France. These environmental conditions are very similar in other European countries that border the Mediterranean (Italy, Greece, Yugoslavia and Spain).

In this case, medics, like perennial rhizomatous and prostrate lucerne, can be considered new forage resources for grazing during winter.

The climatic conditions of the Montpellier area, from the littoral plain to the hilly zones, present the possibility of evaluating plant characteristics such as foliar fungi diseases, frost susceptibility and winter growth under an array of pertinent conditions.

The first results showed that much variability exists among species and ecotypes of medics for these main characteristics and this provides hope for rapid progress in selecting some of these species for our environmental conditions.

References

Crawford, E.J. 1983. Selecting cultivars from naturally occurring genotypes: evaluating annual *Medicago* species. Pages 203-215 *in* Genetic Resources of Forage Plants (J.G. McIvor and R.A. Bray, eds.). CSIRO.

Cocks, P.S. and E.F. Ehrman. 1987. The geographic origin of frost tolerance in Syrian pasture legumes. Journal of Applied Ecology 24:67-68.

Gintzburger, G., J.J. Rochon and A.P. Concsa. 1988. The French mediterranean zones: Sheep rearing systems and the present and potential role of pasture legumes. Pages 179-194 *in* The Role of Legumes in the Farming Systems of the Mediterranean Areas (A.E. Osman, H. Ibrahim and M.A. Jones, eds.). Kluwer Academic Publishers, Dordrecht.

Mansat, P. 1981. Project de developpement d'un laboratoire d'amélioration des plantes fourragères pour la zone méditerranéenne. INRA Montpellier, France. 25 pp.

Masson, P. and G. Gintzburger. 1986. Enherbement des vignobles en climat méditerranéen: Perspectives d'utilisation des légumineuses annuelles. Pages 145-152 *in* Proceedings de 2ème Symposium International sur la Culture de la Vigne, Monpellier, France.

Masson, P. and G. Gintzburger. 1987. Le trèfle souterrain (*Trifolium subterraneum*): Essais préliminaires et perspectives d'utilisation dans une zone méditerranéenne française. Le Roussillon. Fourrages 110:183-204.

Olivieri, I., A. Bory, F. Angevain, M. Angevain, J.M. Prosperi and P. Mansat. 1989. Negative correlations between resource allocation to survival and reproduction: Comparison between annual and perennial species of *Medicago* for juvenile vigor. Pages 195-196 *in* Proceedings XVI Congrès International des Herbages, Nice, France.

Prosperi, J.M., M. Angevain and P. Mansat. 1987. Objectifs de sélection des *Medicago* annuelles pour la zone méditerranéenne française. Proceedings 5th Meeting of Sub-Network on Mediterranean Pastures. FAO-European cooperative network on pasture and fodder crop production, 13-17 October 1987. Montpellier, France.

Prosperi, J.M., V. Gensollen, I. Olivieri and P. Mansat. 1989. Observations sur la répartition et l'écologie de luzernes annuelles et de trèfle souterrain en Corse. Pages 295-296 *in* XVI Congrès International des Herbages, Nice, France.

Prosperi, J.M. and J.F. Soussana. 1984. L'amélioration pastorale des parcours de garrigues par sursemis. Premiers résultats. Fourrages 99:83-110.

Puckridge, D.W. and R.J. French. 1983. The annual legume pasture in cereal-ley farming systems of Southern Australia: A review. Agriculture Ecosystems & Environment 9: 229-267.

Rochon, J.J., J.P. Goby and G. Gintzburger. 1988. Utilisation de prairies à luzernes annuelles pour la production hivernale d'agneaux en plaine du Roussillon. Fourrages 116:409-418.

SCEES. 1980. Annuaire de la statistique agricole. Résultats 1979. Ministère de l'Agriculture, Paris.

SCEES. 1988. Annuaire de la statistique agricole. Résultats 1987. Ministère de l'Agriculture, Paris.

Thiault, M. 1979. Présentation des parcours méditerranéens. III Réflexions à partir de quelques aspects bioclimatiques. Pages 361-373 *in* Utilisation par les ruminants des pâturages d'altitude et des parcours méditerranéens. Xème Grenier de Theix.

Xème Grenier de Theix. 1979. Several authors. Utilisation par les ruminants des pâturages d'altitude et des parcours méditerranéens.

Constraints to Nodulation of Annual Medics by Indigenous Populations of *Rhizobium meliloti* in West Asian Soils

L.A. Materon
ICARDA, Aleppo, Syria

Abstract

Annual *Medicago* species are potentially useful legumes for ley farming systems in West Asia. Some soils within the habitat of these legumes contain no strains of *Rhizobium meliloti* able to induce effective nodulation and fix enough nitrogen to produce and sustain acceptable levels of herbage yields for livestock production. Some *Medicago* species require specific rhizobia to fix nitrogen. Experiments were conducted with 247 isolates of *R. meliloti* collected from diverse arable areas of West Asia. The aim was to define symbiotic characteristics and degrees of host specificity for the rhizobial strains. Six species of annual *Medicago* were inoculated with soil dilutions and aseptically grown *in vitro*. Responses were qualitatively evaluated on the basis of nodule quality and plant vigor. The classification scale included highly effective, partially effective, ineffective and no nodulation. Populations of *R. meliloti* in soils had different abilities to nodulate and fix nitrogen in these legumes. Soils of Syria, Jordan and Turkey contain higher proportions of ineffective rhizobial populations than soils of Cypriot or Lebanese origin. Despite the widespread presence of unsuitable rhizobia, highly effective strains for each of the six *Medicago* species were identified in all five countries. Many of these *R. meliloti* strains already have proved to be satisfactory under field conditions; they are currently being recommended as inoculants for the West Asia region.

Introduction

Lack of and ineffective nodulation have been reported as major constraints in the establishment of integrated farming systems based on the rotation of annual species of *Medicago* with cereals in the Mediterranean basin (Materon and Cocks 1988). The problem is of agricultural significance since ineffective populations cause parasitic nodulation and do not fix enough nitrogen to satisfy the requirements of the plant. Ineffective populations of *Rhizobium meliloti* in the soil often pose a considerable barrier to the introduction of inoculant strains, to the exploitation of annual *Medicago* species and to the improvement of livestock production. Annual *Medicago* species (commonly referred to as 'medics') cannot express their potential unless the soil contains compatible populations of the effective root-nodule bacterium, *R. meliloti*.

Very little is known about the size, distribution or nitrogen-fixing diversity of indigenous populations of *R. meliloti* in west Asian soils. Damirgi (1969) showed that numbers of *R. meliloti* in Iraq were influenced by soil salinity but gave no indication of their symbiotic properties. Radwan *et al.* (1978) observed that in the absence of inoculation native Iraqi medic species, in particular *M. orbicularis* and *M. polymorpha*, nodulated much better than the introduced Australian cultivars. Their conclusions were supported by Hamdi *et al.* (1978). Brockwell (1981) surmised, from the widespread natural occurrence of annual species of *Medicago*, that arable and nonarable soils of the west Asian region contain large and adapted populations of *R. meliloti*. However, analyses of their symbiotic characteristics were not performed. Conversely, we have observed that in Syria, northern Jordan and Lebanon, and in the southeastern Anatolian region of Turkey, some soils that are climatically and edaphically suitable for medic cultivation contain low populations of both effective and ineffective *R. meliloti*. The rather small size of these populations depends on ambient factors and generally ranges from 1 x 10^2 to 1 x 10^3 cells of *R. meliloti* per gram of soil.

Experiments were conducted with 247 isolates of *R. meliloti* collected from diverse arable areas of west Asia (Cyprus, Jordan, Lebanon, Syria and Turkey). The aim was to define symbiotic characteristics and degrees of host specificity of indigenous populations of *R. meliloti* found in arable soils of west Asia. The work also attempted to identify highly effective strains and to formulate inoculation strategies so that annual medic/cereal-based farming systems could be introduced successfully into the region.

Assessment of *Rhizobium* Strains

Soil Sampling

Sampling for native medic rhizobia was conducted during the spring in 1985, 1986 and 1987. Soil samples were collected from arable regions having an average annual precipitation ranging from 250 to 350 mm and where annual medic species occurred and could be potentially exploited as pasture crops. For each site, two to three soil samples (approximately 200 g each) were collected, mixed and kept in the same container. The samples were obtained from the upper 20 cm of the profile and from areas adjacent to medic plants if these were present; otherwise, the samples were taken from representative places. Sampling was done at least 15 m away from any roadside. Exact location of the site and prevalent medic species found in the surrounding area were recorded. Figure 1 illustrates the collection areas. A total of 247 soil samples were collected: 97 from Syria, 40 from Turkey, 58 from Jordan, 36 from Lebanon and 16 from Cyprus. Samples were air-dried at room temperature and sieved to uniform consistency in 500 μm-mesh sieves. The sieves were cleaned and sprayed with ethanol between samples to reduce contamination. Sieved samples were in tight containers and kept refrigerated until analysis.

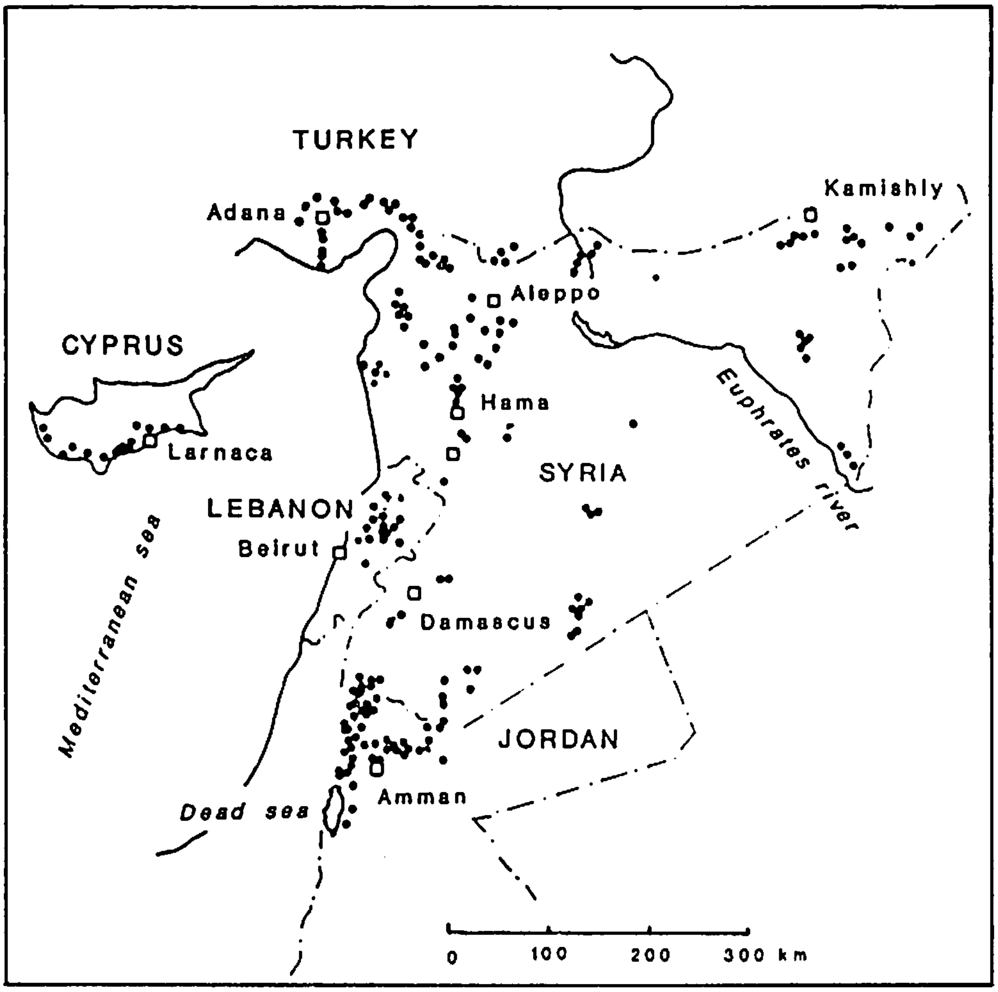


Fig. 1. Location map of the study area illustrating the sites of soil sampling.

Host Legumes

On the basis of agronomic and ecological attributes as well as wide natural occurrence, six promising species of annual medics were selected for these experiments. Their descriptions and origins are presented in Table 1. *Medicago rigidula* occurs in Syria and is often found in alkaline soils derived from limestone, *M. rotata* from soils derived from basalt; *M. noeana* is found very frequently in southeastern Turkey; *M. orbicularis*, *M. polymorpha* and *M. truncatula* are widespread species in Mediterranean countries. Both cultivars of these two last species were naturalized introductions widely used in Australia.

Table 1. Origins of the annual medics used in the experiments.

Species	Country of origin
Medicago rigidula (L.) All. Sel. 716	Jisr Al Shagour, Syria
M. rotata Boiss. Sel. 2123	Agda, Syria
M. noeana Boiss. Sel. 1938	Siirt, Turkey
M. orbicularis (L.) Bart. Sel. 30/3	Blas, Syria
M. truncatula Gaertn. Jemalong	Forbes, Australia
M. polymorpha (L.) Circle Valley	Coolgardie, Australia

Preparation of seedlings and inoculation
All medic seed was mechanically scarified. Surface sterilization was done by exposing seed to 95% ethanol for 1 minute followed by immersion in a 5.25% sodium hypochlorite (NaOCl) solution for 1 minute. After chemical treatment, seed was rinsed repeatedly in de-ionized sterile water as described by Vincent (1970). Seed then was transferred to petri dishes containing 1% water-agar, separated and spread apart on the surface of the gel. Dishes were kept inverted at room temperature to ensure that pregerminated seedlings developed with straight roots. Single seedlings were set out in cotton-plugged tubes (20 cm x 24 mm) containing Fahraeus N-free solution (Gibson 1987) and a 2:1 mixture of vermiculite and gravel. Ten grams of each soil sample were added to a 90-ml sterile water blank. The dilution was thoroughly mixed in a reciprocating shaker for 20 minutes. Each soil dilution was used to inoculate four seedlings corresponding to each of the six medic species. Each seedling root was impregnated with 1 ml of the inoculating soil dilution. It was assumed that this volume of inoculating soil suspension contained enough *R. meliloti* cells of the dominant strain to colonize and induce nodulation on the seedling.

Growth conditions
Immediately after sowing, the wooden racks with tubes were placed in a light-controlled room. The racks were randomly placed and rearranged on a weekly basis. The plants were subjected to a 12-hour photoperiod and a light intensity of 325 $\mu E\ m^{-2}\ s^{-1}$ at plant height. Temperature means were adjusted to 25°C for daylight and 18°C for the night periods.

Symbiotic assessment
The shoots of the plants were harvested after 5 weeks of growth and their mass determined. Plants were graded on their response to nodulation on the basis of vigor and color. Mass of dry shoots was used to measure plant response to nodulation and compared with the mass of uninoculated plants. Effectiveness ratings were graded from 0 to 3:

0 = no nodulation (NN)

1 = less than 50% symbiotic response; corresponded to the presence of ineffective nodulation (I); nodules in this category were parasitic and non-functional

2 = 50 to 75% response (partially effective, PE)

3 = 75 to 100% of maximum symbiotic response (E). Uninoculated plants were used to determine the zero response level, and the maximum response was obtained with nitrogen controls (0.10% KNO_3). An average effectiveness rating was developed for each population of medic rhizobia from each analyzed sample based on the nodulation response to the six medic species tested.

Isolation of rhizobial strains from nodules

Plants showing positive symbiotic response were selected for isolation of the *Rhizobium* occupying their nodules. Cultures were authenticated using the general procedure of Vincent (1970) to demonstrate the capacity to form effective nitrogen-fixing nodules in a wide range of annual medic species. To avoid genetic variation, the bacterial cultures were lyophilized and kept in small vials at 4°C.

Field evaluation of effective strains

Peat-based inoculants contained approximately 1×10^9 rhizobia per gram as determined by plate counts. Antibiotic-resistant mutants were used to determine the relative nodulation success of the inoculant strains. Cultural properties and symbiotic characteristics of the nonresistant parent strains were compared *in vitro* with the corresponding antibiotic-resistant mutants to detect any additional alterations within the mutant cultures (Materon and Hagedorn 1984).

Split-plot designs were used, with four replications; strain was the main plot. Experiments included uninoculated treatments with and without nitrogen fertilizer. Symbiotic response was measured by comparing herbage yields with those of the uninoculated controls. Data were subjected to analysis of variance and means were compared at the 5% probability level.

Results and Discussion

In this study, most of the soil samples collected throughout the region contained populations of *R. meliloti* able to induce nodulation. This was reflected by the production of either effective or ineffective nodulation across the six annual species of *Medicago* tested. Absence of nodules indicated no rhizobia or a marked host specificity for an inoculum, thus precluding infection and nodule formation. In the latter case, low numbers of saprophytic rhizobia in these soils may have been the cause.

Results obtained in these studies showed that highly effective nitrogen-fixing strains are present in west Asia for all the medic hosts, but in low proportions. Conversely, the presence of populations not efficient in producing a healthy symbiosis indicates the necessity of exercising caution whenever these *Medicago* species are introduced for cultivation.

Cyprus

The presence of moderately effective populations of *R. meliloti* was high in the eastern Cypriot region (Fig. 2). All sites sampled contained infective rhizobia. It is therefore assumed that inoculation was practised in the past and that the introduced inoculant strains have largely replaced the indigenous ineffective populations. The proportion of highly and moderately effective soil populations in Cyprus shows that there is a high probability of success for medic establishment. Inoculation of medic seed is thus not as essential as it is in other areas of west Asia. However, herbage increases have been obtained for *M. rotata* and *M. rigidula* by the introduction of elite strains isolated outside Cyprus (I. Papastylianou, pers. comm.).

Jordan

In the drier Jordanian environments the indigenous populations of *R. meliloti* were present in lower numbers than in other soils of the region. Numbers of *R. meliloti* averaged less than 750 per gram of dry soil. Most of the samples contained a very high proportion of ineffective bacteria (Fig. 2). Only *M. rotata* and *M. orbicularis* had a better probability of success in producing a functional symbiosis, as approximately 40% of Jordanian arable soils contain suitable nitrogen-fixing bacteria for these two species. On the other hand, less than 10% of the soil samples did not contain infective rhizobia for any of the species tested. Attempts to introduce *M. rigidula* have failed in Jordan because of the overwhelming presence of incompatible bacteria. In fact, approximately 93% of the soil samples tested contained bacteria not suitable for *M. rigidula*. Results strongly suggest that inoculation of medics is necessary for successful establishment of pastures in Jordanian soils. Introduced strains selected elsewhere in the region have overcome the indigenous ineffective populations and produced functional nodulation in this host with a significant increase of herbage yields (L.A. Materon, unpublished data).

Lebanon

The analysis of populations of *R. meliloti* in Lebanese soils collected in the Beqaa Valley showed that ineffective bacteria were predominant in nodulating *M. rigidula* and *M. noeana*. The latter failed to nodulate when inoculated with dilutions of 41% of the soil samples tested. In more than half of the cases, nodules of *M. noeana* contained the ineffective type of bacteria, thus producing parasitic nodulation in this host (Fig. 3).

It was found that *M. rotata* had normal and healthy symbiosis with the indigenous rhizobia found in Lebanese soils; less than 20% of the samples contained *R. meliloti*, which produced nonfunctional nodulation in this host (Fig. 3). The Australian cultivars of *M. polymorpha* and *M. truncatula* had a better chance of being effectively nodulated by the indigenous bacteria in both Lebanon and Cyprus than in any other country of the

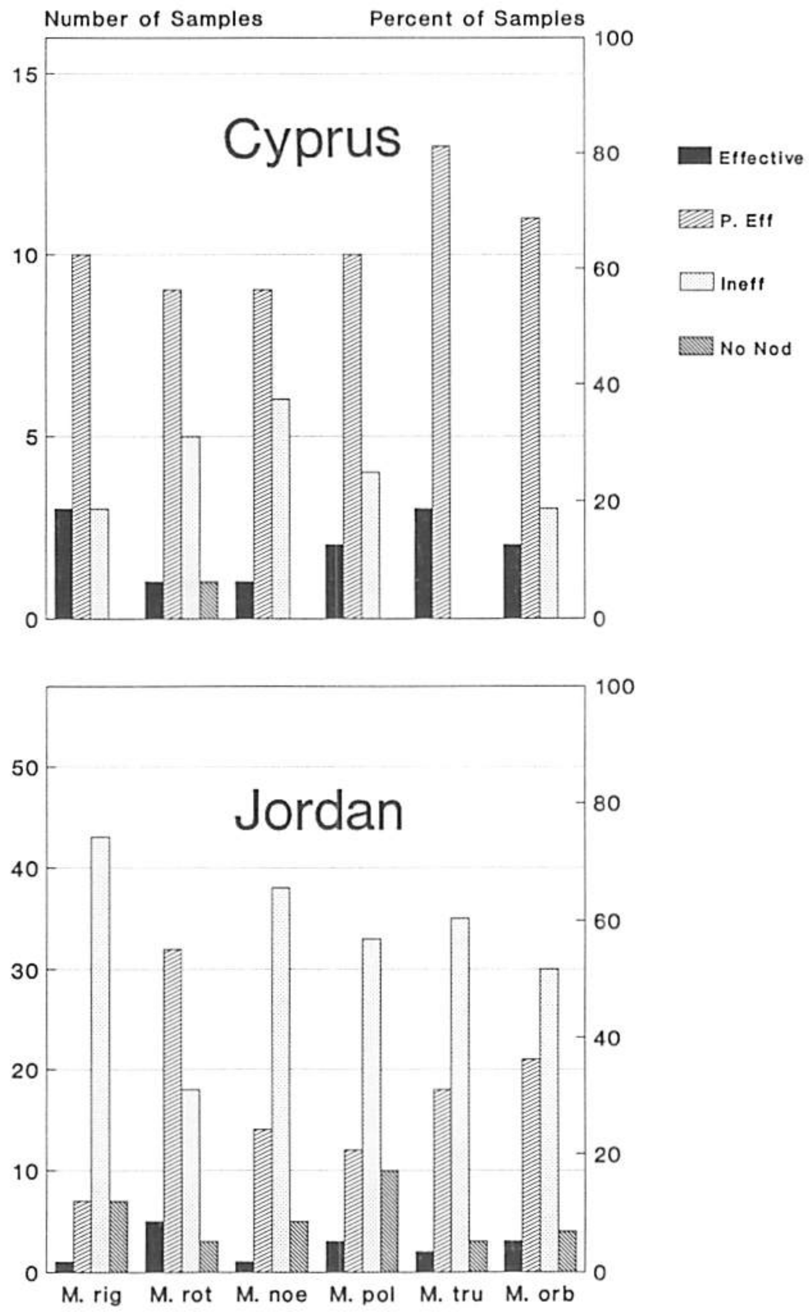


Fig. 2. Symbiotic responses of six annual species of *Medicago* to inoculation with indigenous populations of *Rhizobium meliloti* collected from soils in Cyprus and Jordan.

region. The presence of high numbers of effective and partially effective bacteria in the Beqaa Valley may be due to the environmental conditions, soil fertility and previous history of cultivation.

Syria

A high proportion of partially effective *R. meliloti* able to nodulate all the hosts was found throughout the arable lands of Syria. Moreover, less than 7% of the populations in the soil samples were of the highly effective type, regardless of the host species. Ineffective nodulation of *Medicago* hosts was common as was the presence of partially effective bacteria in Syrian soils (Fig. 3). In contrast to Lebanese and Cypriot soils, it was evident that Syrian soils do not contain suitable *R. meliloti* to effectively nodulate the Australian cultivars of *M. truncatula* and *M. polymorpha*. An inoculation program for these popular cultivars must be included to ensure nodulation success; otherwise, their use should be avoided. Furthermore, it has been observed that effective nodulation of *M. rigidula* occurs when it is associated with the indigenous rhizobial populations encountered in soils of northern Syria. However, when this species is nodulated by rhizobia collected from southern soils, it fails to produce functional nodules. *Medicago rigidula* in the northern part of Syria does not require inoculation, whereas in the southern part inoculation is imperative.

Turkey

The area examined in Turkey included high proportions of *R. meliloti*, which normally nodulated *M. noeana*, *M. polymorpha* and *M. orbicularis*. In contrast, no suitable indigenous *R. meliloti* bacteria were found for *M. rigidula* (Fig. 4). Recent trials in some areas with elite strains of *R. meliloti* selected at ICARDA have shown significant responses of *M. rigidula* to inoculation. Previous research conducted with local strains has shown that this species requires specific rhizobia for effective symbiosis (Brockwell *et al.* 1988). In addition, this species appears to grow better in calcareous soils than in the basaltic type of soils characteristic of southeastern Turkey.

Summary

As indicated in these surveys, populations of *R. meliloti* from each of the five countries under study varied markedly in their symbiotic response with each of the medic hosts. Numbers of viable saprophytic *R. meliloti* ranged from 4.5×10^2 to 7.2×10^3 in areas where medics have not been cropped as components of ley farming systems. Because of these low numbers and the type of rhizobia encountered in most soils, it is advantageous to sow inoculated seed to ensure effective nodulation and successful pasture establishment. In fact, a selected number of highly efficient strains of *R. meliloti* isolated during these studies are currently being recommended to national institutions and research groups in west Asia.

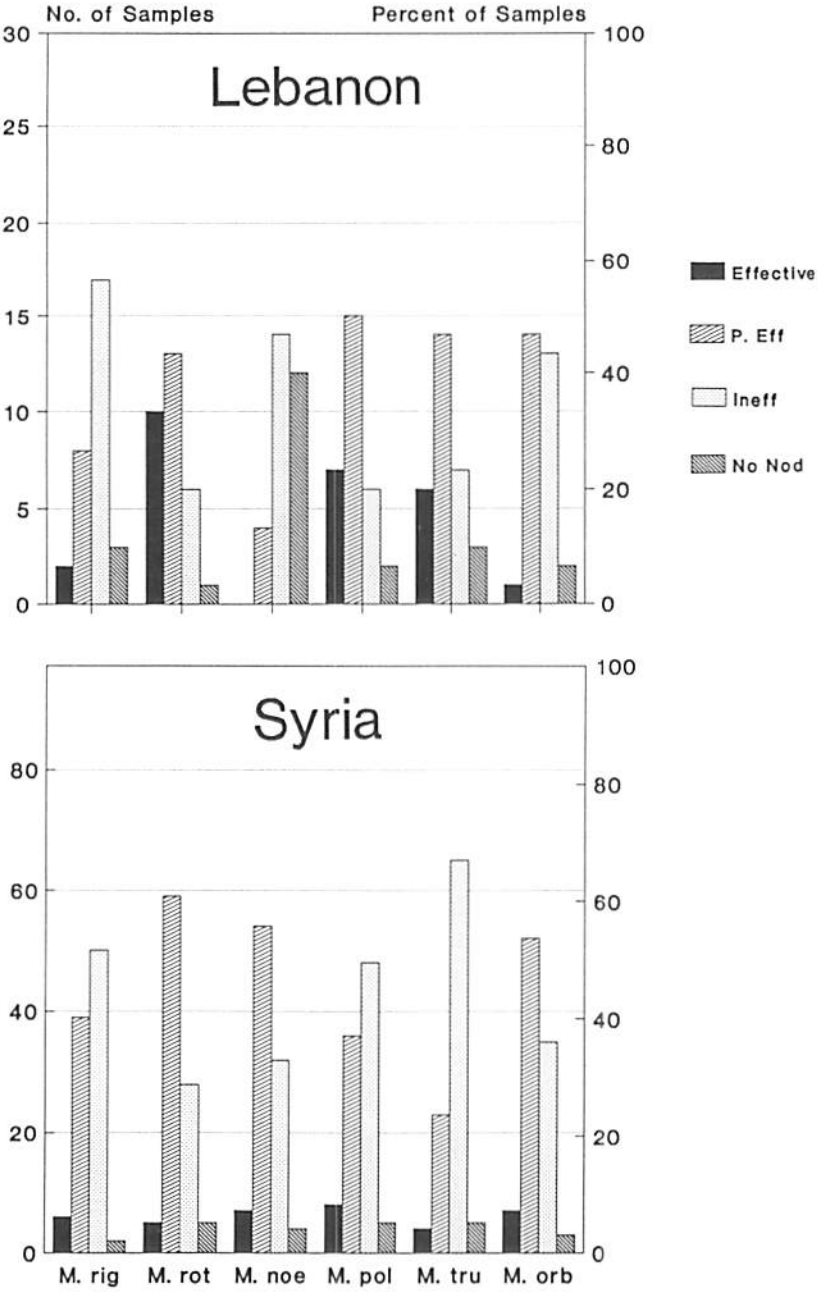


Fig. 3. Symbiotic responses of six annual species of *Medicago* to inoculation with indigenous populations of *Rhizobium meliloti* collected from soils in Lebanon and Syria.

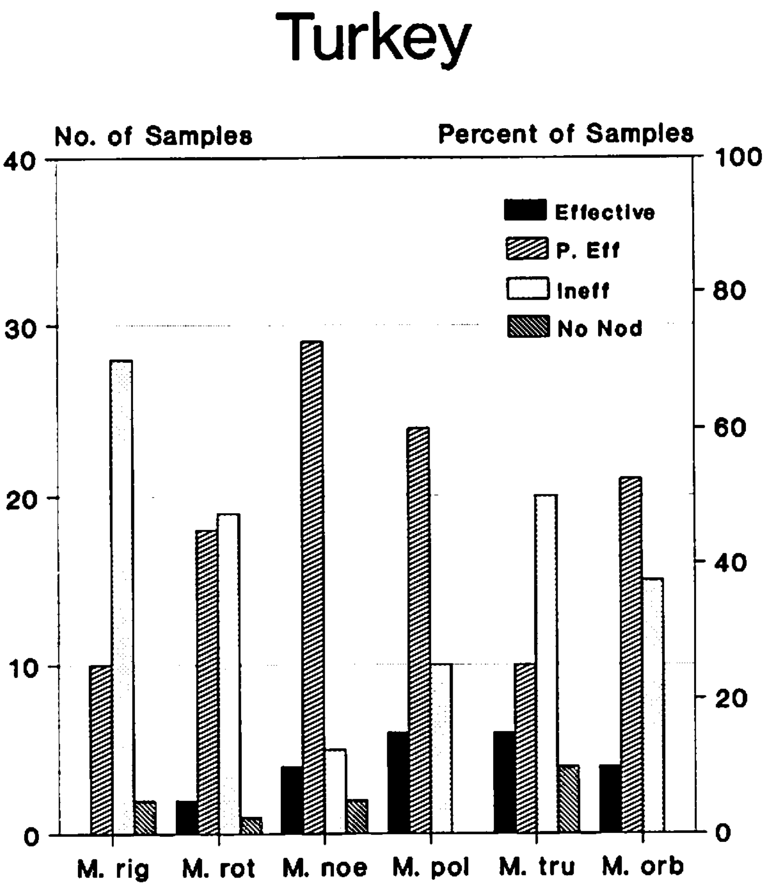


Fig. 4. Symbiotic responses of six annual species of *Medicago* to inoculation with indigenous populations of *Rhizobium meliloti* collected from Turkish soils.

Genetic characterization of populations of *R. meliloti* using all isolates tested in these studies have been analyzed by multilocus enzyme electrophoresis. The analysis revealed that the nominal species of *R. meliloti* consisted of at least two very distinct chromosomal lineages or evolutionary species (Eardly *et al.* 1990).

The need to define symbiotic requirements for the promising annual *Medicago* species and their ecotypes that are to be introduced into ley farming systems in the west Asian region is clear. Indeed, the widespread presence of large populations of ineffective *R. meliloti* in soils of the region poses a barrier to the introduction of annual medics if the seed is not inoculated. It is a matter of considerable importance, particularly if attempts are being made to develop cropping systems that utilize indigenous annual species of

Medicago for livestock production (Materon and Cocks 1988). Symbiotic characteristics of natural populations of *R. meliloti* of west Asian soils as related to environmental parameters such as soil features and vegetation need closer attention in order to formulate proper inoculation strategies.

References

Brockwell, J. 1981. A strategy for legume nodulation research in developing regions of the Old World. Plant & Soil 58:367-382.

Brockwell, J., R. Holliday, D.M. Daoud and L.A. Materon. 1988. Symbiotic characteristics of a *Rhizobium*-specific annual medic, *Medicago rigidula* (L.) All. Soil Biology & Biochemistry 20:593-600.

Damirgi, S.M. 1969. Populations of the naturalized alfalfa nodule bacteria in Central Iraqi soils. Iraqi Journal of Agricultural Science 4:37-44.

Eardly, B., L.A. Materon, D. Johnson and R.K. Selander. 1990. Genetic structure of natural populations of the nitrogen-fixing bacterium *Rhizobium meliloti*. Applied & Environmental Microbiology 56:187-194.

Gibson, A.H. 1987. Evaluation of nitrogen fixation by legumes in the greenhouse and growth chamber. Pages 321-369 *in* Symbiotic Nitrogen Fixation Technology (G.H. Elkan, ed.). Marcel Dekker, New York.

Hamdi, Y.A., A.N. Yousef, A.S.K. Al-Azawi and M. Al-Baquiri. 1978. Distribution of *Rhizobium meliloti* and *R. trifolii* in Iraqi soils. Soil Biology & Biochemistry 10:149-150.

Materon, L.A. and P.S. Cocks. 1988. Constraints to biological nitrogen fixation in ley-farming systems designed for West Asia. Pages 93-106 *in* Microbiology in Action (W.G. Murrell and I.R. Kennedy, eds.). John Wiley and Sons, New York.

Materon, L.A. and C.H. Hagedorn. 1984. Responses of crimson clover to inoculation with genetically-marked strains of *Rhizobium trifolii*. Communications in Soil Science & Plant Analysis 15:33-47.

Radwan, M.S., A.K. Al-Fakhry and A.M. Al-Hassan. 1978. Some observations on the performance of annual medics in northern Iraq. Mesopotamia Journal of Agriculture 13:55-61.

Vincent, J.M. 1970. A manual for the practical study of the root nodule bacteria. IBP Handbook No. 15. Blackwell Scientific Publications, Oxford.

Developing Annual Pasture Legumes for Mediterranean Farming Systems

E. Piano
Istituto Sperimentale per le Colture Foraggere, Lodi Sezione O.P. di Cagliari, 09124 Cagliari, Italy

Abstract

The great edaphic and climatic variation within the Mediterranean region implies the use of a wide range of species and varieties to meet diversified environmental requirements. Development of varieties of annual pasture legumes must be supported by collection of locally adapted populations. Owing to the marked specificity of the association between species and rhizobia, the availability of co-evolved microsymbionts often is required from the first stages of ecotype selection. Selection criteria common to all species are: appropriate maturity, adequate hardseededness, cold resistance, drought resistance, grazing tolerance, winter growth and adaptation to a low nutrient supply. Early vigor and competitive ability also are important. In subterranean clover, varieties of both subspecies *subterraneum* and *brachycalycinum* are required. Long flowering duration is required in environments with intermittent rains in spring. In medics for ley farming systems, high seed yield and long-term seed survival are major selection criteria. Selection of small-seeded types is advocated to improve seed survival after ingestion by sheep. Laboratory techniques are needed for predicting long-term breakdown of seed impermeability and more knowledge is needed on the survival of medic seed buried by tillage. Medic cultivars for arid rangelands must combine earliness with a rapid rate of pod maturity.

Introduction

Introduced in Australia as weeds, the annual self-regenerating legumes are the basis of improved pastures. In the Mediterranean basin, they have not been an unqualified success, neither in continuous pasture systems nor in ley farming (Adem 1974; Francis *et al.* 1977; Radwan *et al.* 1978). One of the main reasons for failure is lack of adapted species and varieties.

The genetic basis of species introduced to Australia was necessarily limited and inbreeding has not facilitated a substantial widening of the intraspecific variation. Natural or deliberate selection also implies specific adaptation to southern Australia (Cocks *et al.* 1980; Gladstones and Collins 1983).

In the early 1970s the Australian medics were representative of only 5 of about 30 species occurring naturally in the Mediterranean region (Heyn 1963). The most widely sown varieties, and hence the most widely tested, were from *Medicago truncatula* and *Medicago littoralis*, both warm winter species not tolerant of frost. Subterranean clover is represented in Australia only by species *brachycalycinum*, perhaps the most widespread in the Mediterranean, cv. Clare and a few naturalized strains (Gladstones and Collins 1983) and by species *yanninicum*, until recently by only one strain. All of the early Australian cultivars were naturalized strains or derivatives of natural strains by crossing or artificial mutation.

It is not surprising, therefore, that when introduced to a wide range of edaphic and climatic conditions in the Mediterranean basin, they often failed to persist.

Germplasm Collection and Selection Programs

Requirements for Diversified Genetic Resources

The Mediterranean region is noted for its great variation in climate and soils to which annual legumes have developed a specific adaptation. To meet the very diversified environmental and economic requirements, development of cultivars will have to be based on diversified genetic resources. Selection from locally occurring species is a basic principle.

Development needs to be supported by germplasm collection. Together with providing genetic variability the collections will also provide: a definition of the ecology of each species with precise information on distribution in relation to soils and climate; information on the relationship between physiological variation and variation of natural habitats, and knowledge of the rhizobial component and on the specificity of host-rhizobia associations.

Target Species

Subterranean clovers

In subterranean clover, varieties of both sspp. *subterraneum* and *brachycalycinum* are required. Selection for appropriate maturity must consider the different maturity requirements. Development of cultivars with higher hardseededness, distinct burr burial ability and capacity to set seed when burial is prevented are main selection criteria. Long flowering duration is required in environments with intermittent rains in spring. Subterranean clover is a major target for areas with moderate rainfall (> 500 mm) and acid/slightly alkaline soils. The ecological specialization of the subspecies is as follows: ssp. *subterraneum* is best for acid/neutral, light-textured soils and for heavy grazing pressure; ssp. *brachycalycinum* for moderately alkaline, heavy and hard-setting soils, and ssp. *yanninicum* for areas subject to seasonal flooding (Francis *et al.* 1975; Francis and Katznelson 1977; Gladstones 1976; Francis and Gillespie 1981; Piano *et al.* 1982). Owing to the higher frequency of alkaline soils in the Mediterranean region, ssp. *brachycalycinum* is likely to play a much more important role than it does in southern Australia, where the prevailing soil types are more suitable to ssp. *subterraneum* (Gladstones and Collins 1983).

Subterranean clover is not likely to be as important as medics in ley farming because of its lower hardseededness (Bolland 1986). However, attention must be paid to specific genetic sources, such as the large-seeded 'Moroccan type' which exhibits high levels of hardseededness (Francis and Gladstones 1983).

Medicago species
Among the medics, *Medicago polymorpha* is the most widespread irrespective of soil, climate, or grazing pressure. Its potential is still to be exploited.

Medicago truncatula should be the focus in warm winter environments with limestone-based loamy and clay-loamy soils in medium (300-500 mm) rainfall areas. However, recent collections in cold winter environments in north Africa (Francis 1987; Abdelguerfi *et al.* 1988) suggest that some ecotypes have high levels of cold tolerance, which could be utilized for frost-prone environments.

The specificity of *Medicago rigidula* to cold winter environments is well recognized (Cocks and Ehrman 1987; Dauro and Gintzburger 1987; Francis 1986, 1987; Francis and Katznelson 1977; Abdelguerfi *et al.* 1988). It now provides a genetic basis for frost-prone regions (Abd El Moneim and Cocks 1986). Cold tolerance also is exhibited by *Medicago aculeata* (Francis 1987), which is more frequent in north Africa, and by the relatively rarer *Medicago rotata* and *Medicago noeana*, both limited to west Asia (Cocks and Ehrman 1987).

The warm winter species *M. littoralis* and *Medicago tornata*, which prefer sandy soils, are not likely to play a significant role in the Mediterranean region because of their frost susceptibility and the distribution of suitable soils (Gintzburger *et al.* 1984).

Medicago murex came to attention when collection tours in Sardinia (Francis and Gillespie 1981; Piano *et al.* 1982) indicated its unique adaptation to acid soil. It is considered an alternative to subterranean clover for ley farming in acid soils. It nodulates effectively even in soils with a pH close to 4, provided that acid-tolerant strains of *Rhizobium meliloti* are used (Howieson and Ewing 1986).

Medicago rugosa is quite rare. A recent collection in Sicily confirmed its adaptation to calcareous soils with moderate rainfall (Piano *et al.*, unpublished data), where it exhibits high pod production even under grazing.

Medicago laciniata is a dominant species in dry areas of north Africa. It is the most likely to survive near the arid boundary (Gintzburger and Blasin 1979; Francis 1987). The spiny burr, particularly in *M. laciniata*, is likely to be a problem in improved pastures (Francis 1987).

Among the other medics, the large-podded *Medicago scutellata* and *Medicago intertexta*, which share the same requirements for heavy alkaline calcareous soils and warm winters, are vulnerable to summer grazing and, particularly in *M. scutellata*, to frost. Similar considerations apply to *Medicago orbicularis*, a ubiquitous species, but never dominant in heavily grazed situations. *Medicago arabica* exhibits a wide edaphic adaptation and is tolerant to grazing but is restricted to wet areas (> 500 mm) (Francis and Katznelson 1977; Piano *et al.* 1982).

The Rhizobia

The adaptation of a legume for its environment is accompanied by adaptation of its microsymbiont; for example, successful introduction of *M. murex* to Australia was dependent on introducing acid-tolerant strains of *R. melilotii* from Sardinia (Howieson and Ewing 1986). The collection and evaluation of both legumes and rhizobia clearly indicate a marked specificity which is often related to the origin of both organisms (Materon and Brockwell 1987).

The specificity of *M. rigidula* in particular leads to serious difficulties in selection programs, particularly when exotic material is under evaluation (Gintzburger *et al.* 1984; Prosperi *et al.* 1987). It seems advisable that adequate mineral nitrogen be available during evaluation in the first stages of selection. Subsequently, the ability of outstanding lines to nodulate and fix nitrogen must be evaluated with the widest range of rhizobial strains, including strains isolated at the same locality as the plant (Robson 1990).

Cultivar Selection in Relation to Environment and Farming System

Pasture legumes may be included in continuous pasture systems and in rotational systems such as ley farming. In the northern Mediterranean region, pasture legumes are recommended mainly for pasture establishment of abandoned land and for rehabilitation of degraded pastures where grazing is the major land use. Continuous pasture is the prevailing system in such conditions, but less conventional agricultural systems that lead to integration of diversified productions have been suggested (Masson and Gintzburger 1986). In north Africa and west Asia, pasture legumes are used to replace fallows and hence rotational systems will be prevalent.

Very high seed yield and distinct long-term seed survival are major selection criteria in medics for ley-farming systems. Higher flower and pod survival, timely flowering and selection of small podded types are criteria related to seed yield. Selection of small-seeded types is advocated to improve seed survival after ingestion by sheep. In order to develop selection criteria for seed survival, laboratory techniques are needed for predicting long-term breakdown of seed impermeability, as well as more knowledge on survival of medic seed buried by tillage practices. Development of medic cultivars for arid rangelands requires a combination of earliness and rapid rate of pod maturity.

In defining selection criteria there are two main requirements: first, the species and variety must fit the edaphic and climatic conditions in which they are to be grown; second, the species and the variety must fit the particular conditions imposed by the farming system. The former is a general and preliminary requirement, the latter requires that criteria should be further adjusted to the system's constraints.

Selection criteria common to all species are: appropriate maturity, adequate hardseededness, cold resistance, drought resistance, grazing tolerance, winter growth and adaptation to low supply of nutrients. Early vigor and competitive ability are also important.

General Requirements of Environmental and Agronomic Adaptation

Appropriate Maturity

Persistence and productivity of annual pasture legumes are associated with seed yield and this is related to maturity (Rossiter 1966). In a given environment, the reproductive phase should take place early enough for adequate seed to be produced before the advent of drought. Because of climatic variability, maturities within species will be greatly diversified in the Mediterranean region, even in restricted areas. A main component of maturity is flowering time. The relationship between flowering time and length of the growing season may help in identifying appropriate maturities for a given environment (Piano 1987a).

Both annual medics and subterranean clover flower in response to vernalization, a short dark period and high temperature (Evans 1959; Clarkson and Russel 1975). Interaction between these factors leads to wide differences in flowering time from site to site. These differences may have negative implications on selection programs in which time of flowering is examined in a single location (Piano 1987b), although models for extending flowering time observations from one location to another can be developed (Archer *et al.* 1987; Hochman 1987).

In Mediterranean regions, flowering of early subterranean clovers is delayed compared with western Australia (Fig. 1), while late lines may be hastened. The difference is consequently shortened (Gomez Pitera *et al.* 1979; Piano 1987b). Variation among ecotypes can be discriminated more clearly in an environment (such as Perth) that displays the variation among genotypes most clearly (Fig. 2).

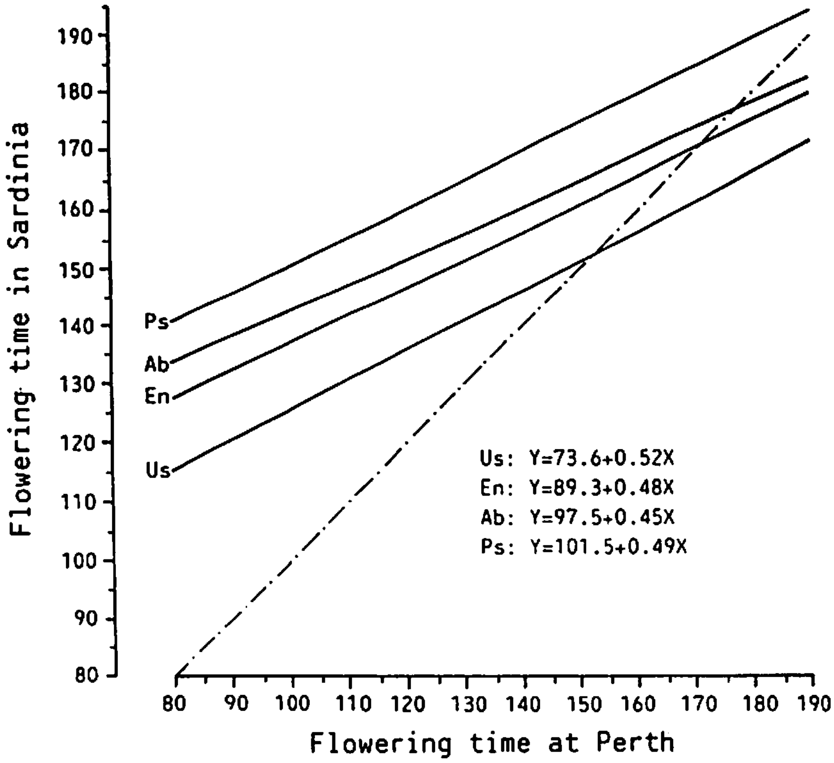


Fig. 1. Relationship between flowering time at four sites in Sardinia (Italy) and Perth (Australia) in Sardinian ecotypes of subterranean clover ssp. *subterraneum*. At the four Sardinian localities winter length and severity increased in the order: Us > En > Ab > Ps.

Important aspects of maturity are time from appearance of first flowers to attainment of seed viability, length of flowering and rate of inflorescence production. In subterranean clover, Francis and Gladstones (1974) found that short and fast-flowering strains produced mature seeds faster than long and slow-flowering strains. In the Mediterranean basin, ecotypes that flower for short periods have an advantage in marginal areas where the rainy season ends abruptly. Rainfall is generally intermittent in spring and periods of water stress occur during flowering; seed yield may be reduced in a variety with a short flowering period whereas one with prolonged flowering may recover and flower again (Andrews *et al.* 1977). Rapid maturation, irrespective of flowering, must be an important selection criterion, particularly so in medics (Gintzburger 1984).

Seed Survival

Insufficient hardseededness of Australian varieties of subterranean clover has been a

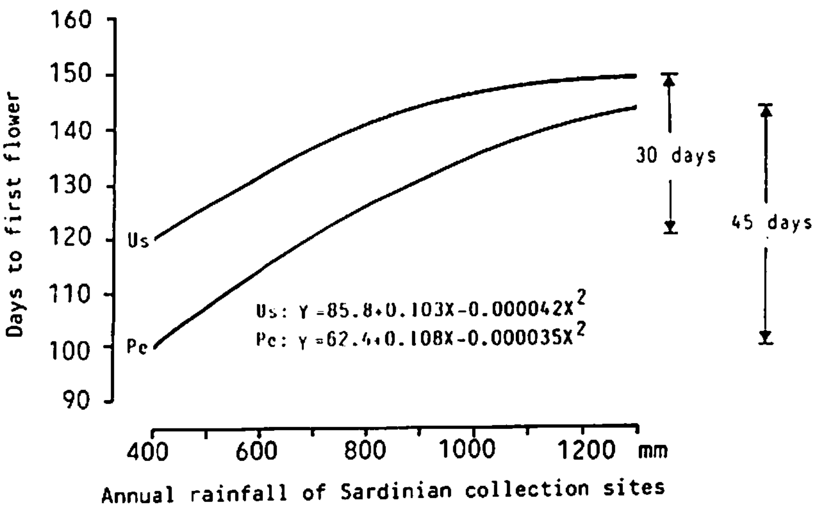


Fig. 2. Relationship between flowering time of Sardinian populations of subterranean clover (ssp. *subterraneum*) and annual rainfall of their collection sites when examined at Ussana (Sardinia) and Perth.

main cause of their failure in the Mediterranean region (Francis *et al.* 1977; Piano 1987a). There is some evidence that in medics the seeds of imported cultivars are softer than those of many native ecotypes (Cocks 1988). Softening is a result of diurnal fluctuations of temperature over the summer (Quinlivan 1961; Taylor 1981) and is most rapid in environments with long summers, high temperatures and large diurnal fluctuations (Quinlivan 1965).

The need for hardseededness is least in high-rainfall, long-season environments where the summers are shorter and cooler and where seed softening is slower. Furthermore, the ability of indigenous strains to remain hard decreases with increasing annual rainfall and altitude of origin.

Embryo dormancy is not considered as important as hardseededness in Mediterranean environments, its effect being limited to seed maturation and the period immediately following (Quinlivan 1971a). However, I have observed in both Spain and Sardinia that newly produced seed of subterranean clover germinates after unseasonal rains in June, before seed coats become hard (Quinlivan 1971b). Perhaps the ecological significance of embryo dormancy needs further study.

Grazing Tolerance

The ability to grow and set seed under heavy grazing is a fundamental attribute of pasture legumes. In subterranean clover there is intraspecific variation in the effect of grazing during flowering (Collins 1978). Particularly in medics, where the pods are more vulnerable to grazing, knowledge of the ideal plant morphology, which allows grazing without removal of the developing pods, is needed.

Frost Tolerance

The main cause of the failure of Australian medics in Mediterranean areas is lack of frost tolerance (Radwan *et al.* 1978; Cocks and Ehrman 1987). The development of frost-tolerant legumes must be accepted as a major selection criterion. Particularly in medics, this applies also in climates with warm winters, where survival may be compromised by episodic frosts, particularly when they coincide with occasional droughts. Better frost tolerance also is required in subterranean clover, particularly in the more susceptible species *brachycalycinum* (Masson and Gintzburger 1987).

Winter Growth

Although winter production of regenerating pastures is dependent on plant density (Abd El Moneim and Cocks 1986), genetic differences also must be exploited. The objective is to combine frost tolerance with ability to grow in winter, which implies some compromise (Prosperi *et al.* 1987). Winter yield is positively correlated to early maturity and this in turn is negatively correlated to frost tolerance (Fig. 3). However, observations of Sardinian ecotypes of subterranean clover indicate that winter vigor and flowering time are largely independent and this indicates the potential for selecting late strains that combine frost tolerance and winter growth. In annual medics the negative relationship between frost tolerance and winter growth is closer in some species than in others (Prosperi *et al.* 1987).

Early Vigor

In the Mediterranean region the opening of the rainy season is less predictable than in Australia and episodic rains may be frequent. A rather common feature is a late opening accompanied by early onset of low temperatures. In such conditions, early vigor, associated with frost tolerance, is important for establishment. Good seedling vigor, combined with high density, is a major determinant of winter yield and a main component of competitive ability. Selection for early vigor implies studies on root elongation, effect of seed size, water retention of germinating pods and relative growth rate of seedlings.

Drought Resistance

Water stress is critical at two periods: during plant establishment and during reproduction. Therefore, both seedling drought resistance and a plant's ability to recover after water stresses during flowering and produce adequate seed could be assumed as

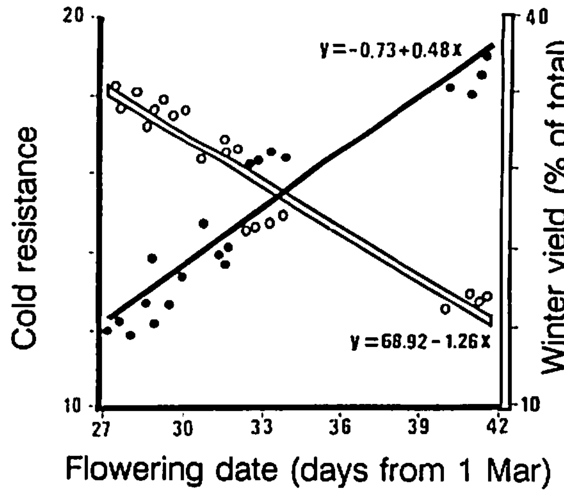


Fig. 3. Relationship of flowering time to cold resistance and winter yield in cultivars and ecotypes of subterranean clover evaluation in southern Tuscany (Italy). (From Talamucci and Pardini 1987)

selection criteria. There are known differences among species in seedling survival under water stress (Cornish 1974), but the subject has been little investigated, particularly for intraspecific variability. Once flowering has begun, water stress generally hastens the reproductive phase in both annual medics and subterranean clover (Clarkson and Russell 1976; Andrews *et al.* 1977). However, recent investigations have indicated that a water stress imposed for 3 weeks during flowering reduces seed yield in subterranean clover but not in medics. Seed yield reduction in the former is, however, lower in strains with a longer flowering duration (Andrews *et al.* 1977).

Adaptation to Low Supply of Nutrients

There may be scope for selecting genotypes able to grow with a low supply of phosphorus and other nutrients. In this sense there is wide inter- and intraspecific variation. Compared with subterranean clover, serradella (*Ornithopus compressus* L.) has been found to need only about half the amount of phosphorus to produce a given herbage yield (Bolland 1986b). Robson (1990) reports that within genotypes of subterranean clover there are remarkable differences in ability to grow well with a low phosphorus supply and that these differences are related mainly to variability in phosphate uptake rather than in efficiency of phosphorus utilization within the plant. Further investigation on this aspect could aid in developing more efficient varieties for the Mediterranean regions.

Farming System Constraints and Selection Objectives

In both continuous pasture and rotational systems, adequacy of pasture regeneration depends on quantity of germinable seed at the break of the season and thus on plant establishment. At least 1000 plants/m^2 are required in southern Australian conditions to allow adequate pasture regeneration (Puckridge and French 1983). In both systems, a quantity of seed must remain dormant and constitute a reserve to allow long-term pasture regeneration following cropping and/or adverse seasons in which little seed is produced. Also in both systems, grazing of seed during summer is an important stabilizing factor for the pastoral enterprise although it may imply danger of seed depletion and jeopardize pasture regeneration.

The quantity of germinating seed at the break of the season is a result of: the amount of seed initially produced; the quantity left over after summer grazing; the quantity able to germinate, unrestricted by coat impermeability, and the quantity near enough the soil surface to emerge successfully. Selection criteria, in terms of the level of expression of some plant characteristics, are largely influenced by the interactions between these factors and the management system.

Seed yield must be far higher in varieties for crop pasture rotations because:
- unlike in a continuous pasture system, seed that germinates in autumn is lost because it is destroyed by cultivation and herbicide application during the cropping phase, the amount of losses being related to the level of permeability;
- the remaining hard seeds are buried at different depths depending on tillage practices (Taylor 1985); some are destroyed by microbial decomposition (Taylor 1984) or lost due to germination at depth and only the portion nearest the soil surface will be available for the following pasture phase[2].

Allowing for the proportion of seed that must remain dormant, it has been estimated that in a ley farming system 400 kg/ha of seed is required for most medics to allow an effective regeneration of pastures (1000 plants/m^2). Much more seed must be produced if summer grazing is contemplated (Cocks 1988). Hardseededness and long-term seed viability also must be higher in species and varieties for ley farming systems, the seed remaining longer exposed to the softening effect of high summer temperatures or long buried in the soil.

Early vigor and competitive ability deserve more consideration in varieties for continuous pasture systems where, in the absence of the cropping phase, there is no control of volunteer species (Prosperi *et al.* 1987). They are mainly important in the European

[2] Seeds buried deeper may, however, be uplifted by a subsequent tillage and those that do not germinate may be available, after oversummering, in the next regenerating phase.

Mediterranean region where annual legumes, used in pasture conversion of abandoned land and in rehabilitation of degraded pastures, must cohabit with a rich and aggressive flora and often must be overseeded on native swards and sown in mixtures with grasses.

Development of Adapted Varieties of Subterranean Clover

The reliability of seed production of a subterranean clover variety in a given environment is influenced by a number of plant characteristics. Together with direct and indirect components of seed yield common to other pasture legumes, in this species burr burial capacity and ability to set seed above the soil surface when burial is prevented are additional and overriding features.

The species *subterraneum* and *brachycalycinum* will both be important in the Mediterranean basin, where they are largely sympatric. In terms of agronomic utilization, they often are expected to share soils located in the same or similar climatic areas or to be cultivated in mixture. Selection of cultivars of appropriate maturity must take into account the different maturity requirements of the two subspecies (Piano 1987c).

Independent observations on Mediterranean ecotypes have indicated that members of ssp. *brachycalycinum* are generally later than members of ssp. *subterraneum* from the same area (Crespo 1970; Francis *et al.* 1977; Piano 1987a). A main selection criterion that emerges is that the varieties of ssp. *subterraneum* should be adequately earlier than the varieties of ssp. *brachycalycinum* for similar climatic environments. Other observations (Piano 1987c) also indicate that the mean maturities of the populations vary much more in ssp. *subterraneum* than in ssp. *brachycalycinum* when the length of the growing season of the collection sites varies, and that the difference in maturity between the two subspecies is much greater in the sympatric populations originating from the driest environments than in those originating from the wettest environments (Fig. 4). There is also evidence that the changes in mean maturity depend mainly on the variation in altitude in ssp. *brachycalycinum* and mainly on the variation in rainfall in ssp. *subterraneum* (Piano 1987c).

The relatively stable flowering time of the populations of ssp. *brachycalycinum* suggests that fewer varieties than in ssp. *subterraneum* are required to cover similar ranges of climatic variation. The later flowering behavior of ssp. *brachycalycinum* with respect to ssp. *subterraneum* from the same environments indicates that, particularly in short-season environments, a longer vegetative growth and a greater production is expected in the former. This seems corroborated by some experimental evidence (Fig. 5), although this higher yield potential is mainly expressed in fertile soils and is partly jeopardized by the lower grazing tolerance of ssp. *subterraneum*.

In most Mediterranean regions suitable for the introduction of subterranean clover, breeding of very early maturing clovers of ssp. *subterraneum* seems less important than

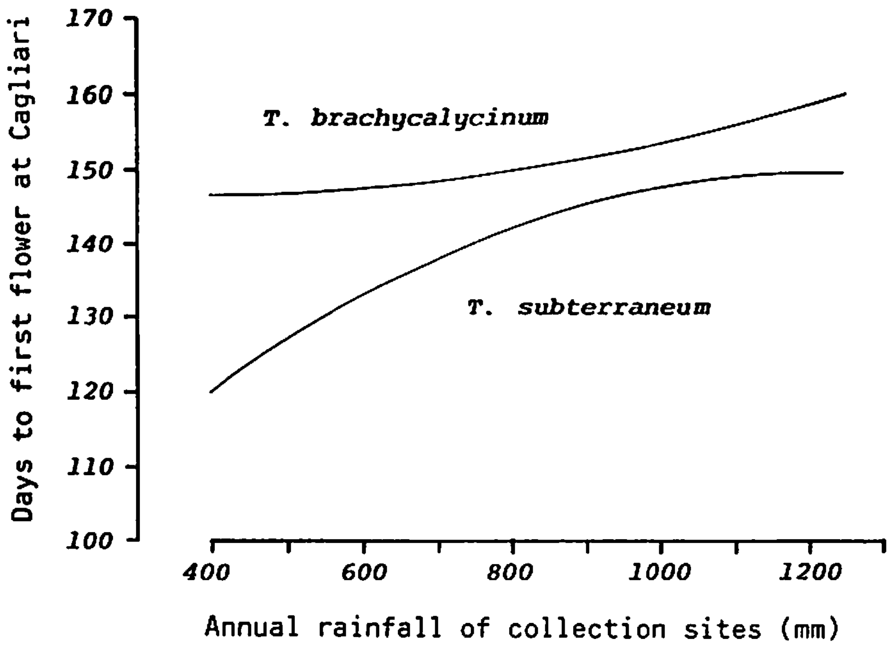


Fig. 4. Relationship between mean flowering time and annual rainfall of collection sites in Sardinian populations of subterranean clover.

in Australia. Even in very short-season environments, winters are longer and colder than in similar environments in southern Australia and particularly the earliest strains are strongly delayed in flowering by the slowing effect of the cold in the post-initiation phase (Fig. 1). The differences in maturity among strains of the early range are remarkably similar. In southern Sardinia the difference in flowering time between the cultivars Dwalganup and Seaton Park is less than 10 days compared with about 30 days in west Australia (Fig. 6). In such conditions it is pointless to emphasize earliness beyond certain limits and consequently limit potential herbage production. Later flowering than the Australian early maturity limits, combined with good seed production when conditions allow, and higher hard seed content are better selection criteria.

In the European Mediterranean regions a selection objective for ssp. *brachycalycinum* is to develop varieties somewhat later than cv. Clare, the only one available (Francis *et al.* 1977; Piano 1987a). Earlier cultivars are required in more southern regions.

Subterranean clover strains vary substantially in flowering duration, rate of flower production and rate of seed development (Francis and Gladstones 1974). Among the early varieties, Geraldton starts flowering after Dwalganup but flowers more intensely for a shorter period and produces viable seed earlier. In terms of dry matter production, a model with a relatively longer vegetative growth period followed by a shorter period

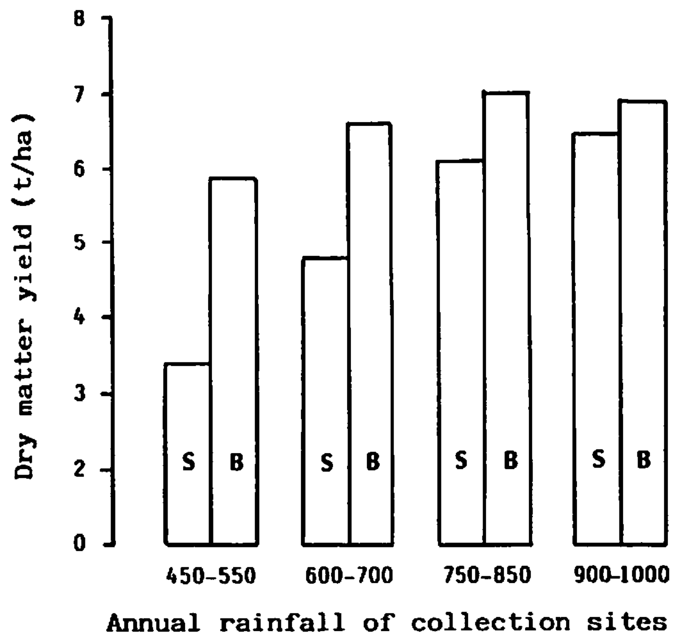


Fig. 5. Comparison between dry matter yield (t/ha) of ecotypes of sspp. *subterraneum* (S) and *brachycalycinum* (B) originating from similar rainfall environments. B ecotypes from low-rainfall environments are far later than S ecotypes from the same environments, the difference in maturity decreasing with increasing annual rainfall for the sites of origin.

of intense flowering would be more suitable than a model with a shorter period of vegetative growth and a longer period of flowering. However, because intermittent rains occur from late winter to spring in most areas of the Mediterranean region, a model with a long flowering duration coupled with a reasonably early commencement of flowering seems more reliable for seed yield and persistence, particularly in midseason to late varieties (Moreno and Olea 1988).

A higher level of residual hardseededness is a selection criterion, particularly for midseason to late varieties, which are the most permeable among the Australian cultivars. This is confirmed by the comparison between the hardseededness of native ecotypes from different climatic conditions and the inherent hardseededness of the Australian cultivars which, according to their maturity, are commonly grown in the same environments (Table 1). Although subterranean clover is on average less hardseeded than annual medics, great interspecific variation occurs to allow successful selection of more hardseeded types to be used in crop-pasture rotation (Fig. 7). Selection for high levels of hardseededness is of particular importance in ssp. *brachycalycinum*, a member of the subterranean clover group generally more permeable than the others.

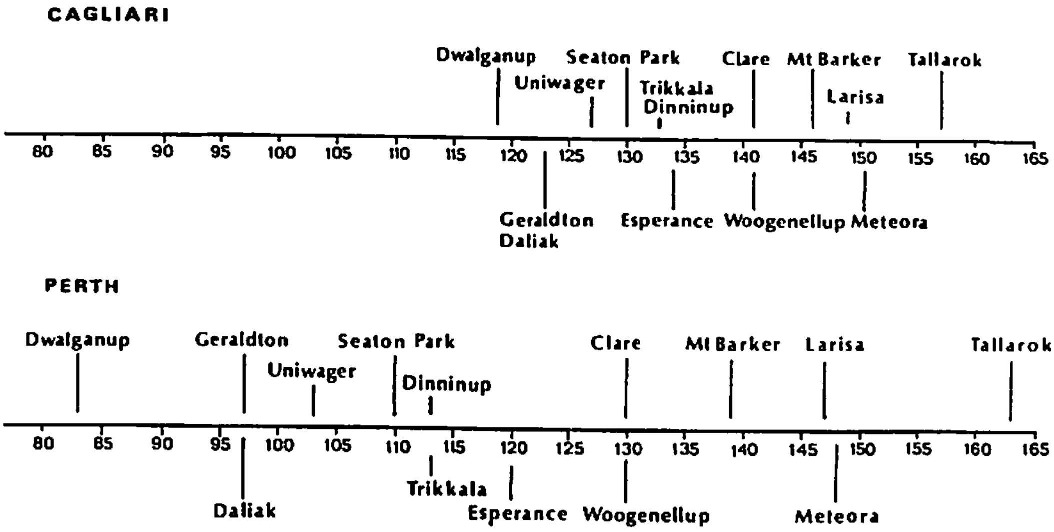


Fig. 6. Days to first flower of some Australian varieties of subterranean clover when grown at Perth and Cagliari.

Table 1. Comparison between the average residual hard seed content of Australian cultivars with ecotypes collected in environments differing in annual rainfall and hard seed content when grown in the same environment.

Maturity grading†	Rainfall (mm)	Cultivar	Residual hard seed (%)‡ Cultivars	Residual hard seed (%)‡ Ecotypes
E	< 500	Geraldton	37	40
EM	500-650	Seaton Park	24	34
EM	500-650	Trikkala	13	34
M	650-800	Clare	12	30
M	650-800	Woogenellup	12	30
M	650-800	Bacchus Marsh	1	30
ML	800-1000	Mt. Barker	3	25
ML	800-1000	Larisa	7	25
L	> 1000	Tallarook	2	20

† E=early; EM=early midseason; M=midseason; ML=midseason-late; L=late.
‡ After 6 months of seed exposure to daily fluctuating temperatures (15-60°C).

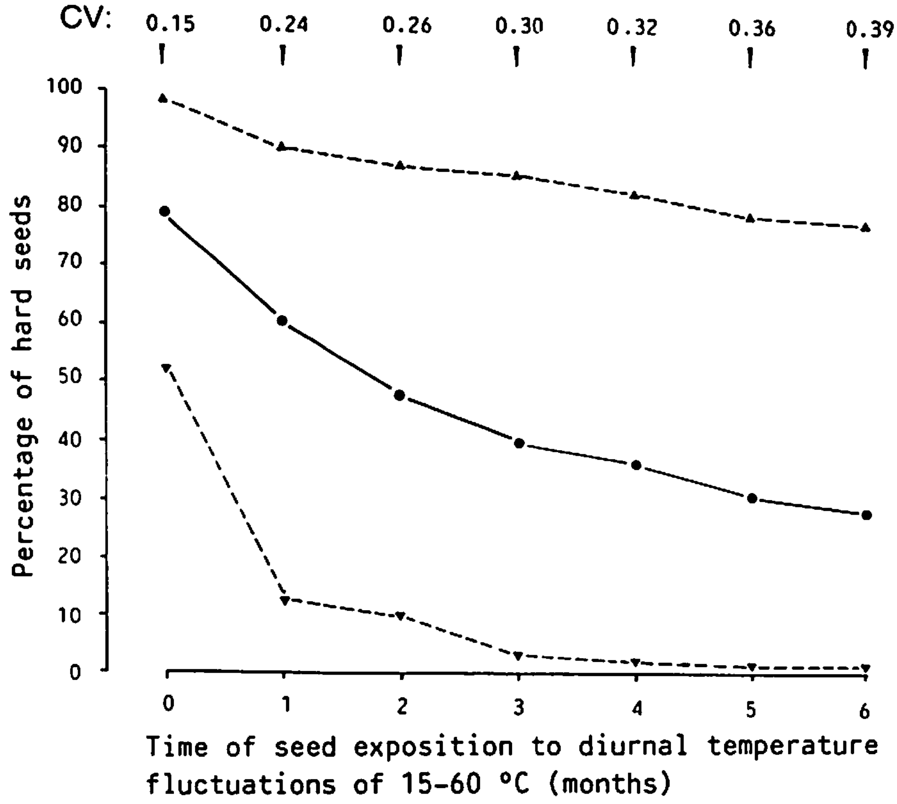


Fig. 7. Decline of hard seed content with increasing time of seed exposure to daily fluctuating temperatures in a collection of Sardinian lines of *Trifolium subterraneum* ssp. *subterraneum* (solid line indicates the mean and broken lines the extremes in the range of variation; cv = coefficient of variation).

Sandy soils that facilitate burr burial are less common in the Mediterranean basin than in Australia. In many soils burr burial can be severely restricted or prevented because the surface sets hard and crusts prematurely in spring. Since lack of burr burial leads to strong reduction in seed yield, seed viability and hardseededness (Quinlivan and Francis 1971; Collins *et al.* 1976), a main objective of subterranean clover improvement in the Mediterranean basin is to select strains able to bury a high proportion of burrs when soil conditions are suitable and to produce viable seeds above the soil surface when burr burial is prevented. The high frequency of hard-setting soils stresses the opportunity of improving the ssp. *brachycalycinum*, which is less geocarpic than ssp. *subterraneum* but well adapted to set seed on hard, self-mulching soils, or those cracking at the end of the season. Its sarmentous peduncle elongates extensively until a soil crack is found to bury its burr. There is also practical evidence that this subspecies is more tolerant to lack of burial.

Tolerance of flooding is important because soils prone to waterlogging in winter are common in the Mediterranean basin. In such situations ssp. *yanninicum* performs better than the other subterranean clovers (Francis and Devitt 1969). The development of local varieties imposes the broadening of the limited availability of genetic resources in this subspecies, which can hinder an effective multitrait selection based on traditional methodologies.

Low oestrogenic activity is a primary selection criterion in the subterranean clover improvement program in Australia (Stern *et al.* 1981). So far there is no clear evidence of 'sheep clover disease' in the Mediterranean region, but specific studies have never been made. However, it must be considered that, particularly in continuous pasture systems, complete clover dominance is difficult to realize in the Mediterranean basin and this may account for the lack of oestrogenic activity. Nonetheless, selection for low oestrogen content has to be quoted as a main objective of the selection programs in the region, depending also on the possibility that seed multiplication of local varieties should be carried out in Australia where cultivars rich in oestrogens are unlikely to be accepted. On the other hand, the examination of a wide collection of Sardinian strains (Piano, unpublished data) has indicated that a preliminary screening for low formononetin content implies a strong reduction of the genetic basis originally available only in ssp. *yanninicum* where 55% of the lines were excluded, while it preserved almost completely the genetic basis of ssp. *brachycalycinum* and implied the exclusion of only 20% of the lines in ssp. *subterraneum*. This stresses the need to broaden the limited genetic resources of ssp. *yanninicum* available for selection programs.

Grazing tolerance deserves particular attention in ssp. *brachycalycinum*, a member of the subterranean clover group generally less tolerant to heavy and continuous grazing than the others. However, where burr burial is favored by soils self-mulching in late spring (such as the basaltic loams), ssp. *brachycalycinum* seems to persist as well as ssp. *subterraneum* (Piano *et al.* 1982). This suggests that its poor persistence under heavy grazing often may be due to the vulnerability to summer grazing of unburied burrs in unsuitable soils. In any event, the use of selection procedures based on simulated or real grazing conditions from the very early stages of evaluation is important in this subspecies.

Resistance to diseases is a less tangible selection objective in the Mediterranean basin as serious adversities such as clover scorch [*Kabiatella caulivora* (Kirch Karak) and root rots (*Fusarium* and *Pythium* spp.)] never have been reported. It is evident, however, that this may be related to the still low diffusion of subterranean clover-sown pastures and not only to climatic conditions hindering serious outbreaks of these diseases.

Development of Adapted Varieties of Annual Medics

Annual medics will have a major role in crop-pasture rotation systems where the cultivar's major characteristics must be very high seed yield and distinct long-term seed survival. These aspects will therefore be discussed in more detail.

In an agronomic context, which implies medic introduction in a wide range of climatic conditions, development of cultivars with appropriate maturity remains a basic selection criterion. Timely commencement of flowering should be associated with rapid attainment of pod maturity. Particularly in stressed conditions, time to first mature pod is a more correlated selection index than flowering time *per se* to pod and seed yield (Table 2).

Seed production depends on pod production, seeds per pod and individual seed weight. The relative importance of such components in affecting seed yield may vary with plant density; the number of seeds per pod is a relatively stable character, whereas seed size can diminish in a high-density, stressed environment (Cocks 1987, 1988). In any event, the number of pods per unit area is the component most affecting seed yield and must be quoted as a major selection criterion (Table 3).

Table 2. Relationship (r) of time to first flower and time to first mature pod with seed and pod production in varieties and ecotypes of annual *Medicago* species examined in dense swards.

	Seed yield		Pod yield	
Character	Weight	Number	Weight	Number
Days to first flower	-0.78**	-0.43*	-0.66**	-0.38ns
Days to first mature pod	-0.77**	-0.66**	-0.78**	-0.66**

* P<0.05; ** P<0.01; ns=not significant.

Table 3. Correlation matrix of variables related to seed production measured in varieties and ecotypes of annual *Medicago* species grown in dense swards.

	2	3	4	5	6	7
1. Seed no. (+)	0.68**	0.92**	0.43*	-0.15ns	-0.49*	-0.46*
2. Seed wt.		0.62**	0.83**	-0.15ns	0.24ns	0.16ns
3. Pod no. (+)			0.24ns	-0.49*	-0.40*	-0.56**
4. Pod wt. (+)				0.22ns	0.31ns	0.50*
5. Seeds/pod					-0.06ns	0.45*
6. Seed mass						0.83**
7. Pod mass						

* P<0.05; ** P<0.01; ns=not significant.
(+) per unit area.

The improvement of the efficiency of medics to produce pods may require a great improvement of flower and pod retention. Pod production in annual medics seems well below its potential, since up to 95% of the flowers fail to produce mature pods (Cocks 1988). As the number of pods that reach maturity is far below the number of immature pods produced, clearly the critical factor is pod abortion rather than flower abortion, an aspect that requires appropriate physiological studies. However, there is great variability among and within species both in the capacity to produce flowers and in the proportion of pods set per flower produced, suggesting that selection for a high rate of pod production is possible. There is a close negative relationship among and within species between pod survival and pod size, suggesting that selection for small-podded types would result in selection for types with high flower or pod survival (Cocks 1987).

The importance of a timely flowering time is critical also for flower survival. Flowering time controls the node of the first flower and the moment of peak flowering, which is obviously a period of great significance for potential production. In all species the trend is that the earlier the flower is produced, the higher the probability of giving a mature pod. In a given environment, pod survival at peak flowering is far lower in late-flowering types than in early flowering types, the latter localizing the peak flowering in more favorable environmental conditions (Cocks 1988). The aspects just discussed indicate that besides appropriate flowering time, a main selection criterion for seed yield is selection of species and ecotypes with small pods, which is often expected to imply selection for small seeds. The number of seeds per pod being a character of high phenotypic stability, it is evident that the selection of species with inherent higher seed number could be an additional selection criterion.

As summer grazing is essential in the economy of the farming system, there could be scope to select for seed ability to survive ingestion and therefore to be returned viable to the pasture. On average, only 2% of medic seeds survive ingestion of intact pods by sheep (Carter 1980). Selection for small-seeded ecotypes also has been advocated to alleviate the serious consequences on pasture regeneration of heavy grazing on pods during summer. Results by Thomson *et al.* (1987) indicated that the smaller the seeds, the higher their survival to ingestion, and that the passage through the digestive tract of the sheep has little influence on the hardseededness of survivors. This result is consistent with observations made in the small-seeded *Trifolium glomeratum* (Granda Losada, pers. comm.). Another additional advantage of selecting small-seeded medics may be related to their ability to mature seeds faster than large-seeded types (C.M. Francis, pers. comm.).

Selection for small seeds may imply, however, some disadvantages for successful plant establishment. Small seeds need to be closer to the soil surface to germinate and establish seedlings successfully. Furthermore, those buried below an optimal depth during the cropping phase are less likely to emerge than bigger seeds. Another aspect may be related to seedling vigor, which in the first stages of establishment appears positively related to seed size (Crawford 1970), although the relative growth rate of plants from small seeds is higher subsequently (Stebbins 1976). In the clay, crusting soils of many

Mediterranean areas, large seeds are important for successful emergence. In the presence of contrasting requirements, selection for small-seeded types cannot be an unequivocal criterion; the development of large-seeded varieties for use in specific edaphic conditions in mixtures with small-seeded types is required.

Selection for appropriate hardseededness requires even more attention in medic varieties if they have to persist in a ley farming system. Most of the seed produced in the first-year pasture (theoretically all the seed) must remain dormant during the following summer, not germinate in the subsequent cropping phase, overcome another summer and finally germinate promptly in the autumn of the third year to regenerate a dense pasture. This pattern is probably only a breeder's wish that nature cannot comply with, but it remains a selection goal. To avoid a quite onerous 3-year cycle-based selection, there is a need to develop laboratory methodologies for predicting the long-term softening pattern and viability of hard seeds (Cocks 1988). Selection based on rate of breakdown of hardseededness in the first year fits varieties for continuous pasture, rather than ley farming systems. There is some indirect evidence that the rate of seed softening in the first summer is not necessarily related to the subsequent pattern of seed softening (Abd El Moneim and Cocks 1986). Deeper studies on the sequential softening of hard seeds within pods, which is known to be nonrandom and related to maternal influence (McComb and Andrews 1974), are perhaps required for a better understanding of the plant dynamics and of the implications on selection criteria.

Seed burial resulting from soil tillage in the cropping phase of a ley farming system decreases the rate of seed softening in both subterranean clover and annual medics (Taylor 1985; Taylor and Ewing 1988). However, it has been recently demonstrated that burial has a much smaller effect on medics than on subterranean clover in slowing the loss of impermeability (Taylor and Ewing 1988). This means that more seed will be lost for germination at depth in medics than in subterranean clover.

The development of medic cultivars for very arid rangelands, where the whole cycle from germination to ripe seed must be completed in a very short period, is important for some areas of north Africa and the near East. Such cultivars must combine earliness of flowering with a very rapid rate of pod maturity and ability to produce adequate hard seed. That ecotypes of *M. laciniata* from subdesert areas in Libya are relatively later than ecotypes from more favorable areas, and that nonetheless when evaluated in dry rangeland conditions they do not seem to suffer from the poor finish of the season, exhibiting also high levels of hardseededness, all emphasizes that more knowledge is needed on the pod maturity phase to define selection criteria for medic varieties for dry rangeland conditions (Gintzburger *et al.* 1984).

Screenings among and within promising species for identification of types with a plant morphology that can limit removal of pods by grazing during the reproductive phase are advisable. This may evoke a plant ideotype close to subterranean clover.

Ability to delay plant senescence may deserve some consideration in breeding programs after observations that *M. murex* remains green much longer than other legumes of similar maturity. Sheep grazing on *M. murex* gained weight much faster in late spring and early summer than those grazing on the other senescent species. Information is required on the possible physiological nature of this characteristic and on the interaction with the pod maturity phase.

In medics, tolerance of waterlogging may be of some importance in particular conditions. Apart from the large-podded *Medicago ciliaris* and *M. intertexta*, a variable tolerance also is exhibited by *M. murex*, *M. arabica*, *M. rugosa* and ecotypes of *M. polymorpha*.

Selection for resistance to nematodes may be important. Observations by Abd El Moneim *et al.* (1987) in Syria indicated that medics may be severely attacked by root knot nematode (*Meloidogyne artiella*) rather than cyst nematode (*Heterodera rosii*). The level of susceptibility varied greatly among and within species.

As for subterranean clover, a preliminary screening for low oestrogen content is important in medics as high coumesrol content may inhibit estrus in ewes and produce follicular abnormalities. Similar consideration is necessary, particularly in the wetter environments of Mediterranean Europe, for resistance to many fungal diseases and even moreso to black stem (*Phoma medicaginis*), which may cause serious damage (G. Gintzburger, pers. comm.).

Other Pasture Legumes

Other legumes may deserve some consideration for selection programs in the Mediterranean region. Among clovers, the wide range of climatic and edaphic adaptation of *Trifolium cherleri*, together with its distinct tolerance to heavy grazing, may suggest the possibility of improving the species for possible use in pasture/cereal rotation systems (Francis 1987). *Trifolium glomeratum* has been used in selection programs in Spain, where it is indicated for distinct marginal conditions (Moreno and Olea 1988).

Following the relative success obtained in some areas of Australia (Bolland 1986), *Ornithopus* spp. deserve some attention in the Mediterranean region and selection programs have been activated in Portugal and Spain (Moreno and Olea 1988).

The discovery of subterranean vetches may open new prospects to this species as a full pasture plant. Many pasture legumes can be introduced usefully in farming systems. In many cases their improvement requires systematic plant collection activity.

Acknowledgements

The author wishes to thank Mrs. M. Gabrielle Piras from Istituto Sperimentale per le Colture Foraggere for her precious technical collaboration in preparing the manuscript.

References

Abdelguerfi, A., J.Y. Chapot and A.P. Conesa. 1988. Contribution a l'etude de la repartition de luzernes annuelles spontanees en Algerie selon certain facteurs du milieu. Fourrages 113:89-106.

Abd El Moneim, A. and P.S. Cocks 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., G. Faddoul and J. Swedan. 1987. Screening annual medics for nematode resistance. Annual Report of the Pasture Forage and Livestock Program. ICARDA, Aleppo, Syria.

Adem, L. 1974. Etude du comportament des *Medicago* annuelles. Thèse, Institut National Agronomique Universitaire, Alger, Algeria.

Andrews, P., W.J. Collins and R.W. Stern. 1977. The effect of withholding water during flowering on seed production in *Trifolium subterraneum* L. Australian Journal of Agricultural Research 28:301-307.

Archer, K.A., E.C. Wolfe and B.R. Cullis. 1987. Flowering time of cultivars of subterranean clover in New South Wales. Australian Journal of Experimental Agriculture 27:791-797.

Bolland, M.D.A. 1986. A laboratory assessment of seed softening patterns for hard seeds of *Trifolium subterraneum* subspp. *subterraneum* and *brachycalycinum* and of annual *Medicago* spp. Journal of the Australian Institute of Agricultural Science 52:91-94.

Carter, E.D. 1980. The survival of medic seeds following ingestion of intact pods by sheep. Page 178 *in* Proceedings of the Australian Agronomy Conference, Lawes, Queensland, Australia.

Clarkson, N.M. and J.S. Russel. 1975. Flowering responses to vernalization and photoperiod in annual medics (*Medicago* spp.). Australian Journal of Agricultural Research 26:831-838.

Clarkson, N.M. and J.S. Russel. 1976. Effect of water stress on the phasic development of annual *Medicago* species. Australian Journal of Agricultural Research 27:227-234.

Cocks, P.S. 1987. Seed production of promising medics at two densities. Annual Report of the Pasture Forage and Livestock Program. ICARDA, Aleppo, Syria.

Cocks, P.S. 1988. Seed production and seed survival under grazing of annual medics (*Medicago* spp.) in north Syria. Journal of Agricultural Science, Cambridge 110:455-463.

Cocks, P.S. and T.A.M. Ehrman. 1987. The geographic origin of frost tolerance in Syrian pasture legumes. Journal of Applied Ecology 24:673-683.

Cocks, P.S., M.J. Mathison and E.J. Crawford. 1980. From wild plants to pasture cultivars: annual medics and subterranean clover in southern Australia. Pages 569-596 *in* Advances in Legume Science (R.J. Summerfield and A.H. Bunting, eds.). Royal Botanic Gardens, Kew.

Collins, W.J. 1978. The effect of defoliation on inflorescence production, seed yield and hardseededness in swards of subterranean clover. Australian Journal of Agricultural Research 29:789-801.

Collins, W.J., C.M. Francis and B.J. Quinlivan. 1976. The interrelation of burr burial, seed yield and dormancy in strains of subterranean clover. Australian Journal of Agricultural Research 27:787-797.

Cornish, P.S. 1974. Drought resistance of seedlings of annual *Medicago*. Pages 331-336 *in* Proceedings of the XII International Grassland Congress, Moscow, USSR.

Crawford, E.J. 1970. Variability in a large Mediterranean collection of introduced lines of *Medicago truncatula* Gaerth. Pages 192-196 *in* Proceedings of the XI International Grassland Congress, University of Queensland Press, St. Lucia, Australia.

Crespo, D.G. 1970. Some agronomic aspects of selecting subterranean clover (*Trifolium subterraneum* L.) from Portuguese ecotypes. Pages 207-210 *in* Proceedings of the XI International Grassland Congress, University of Queensland Press, St. Lucia, Australia.

Dauro, D. and G. Gintzburger. 1987. Effet de la fertilization phosphatée sur le parcours naturel contenant des luzernes annuelles en region Mediterranéenne française et froide. FAO-European Cooperative Network on Pasture and Fodder Crop Production, Bull. No. 5:23-28.

Evans, L.T. 1959. Flower initiation in *Trifolium subterraneum* L. I: Analysis of the partial processes involved. Australian Journal of Agricultural Research 10:17-26.

Francis, C.M. 1986. Legume and barley seed collection tour in northwest Syria and northern Cyprus. WA Department of Agriculture, Perth, Australia.

Francis, C.M. 1987. Morocco, a plant collection tour 1987. WA Department of Agriculture, Perth, Australia.

Francis, C.M. and A.C. Devitt. 1969. The effect of waterlogging on the growth and isoflavone concentration of *Trifolium subterraneum* L. Australian Journal of Agricultural Research 20:819-825.

Francis, C.M. and D.J. Gillespie. 1981. Ecology and distribution of subterranean clover and *Medicago* species in Sardinia. Australian Plant Introduction Review 113:15-25.

Francis, C.M. and J.S. Gladstones. 1974. Relationship among rate and duration of flowering and seed yield components in subterranean clover (*Trifolium subterraneum* L.). Australian Journal of Agricultural Research 25:435-442.

Francis, C.M. and J.S. Gladstones. 1983. Exploitation of the genetic resources through breeding: *Trifolium subterraneum*. Pages 251-260 *in* Genetic Resources of Forage Plants (J.G McIvor and R.A. Bray, eds.). CSIRO, Melbourne, Australia.

Francis, C.M. and J.S. Katznelson. 1977. Observations on the distribution and ecology of subterranean clover, some other clovers, and medics in Greece and Crete. Australian Plant Introduction Review 12:17-25.

Francis, C.M., J.S. Katznelson and W.J. Collins. 1975. Report on a legume seed collection tour of Turkey. Australian Plant Introduction Review 10:1-10.

Francis, C.M., M.A. Ramos Monreal and B.J. Quinlivan. 1977. Predicting the maturity requirements of subterranean clover cultivars for farm grazing in Extremadura, Spain. Australian Plant Introduction Review 12:14-28.

Gintzburger, G. 1984. Annual medics for rangeland zones. Species, selection and establishment methods. Libyan medic evaluation project. Final Report. WAOPA-WADA, Perth, Australia.

Gintzburger, G. and L. Blasin. 1979. Genetic conservation in Libya: Indigenous forage legume collection in northern Libya. Distribution and ecology of *Medicago* spp. Part III. FAO-ARC TFUB 6:234-279.

Gintzburger, G., A. Sbeta and C.M. Francis. 1984. Libyan medic evaluation project. Final Report. WAOPA-WADA, Perth, Australia.

Gladstones, J.S. 1976. Observations on the environment and ecology of some annual legumes in southern Italy. Australian Plant Introduction Review 9:11-29.

Gladstones, J.S. and W.J. Collins. 1983. Subterranean clover as a naturalized plant in Australia. Journal of the Australian Institute of Agricultural Science 49:191-210.

Gomez Pitera, C., A. Ramos Monreal and C.M. Francis. 1979. Diferencias en tiempo de floracion y contenido estrogenico en el trebol subterraneo en dos ambientes Mediterraneos de Espana y Australia. Annales INIA, Serie Prod. Vegetal 10:59-66.

Heyn, C.C. 1963. The annual species of *Medicago*. Scripta Hierosolymitana. Hebrew University, Jerusalem, Israel.

Hochman, Z. 1987. Quantifying vernalization and temperature promotion. Effects on time of flowering of three cultivars of *Medicago truncatula* Gaertn. Australian Journal of Agricultural Research 38:279-286.

Howieson, J.G. and M.A. Ewing. 1986. Acid tolerance in the *Rhizobium meliloti-Medicago* symbiosis. Australian Journal of Agricultural Research 37:55-64.

Masson, P. and G. Gintzburger. 1986. Enherbement de vignobles en climate Mediterraneen: perspectives d'utilization de legumineuses annuelles. Pages 145-151 *in* Proceedings de 2ème Symposium International sur la Culture de la Vigne, Montpellier, France.

Masson, P. and G. Gintzburger. 1987. Le trefle souterrain (*T. subterraneum* L.): Essays preliminaires et perspectives d'utilization dans une zone Mediterranéenne française: le Roussillon. Fourrages 110:183-203.

McComb, J.A. and R. Andrews. 1974. Sequential softening of hard seeds in burrs of annual medics. Australian Journal of Experimental Agriculture and Animal Husbandry 14:68-75.

Materon, L.A. and J. Brockwell. 1987. Symbiotic response of medic species to indigenous rhizobia. Annual Report of the Pasture Forage and Livestock Program. ICARDA, Aleppo, Syria.

Moreno, V. and L. Olea. 1988. The selection of annual legumes for Mediterranean pasture improvement. Herba 1:19-24.

Piano, E. 1987a. Main objectives of subterranean clover improvement in Sardinia. Pages 33-47 *in* Annual Self-reseeding Legumes for Mediterranean Pastures. Proceedings of the AGRIMED Working Group on Annual Legumes, 27-30 April 1987, Cagliari, Sardinia.

Piano, E. 1987b. Aspects of the variability of subterranean clover populations and their implications in breeding. II. The environmental influence on flowering time. Pages 45-52 *in* Natural Variation and Breeding for Adaptation. Proceedings of the EUCARPIA Fodder Crops Section, 22-24 September 1987, Lusignan, France.

Piano, E. 1987c. Aspects of the variability of subterranean clover populations and their implications in breeding. I. Maturity differences between the subspp. *brachycalycinum* Katzn. et Morley and *subterraneum* L. Pages 49-64 *in* Annual Self-reseeding Legumes for Mediterranean Pastures. Proceedings of the AGRIMED Working Group on Annual Legumes, 27-30 April 1987, Cagliari, Sardinia.

Piano, E., M. Sardara and S. Pusceddu. 1982. Observations on the distribution and ecology of subterranean clover and other annual legumes in Sardinia. Rivista di Agronomia 16:273-283.

Prosperi, J.M., M. Angevain and P. Mansat. 1987. Objectifs de selection des luzernes annuelles pour la zone Mediterranéenne française. FAO-European Cooperative Network on Pasture and Fodder Crop Production, Bull. No. 5:43-48.

Puckridge, D.W. and R.J. French. 1983. The annual legume pastures in cereal-ley farming systems of southern Australia: a review. Agriculture Ecosystems & Environment 9:229-267.

Quinlivan, B.J. 1961. The effect of constant and fluctuating temperatures on the permeability of the hard seeds of some legume species. Australian Journal of Agricultural Research 12:1009-1022.

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. 1971a. Embryo dormancy in subterranean clover seeds. II. Its value relative to impermeability in field germination regulation. Australian Journal of Agricultural Research 22:607-614.

Quinlivan, B.J. 1971b. Seed coat impermeability in legumes. Journal of the Australian Institute of Agricultural Science 37:283-295.

Quinlivan, B.J. and C.M. Francis. 1971. The effect of burr burial of the seed of some early maturing subterranean clover cultivars. Australian Journal of Experimental Agriculture and Animal Husbandry 11:35-38.

Radwan, M.S., A.K. Al Fakhry and A.M. Al-Hasan. 1978. Some observations on the performance of annual medics in northern Iraq. Mesopotamia Journal of Agriculture 13:55-67.

Robson, A.D. 1990. Role of self-regenerating pastures in rotation with cereals in Mediterranean areas. Pages 217-236 *in* The Role of Legumes in the Farming Systems of the Mediterranean Areas (A.E. Osman, M.H. Ibrahim and M.A. Jones, eds.). Kluwer Academic Publishers, The Netherlands.

Rossiter, R.C. 1966. Ecology of the Mediterranean annual-type pasture. Advances in Agronomy 18:1-56.

Stebbins, G.L. 1976. Seed and seedling ecology in annual legumes. Oecologia Plantarum 11:321-344.

Stern, W.R., J.S. Gladstones, C.M. Francis, W.J. Collins, D.L. Chatel, D.A. Nicholas, D.J. Gillespie, E.C. Wolfe, C.R. Southwood, P. Beale and B.C. Curnow. 1981. Pages 116-118 *in* Subterranean Clover Improvement: An Australian Program. Proceedings of the XIV International Grassland Congress, Lexington, KY, USA.

Talamucci, P. and A. Pardini. 1987. Behavior of some annual self-reseeding legumes observed in a Mediterranean environment in southern Tuscany (Italy). Pages 83-92 *in* Annual Self-reseeding Legumes for Mediterranean Pastures. Proceedings of the AGRIMED Working Group on Annual Legumes, 27-30 April 1987, Cagliari, Sardinia.

Thomson, E.F., S. Rihawi and P.S. Cocks. 1987. The survival of medic seed ingested by sheep. Annual Report of the Pasture, Forage and Livestock Program. ICARDA, Aleppo, Syria.

Taylor, G.B. 1981. Effect of constant temperature treatments followed by fluctuating temperatures on the softening of hard seeds of *Trifolium subterraneum* L. Australian Journal of Plant Physiology 8:547-558.

Taylor, G.B. 1984. Effect of burial on the softening of hard seeds of subterranean clover. Australian Journal of Agricultural Research 25:201-210.

Taylor, G.B. 1985. Effect of tillage practices on the fate of hard seeds of subterranean clover in a ley-farming system. Australian Journal of Experimental Agriculture 25:568-573.

Taylor, G.B. and M.A. Ewing. 1988. Effect of depth of burial on the longevity of hard seeds of subterranean clover and annual medics. Australian Journal of Experimental Agriculture 28:77-81.

Australian Contribution to the Conservation of Medic Germplasm

E.J. Crawford and G.C. Auricht
South Australian Department of Agriculture, Adelaide SA 5001, Australia

Abstract

Australia's contribution to the conservation of *Medicago* (medic) germplasm follows recognition of the value of annual medics to ley farming in southern Australia. The lack of herbage legumes in Australia resulted in the collection and introduction of medics from their center of origin in the Mediterranean basin and southwest Asia: 16 200 accessions from 52 collections and donations over a period of 38 years. The collection is housed at the Australian *Medicago* genetic resource center in Adelaide. Medics are characterized and evaluated for a wide range of morphological and agronomic traits. Seven of these are discussed, emphasizing predominant countries of origin and species groups for each characteristic. The paper highlights Cyprus, Morocco and Tunisia as major sources of accessions with high winter production and Algeria, Greece and Tunisia as the best sources of high seed yield. Accessions showing insect resistance are rare for most species and, where available, are found only in localized areas in Armenia, southern France and northwest Africa. The collection is recognized as the world collection of annual medics and provides resources for plant breeders and agronomists whenever required.

Introduction

Southern Australia's latitude (30-40°S) is similar to that of the Mediterranean basin and west Asia and it has a similar climate. The absence of high mountain ranges means that Australian winters have less frost and snow than parts of the Mediterranean and west Asia. Although rainfall extends from 150 to 1500 mm, most agricultural areas are in areas where annual precipitation is between 250 and 750 mm.

Figure 1 compares the expanse of neutral to calcareous soils (edaphic regions) in southern Australia (Fig. 1a) with those of the Mediterranean Basin (Fig. 1b).

The native vegetation comprises perennial grasses such as *Danthonia* and *Stipa*, and browse shrubs such as *Atriplex* and *Maireana*, the only legumes being shrubs and trees. These were unproductive and responded poorly to chemical fertilizer; none were suitable as crop plants and the need for plant introduction was evident from the advent of European settlement. Although some Mediterranean species were accidentally introduced

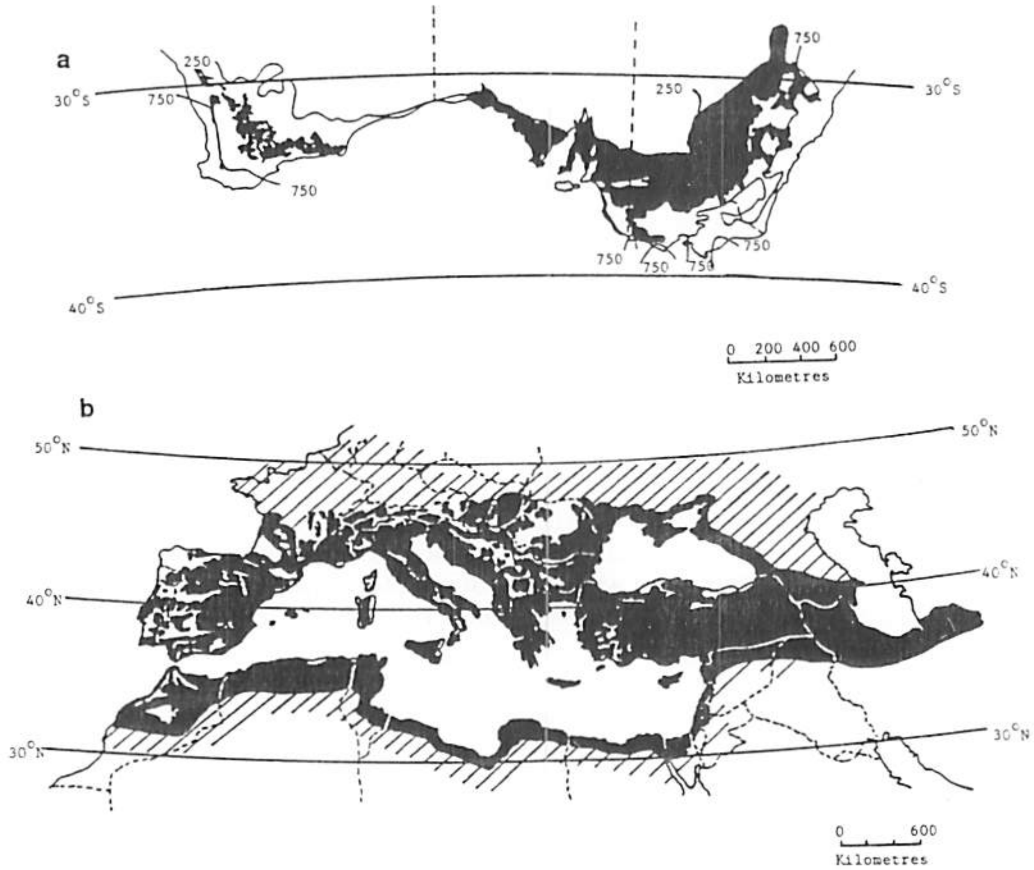


Fig. 1. Major edaphic regions of annual medic adaptation in (a) southern Australia, (b) the Mediterranean Basin and southwest Asia.

in the 19th century, it was not until phosphate was used for cereals early in the 20th century that they actively colonized certain environments. Subterranean clover (*Trifolium subterraneum*) was the first to be recognized and medics (especially *M. polymorpha*) were soon observed, the latter showing a specific affinity for calcareous soils in low-rainfall areas.

It was not until the early 1930s, following the widespread use of phosphate fertilizer, that the true value of medics was appreciated (Halse, this volume). Since then they have with subterranean clover become an essential part of Australian agriculture, contributing the major nitrogen inputs and supporting the Australian wool and meat industries.

Plant Collection and Introduction

The first deliberate introduction of medics was by von Mueller just prior to the 20th century, who introduced *Medicago orbicularis* and *Medicago scutellata* because they had spineless pods which did not adhere to wool. This remains an important characteristic in developing new medic cultivars.

Hutton (1934) was the first to recognize the importance of *Medicago truncatula* in south Australia (see Halse, this volume, for western Australia) and Trumble (1939) outlined its development and initial commercialization. By the late 1940s, barrel medic was established as a prominent legume and a national study of Australian naturalized ecotypes resulted in the commercialization, in 1955, of strain 173, later to be named Jemalong. By then scientists had argued that, because little opportunity had existed for the accidental introduction of medics (and other legumes), useful species must exist in their natural habitat. This resulted in the first systematic attempt to collect medics; in 1951 Donald and Miles collected from most of the countries bordering the Mediterranean Sea and alerted scientists of the vast variability in medics (Crawford 1970). Their mission resulted in the commercialization in 1959 of the first medic cultivar developed by deliberate introduction (Cyprus barrel medic).

There were 13 collecting missions by Australian and international organizations between 1951 and 1971 (Neal-Smith 1967, Neal-Smith and Johns 1971, Crawford 1983), 31 by Australians since 1972 and 8 by international organizations since 1972. These have contributed to the development of the 21 cultivars in Table 1.

The Australian *Medicago* Genetic Resource Centre

Australia's recognition of the need to preserve plant genetic resources led to the establishment of eight Australian centres. Of these, the Australian *Medicago* Genetic Resource Centre (AMGRC) is managed by the South Australian Department of Agriculture. It has an international mandate as the IBPGR-designated world base collection for annual medics.

The AMGRC is funded by the South Australian Government and by rural industry research funds. In addition, the Australian Government provides computing and storage facilities for maintaining the collection and the data associated with it.

Computer Facilities

Much of the passport, characterization, evaluation and seed inventory data are processed using a relational database package operating on a microcomputer with two 40 megabyte hard disks. In addition, software for a hand-held computer is being developed for direct field data recording.

Table 1. Cultivars of annual *Medicago* species commercialized in Australia.

Species	Cultivar	Country of origin
M. littoralis	Harbinger	Iran
M. littoralis	Harbinger AR	Australia (bred)
M. murex	Zodiac	Sardinia
M. polymorpha	Circle Valley	Australia (naturalized)
M. polymorpha	Serena	Australia (bred)
M. polymorpha	Santiago	Chile
M. rugosa	Paragosa	Portugal
M. rugosa	Paraponto	Italy
M. rugosa	Sapo	Portugal
M. scutellata	Robinson	Australia (naturalized)
M. scutellata	Sava	Unknown
M. scutellata	Kelson	Hungary
M. tornata	Tornafield	Australia (bred)
M. tornata	Rivoli	Morocco
M. truncatula	Ascot	Australia (bred)
M. truncatula	Borung	Tunisia
M. truncatula	Cyprus	Cyprus
M. truncatula	Hannaford	Australia (naturalized and selected)
M. truncatula	Jemalong	Australia (naturalized and selected)
M. truncatula	Parabinga	Jordan
M. truncatula	Paraggio	Italy
M. truncatula	Sephi	Israel

Seed-drying Facilities

Prior to long-term storage, seed moisture content is reduced as much as possible. This is achieved by drying the seed first in ovens before cleaning, and secondly, in a seed-drying room before the samples are sealed in moisture-proof foil packets. The seed-drying room operates at 15% relative humidity and 15°C and has a total capacity of 38 m^3.

Seed Storage Facilities

Seed may be stored under four different sets of conditions depending on the quantity. First, a sample of 8 grams is stored in the base collection. This is accessed only for regeneration purposes and is stored in a freezer running at -20°C. The total capacity is sufficient for 60 000 samples.

Second, samples averaging 10-50 g are stored in the active collection, used for distribution of 1-g samples for research purposes. The active collection is in two cold rooms running at 2°C, with a total capacity of 167 m^3 and shelving capacity of 73 m^3. About 100 000 samples can be stored in this way.

Third, additional samples are stored as pods without temperature or humidity control. These are used for current field trials or to supplement the active collection.

Fourth, 20 000 samples of a few grams each can be stored in liquid nitrogen. At present this facility is not in use.

A Description of the Australian Medic Collection

The Australian medic collection currently contains 16 200 accessions (Table 2), with accessions from 58 countries. Material from continents other than Africa, Europe and Asia is not considered in this paper even though it is recognized that medics have been in Chile, South Africa and the United States for over 300 years. The remaining accessions are distributed widely over 48 countries, only 19 of which have contributed more than 100 accessions (Table 3). These are the countries that border the Mediterranean Sea and west Asia in latitudes 30-45°N.

The value of the collection lies not only in the physical preservation of the resource *per se* but also in the availability and analysis of data obtained in nursery row evaluations (Fig. 2).

Attributes evaluated in the Australian collection are seedling vigor, winter herbage production, flowering time, seed production, pod spininess, changes in seed coat permeability and resistance to insect pests (Crawford 1991). For all traits except seedling vigor and winter growth, the cultivar Jemalong of *M. truncatula* is used as a control. For seedling vigor and winter growth, established cultivars are used as standards for the species which have cultivars: Harbinger for *Medicago littoralis*, Paragosa for *Medicago rugosa*, Robinson for *M. scutellata* and Tornafield for *Medicago tornata*. All other species use Jemalong as the control for all characteristics.

In interpreting these data it should be appreciated that many collections were made on an opportunity basis or even by exchange and not on a random basis: they do not therefore reflect the entire range of variability. Moreover, the data were collected at Parafield Plant Introduction Centre near Adelaide and therefore ignore possible genotype by environment effects.

Seedling vigor

Good seedling vigor assists establishment and, associated with plant density, determines early winter growth. Rate of germination and radicle elongation influence vigor, particularly in areas that experience moisture stress or extended windy periods. Natural regeneration from pods on the soil surface is aided by rapid and vigorous germination and good seedling vigor.

Table 2. Number of accessions of annual *Medicago* species indexed and evaluated by the Australian *Medicago* Genetic Resource Centre in south Australia at 17 March 1989. (Data of 8881 accessions available on computer.)

Species	No. in collection	No. evaluated 1968-1988
**M. aculeata*	627	565
**M. arabica*	327	217
M. blancheana	79	61
**M. constricta*	192	186
M. coronata	28	8
M. disciformis	78	20
**M. doliata*	96	66
M. granadensis	12	8
M. heyniana	1	1
**M. intertexta*	353	299
**M. laciniata*	302	7
M. lanigera	1	0
**M. littoralis*	1683	980
M. minima	352	46
**M. murex*	424	414
M. muricoleptis	10	2
**M. noena*	54	28
**M. orbicularis*	1420	986
**M. polymorpha*	2941	1106
M. praecox	38	9
**M. rigidula*	983	566
**M. rotata*	141	110
**M. rugosa*	286	254
M. sauvagei	3	3
**M. scutellata*	364	348
**M. soleirolii*	15	10
M. tenoreana	1	1
**M. tornata*	655	483
**M. truncatula*	4372	3303
**M. turbinata*	240	217
Unidentified	122	1
Total	16 200	10 305

* Species of major importance.

Table 3. Countries and major islands from which >100 accessions received.

Country	Grown to 1988	Awaiting growing
Algeria	1008	228
Crete	111	17
Cyprus	562	153
France	136	11
Greece	738	409
Iran	146	56
Iraq	105	57
Israel	775	87
Italy	311	73
Jordan	227	82
Libya	632	1267
Morocco	867	212
Portugal	270	47
Sardinia	279	91
Sicily	378	330
Spain	157	42
Syria	317	279
Tunisia	1397	134
Turkey	584	493
Total	9000	4068

Of the 8881 accessions grown between 1968 and 1986, 1462 representing 20 species from 32 countries had better seedling vigor than the control. Algeria, with 25.1% of accessions more vigorous than the controls, was the best source both in terms of the absolute number of accessions and as a percentage of all accessions received.

The greatest number of accessions where seedling vigor was greater than the control was in *M. truncatula* (520). This represented 35.6% of all vigorous accessions but only 18.3% of all accessions tested. The best species was *Medicago intertexta* (there being 18.9% of all accessions) with better seedling vigor than Jemalong. The distribution of species from the major countries of origin is detailed in Table 4.

These data emphasize the importance of Algeria and Morocco as major sources of species with good seedling vigor with specific species likely to be found in other regions e.g., *M. intertexta* in Tunisia, *Medicago arabica* in Cyprus and *M. rugosa* in Greece (Table 4).

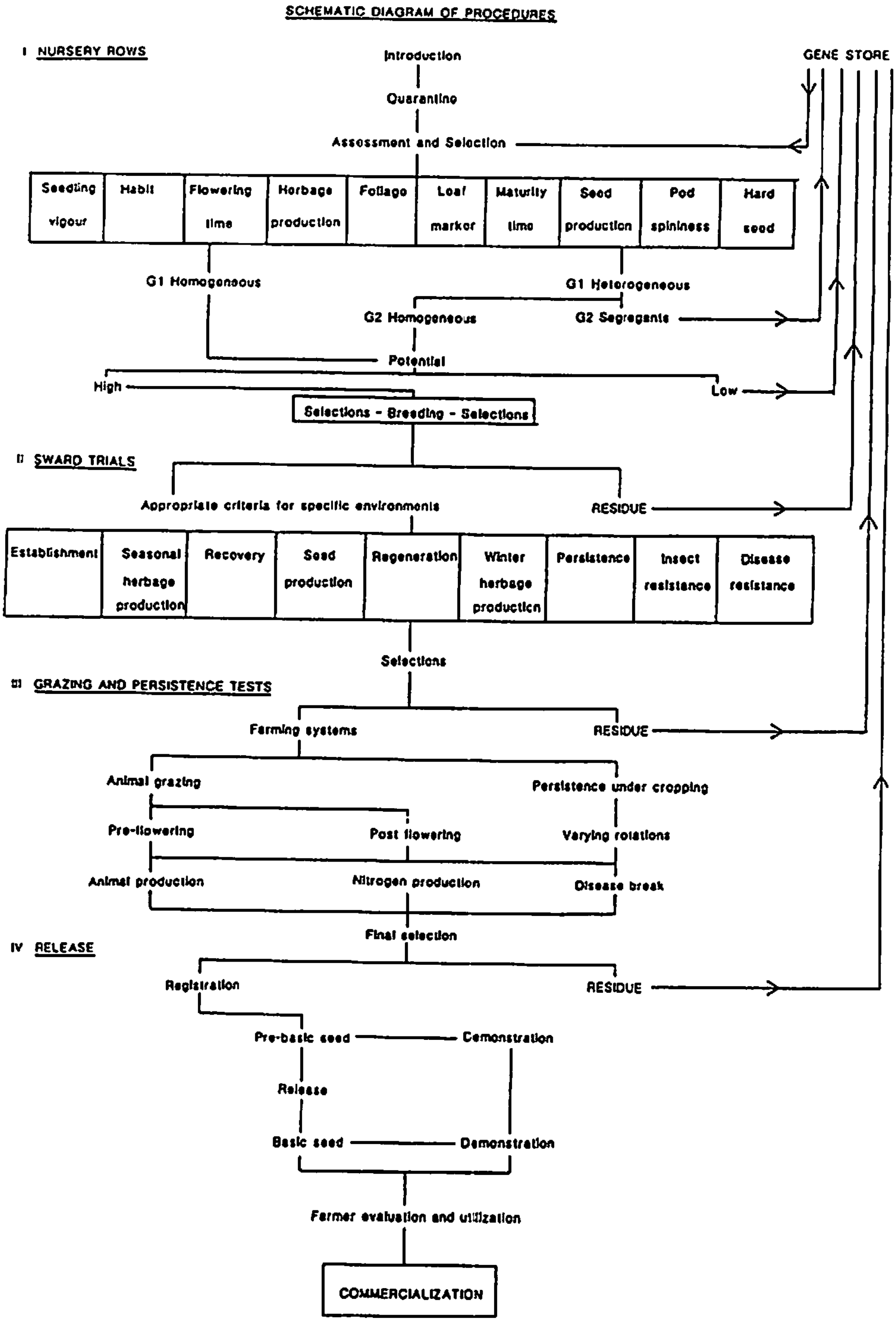


Fig. 2. South Australian Plant Introduction and Herbage Plant Cultivar Development Program.

Table 4. Accessions grown from 1968-1986 that had seedling vigor greater than the standard cultivars, and their relationship to the total grown.

Origin	No. of access.	% of country total	% of species total/country
Algeria	367		
M. truncatula	188	51.2	35.6
M. intertexta	84	22.9	96.6
M. aculeata	55	15.0	50.9
M. polymorpha	31	8.4	29.5
4 other species	9	2.5	-
Tunisia	283		
M. truncatula	127	44.9	16.2
M. intertexta	107	37.9	84.9
9 other species	49	17.3	-
Israel	199		
M. polymorpha	72	36.2	40.7
M. truncatula	58	29.1	39.2
M. littoralis	24	12.1	16.0
M. intertexta	13	6.5	100.0
8 other species	32	16.0	-
Morocco	180		
M. tornata	74	41.1	38.9
M. truncatula	57	31.7	30.8
M. aculeata	23	12.8	33.8
5 other species	26	14.4	-
Cyprus	62		
M. arabica	34	54.8	49.3
M. littoralis	11	17.7	9.8
4 other species	17	27.4	-
Greece	59		
M. rugosa	19	32.2	47.5
M. truncatula	16	27.1	13.2
8 other species	24	40.7	-

Winter herbage production

In southern Australia winter growth is often regarded as more important than spring growth since germination late in autumn or even midwinter results in growth rates of less than 15 kg ha^{-1} day^{-1}. Preliminary data are based on spaced plants: selections are then grown in swards in later stages of evaluation.

Of the 8881 accessions, 1900 had better winter production than the standard cultivar, in this case Jemalong for all accessions (Table 5). Of these the greatest number originated in Tunisia (410) representing 29.4% of the total Tunisian collection. However, some countries with fewer accessions had even higher proportions with high winter production; for example, Cyprus with 95.7% of 66 *M. arabica* accessions (Table 5), which perhaps reflects the distribution of *M. arabica* rather than the value of collecting in Cyprus.

Although *Medicago polymorpha* had the most accessions with good winter growth (586), the highest proportion of accessions was in *M. intertexta* (Table 5).

Flowering time

Persistence depends largely on ability to flower and set seed before the onset of dry weather in late spring. Environments with a short growing season should be supplied with cultivars that not only flower early but also remain vegetative and continue flowering over an extended period to maximize seed production in seasons of later-than-normal spring rain. Later flowering may be desirable in high-altitude areas prone to winter frosts, provided late spring rains are reliable. Such conditions are more likely to prevail in the high-altitude areas of North Africa and West Asia than in Australia so late flowering could be an important criterion in Algeria, Iran, Iraq and Turkey.

As *M. truncatula* cv. Cyprus is early flowering it is used as the control to determine the centers of origin of this important attribute in all species.

Accessions originating in Libya are the most likely to be early flowering; 383 accessions flower before cv. Cyprus (59% of those collected in Libya and 61% of all early flowering accessions).

Cyprus remains an important germplasm source (Table 6). Of the 614 early flowering accessions, *M. truncatula* (45%), *M. littoralis* (21%) and *M. polymorpha* (10.3%) were the most common sources of earliness. However, this represented only 10, 15 and 6% of the total number of accessions of each of the three species. In contrast, 86% of *Medicago aculeata* (syn. *Medicago doliata*) (31 accessions) flowered earlier than the cultivar Cyprus.

Where late flowering may be advantageous (in elevated areas, for example) selections have been made of accessions at least 3 weeks later than Jemalong, the standard cultivar. These comprise 1244 of the 8881 accessions grown and are represented by 18 species from 28 countries. The major countries of origin are Turkey (25% of all late accessions), Greece (8%), Sardinia, Italy (8%) and mainland Italy (7%). However, the greatest proportion of the accessions are from Turkey (53% of all Turkish accessions) and

Table 5. Accessions grown from 1968-86 that had winter production greater than the standard cultivars, and their relationship to the total grown.

Origin	No. of access.	% of country total	% of species total/country
Tunisia	410		
M. polymorpha	141	34.4	80.1
M. intertexta	119	29.0	94.4
M. truncatula	97	23.7	12.4
Israel	318		
M. polymorpha	165	51.9	93.2
M. orbicularis	40	12.6	64.5
M. truncatula	32	10.1	21.6
M. intertexta	13	4.1	100.0
Algeria	233		
M. truncatula	61	26.2	11.6
M. intertexta	61	26.2	70.1
M. polymorpha	59	25.3	56.2
M. aculeata	44	18.9	40.7
Morocco	180		
M. truncatula	79	44.9	42.7
M. aculeata	30	17.0	44.1
M. tornata	29	16.5	15.3
Cyprus	113		
M. arabica	66	58.4	95.7
M. polymorpha	17	15.0	81.0
Libya	100		
M. truncatula	48	48.0	14.3
M. doliata	20	20.0	64.5

Sardinia (48%). Smaller groups of *Medicago noeana* from Iran, Iraq and Turkey and *M. orbicularis* from Yugoslavia are also late flowering (Table 7). *Medicago rigidula* (55%), *M. arabica* (51%) and *M. orbicularis* (32%) were the latest flowering species.

Seed production

One of the most important selection criterion is ability to produce high seed yields, which not only ensure survival and persistence but also provide an excellent diet for livestock.

Table 6. Accessions grown from 1968-86 that flowered earlier than *M. truncatula* cv. Cyprus, and their relationship to the total grown.

Origin	No. of access.	% of country total	% of species total/country
Libya	363		
M. truncatula	176	48.5	54.2
M. littoralis	101	27.8	80.8
M. doliata	28	7.7	90.3
M. constricta	22	6.1	56.4
6 other species	36	9.9	-
Israel	69		
M. truncatula	32	46.4	21.6
M. polymorpha	25	36.2	14.1
6 other species	12	17.4	-
Cyprus	67		
M. truncatula	15	22.4	10.9
M. polymorpha	14	20.9	66.7
M. scutellata	12	17.9	100.0
M. littoralis	11	16.4	9.8
4 other species	15	22.3	-

Of the 8881 accessions grown, 1681 had a seed yield at least 30% greater than Jemalong (Table 8). These were from 15 species and 28 countries, the greatest number originating in Tunisia (25%). The most frequent source was *M. orbicularis* (532 accessions or 32%), followed by *M. polymorpha* (430, 26%) and *M. truncatula* (331, 20%). *Medicago orbicularis* was also the species with the highest proportion of its accessions exceeding the seed yield of Jemalong (51%).

Pod spininess

Spiny pods cause serious vegetable fault in wool in Australia and emphasis is placed on accessions which are no spinier than Jemalong. Table 9 shows that for the 13 species considered to have agronomic potential there are many accessions which are acceptable (except in *M. arabica* and *M. intertexta*).

Seed coat impermeability

The rate of breakdown of seed coat impermeability is a major factor in the successful regeneration of annual medics. In Australia thunderstorms commonly result in early germination of permeable seed which perishes in the absence of adequate later rains.

Table 7. Accessions grown from 1968-86 that flowered at least 3 weeks later than *M. truncatula* cv. Jemalong, and their relationship to the total grown.

Origin	No. of access.	% of country total	% of species total/country
Turkey	363		
M. rigidula	163	52.9	74.8
M. orbicularis	72	23.4	70.6
Greece	169		
M. orbicularis	53	51.0	40.8
M. arabica	23	22.1	74.2
Sardinia	99		
M. murex	46	46.5	54.8
M. arabica	30	30.3	100.0
Italy	86		
M. orbicularis	30	34.9	63.8
M. arabica	15	17.4	88.2
M. littoralis	11	12.8	21.2

This results in poor regeneration in that year. For this reason we suggest that the optimum level of seed coat permeability in Australia is near 100% until midautumn followed by a rapid decrease to 70% (Crawford 1971). However, given the differences in farming practices, climate and the strong influence of environmental factors affecting seed coat permeability, the results obtained in Australia, and the proposed optimum levels, will be different in the Mediterranean.

Figure 3 illustrates seasonal changes in seed coat permeability of nine medic cultivars using results from the Parafield Plant Introduction Center. Most of the older cultivars (Borung, Cyprus, Jemalong and Robinson) have more than 90% impermeable seed in mid-April, considered to be too high. To overcome this problem, 3581 accessions of 28 medic species were tested to find accessions which reflect the optimum rate of breakdown. As a result the cultivar Paraggio was developed, which has 25% permeable seed in mid-April. In contrast the cultivar Paraponto was selected to replace Paragosa, a soft-seeded cultivar of *M. rugosa*.

This testing has shown that, for the 13 species with agronomic potential in southern Australia, with the exception of *M. rugosa* there are few with seed coat permeability as high as 30%. For this reason 20% permeability is the basis for selection in Table 10 which gives the proportion of the total lines screened having less than 80% impermeable seed by mid-April. It is apparent that most accessions of *M. littoralis*, *M. orbicularis*, *M. polymorpha*, *M. rigidula* and *M. turbinata* maintain high levels of impermeable seed into the start of the growing season.

Table 8. Accessions grown from 1968-86 that had seed yield at least 30% greater than *M. truncatula* cv. Jemalong, and their relationship to the total grown.

Origin	No. of access.	% of country total	% of species total/country
Tunisia	363		
M. truncatula	154	36.1	19.6
M. polymorpha	102	23.9	58.0
M. intertexta	78	18.3	61.9
M. orbicularis	70	16.4	68.6
Israel	251		
M. polymorpha	147	58.6	83.0
M. orbicularis	55	21.9	88.7
Algeria	239		
M. truncatula	89	37.2	16.9
M. polymorpha	62	25.9	59.0
Greece	182		
M. orbicularis	64	52.5	49.2
M. truncatula	15	12.3	12.4
M. rugosa	14	11.5	35.0

Resistance to insect pests

The insects of concern in southern Australia are spotted alfalfa aphid (*Therioaphis trifolii*), blue-green aphid (*Acyrthosiphon kondoi*), cow-pea aphid (*Aphis craccivora*) and red-legged earth mite (*Halotydeus destructor*). Screening has revealed distinct geographical centres of origin for resistance:

1. For spotted alfalfa aphid, widespread resistance in *M. truncatula* occurs in southern and eastern Mediterranean countries and local resistance is in *M. tornata* in Tunisia and Sicily.
2. For blue-green aphid, resistance in *M. truncatula* was found in localized areas in the Levant and in *M. polymorpha*; one accession of *M. murex* resistance was found in Sicily.
3. For cow-pea aphid, resistance in *M. truncatula* was found only in Tunisia, Morocco and Sicily; moderate local resistance in *M. littoralis* was found in parts of Morocco and Spain; local resistance in *M. tornata* was found in parts of Algeria.
4. Local resistance in *M. murex* was found in Greece; rare resistance in *M. truncatula* was found in Tunisia and southern France; good sources of resistance in *M. polymorpha* were centered in Tunisia and Algeria.

Table 9. Accessions of 13 major species grown from 1968-86 with pods not spinier than *M. truncatula* cv. Jemalong.

Species	Accessions < Jemalong	Total assessed	Percent < Jemalong
M. aculeata	324	390	83.1
M. arabica	14	214	6.5
M. intertexta	21	299	7.0
M. littoralis	451	915	49.2
M. murex	88	150	58.7
M. orbicularis	986	986	100.0
M. polymorpha	379	1100	34.5
M. rigidula	364	559	65.1
M. rugosa	129	129	100.0
M. scutellata	311	311	100.0
M. tornata	334	359	92.0
M. truncatula	1449	2767	52.4
M. turbinata	145	155	93.5
Total	4995	8334	59.9

Table 10. Accessions of 13 major species grown from 1968-85 that had greater than 20% permeable seed by midautumn.

Species	Accessions > 20%	Total assessed	Percent > 20%
M. aculeata	147	390	37.7
M. arabica	50	214	23.4
M. intertexta	57	299	19.1
M. littoralis	105	899	11.7
M. murex	63	150	42.0
M. orbicularis	28	986	2.8
M. polymorpha	104	1100	9.5
M. rigidula	52	559	9.3
M. rugosa	66	123	53.7
M. scutellata	48	177	27.1
M. tornata	118	359	32.9
M. truncatula	626	2706	23.1
M. turbinata	10	155	6.5
Total	1474	8117	18.2

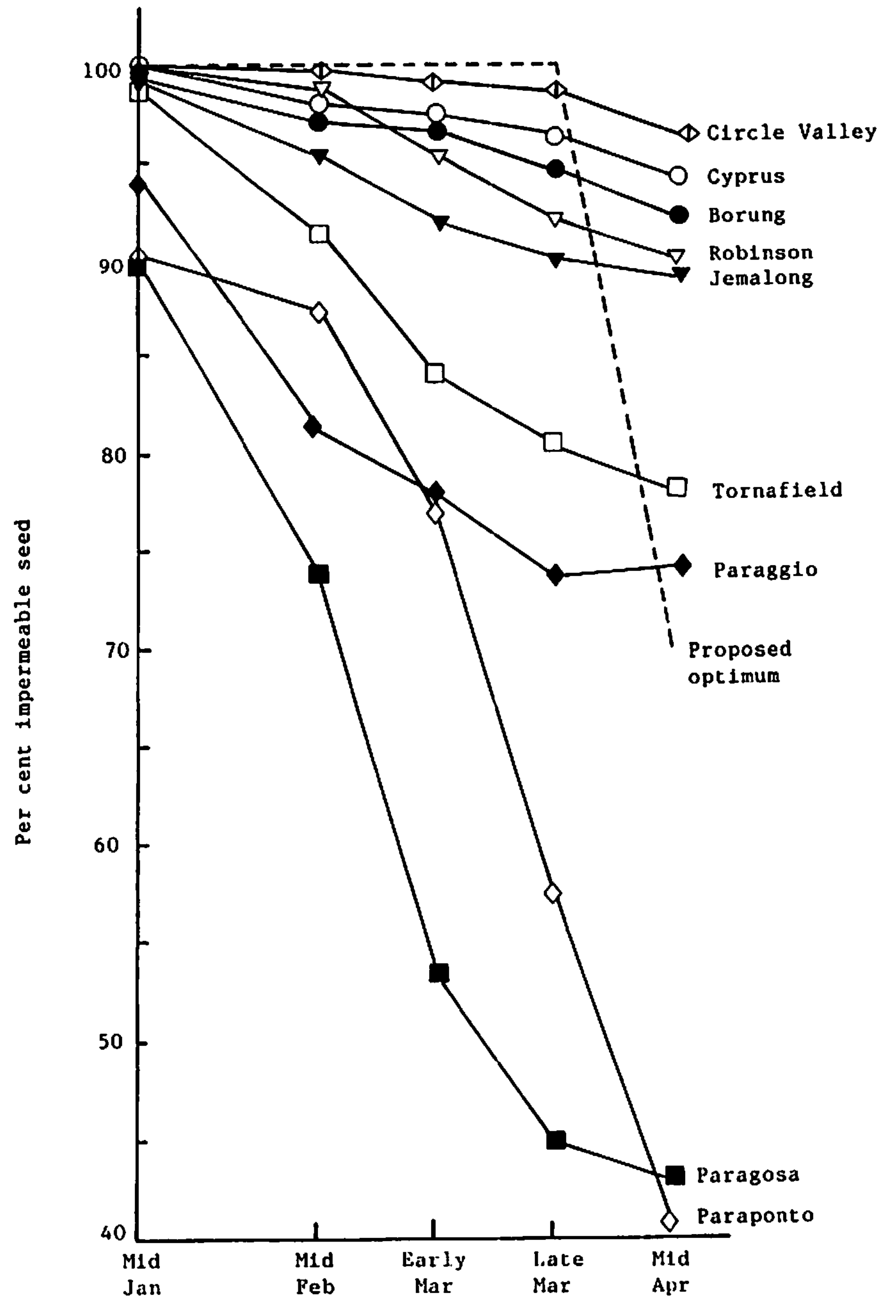


Fig. 3. Seasonal changes in seedcoat permeability in nine commercial annual medic cultivars at Parafield Plant Introduction Center, South Australia.

Intensive collection of resistance sources in northwest Africa, southern Russia, Armenia, the Iberian Peninsula, southern France and the Balkan States is required.

The Future of the Australian Medic Genetic Resource Centre

After many years, AMGRC now has adequate facilities to enable the evaluation and conservation of annual medics well into the future. Staff resources remain inadequate and this has resulted in a large backlog of material awaiting evaluation (Table 2) and a large volume of data awaiting input into the database.

The collection is increasing at an average of 1300 accessions per year but only 1000 of these can be evaluated. Australian rural industry funds will help to reduce this in the short term, but in the longer term increased funding is necessary to secure the future of the collection.

References

Crawford, E.J. 1970. Variability in a large Mediterranean collection of introduced lines of *Medicago truncatula* Gaertn. Pages 188-192 *in* Proceedings of the XIth International Grasslands Congress, Surfers Paradise, Queensland, Australia.

Crawford, E.J. 1971. Seasonal changes in seedcoat permeability in 155 lines of *Medicago truncatula* Gaertn. under natural field conditions. Pages 1c-16 *in* Proceedings of the Australian Seed Research Conference, Mt. Gambier, South Australia.

Crawford, E.J. 1983. Selecting cultivars from naturally occurring genotypes: evaluating annual *Medicago* species. Pages 213-215 *in* Genetic Resources of Forage Plants (J.C. McIvor and R.A. Bray, eds.). Vega Press, Blackburn, Victoria, Australia.

Crawford, E.J. 1991. Descriptor list for annual *Medicago* species. International Board for Plant Genetic Resources, Rome, Italy. (33 pp. in French and English).

Hutton, E.M. 1934. The important pasture plants of South Australia considered as to their identification and characteristics. Journal of Agriculture, South Australia 38:336-344.

Neal-Smith, C.A. 1967. Australian plant exploration 1947-67. Plant Introduction Review 4:1-6.

Neal-Smith, C.A. and D.E. Johns. 1971. Australian plant exploration, August 1967-1971. Plant Introduction Review 8:17-28.

Trumble, H.C. 1939. Barrel medic (*Medicago tribuloides* Desr.) as a pasture legume. Journal of Agriculture, South Australia 42:953-958.

The Chromosomal Genetic Structure of *Rhizobium meliloti* Populations in Southwest Asia

B.D. Eardly[1], L.A. Materon[2] and R.K. Selander[1]
[1] *Department of Biology, Pennsylvania State University, University Park, Pennsylvania, USA*
[2] *ICARDA, Aleppo, Syria*

Abstract

Several species of plant-associated soil bacteria of the family Rhizobiaceae are defined and identified on the basis of plant-host range, a trait mediated by plasmid-borne genes in at least two genera within this family. Although this system is agronomically convenient, it does not provide an accurate framework describing genomic relatedness of strains within these species. Thus, we suggest an alternative approach for determining the genetic structure and species limits with the Rhizobiaceae, which involves the sequential analysis of chromosomal and plasmid genetic structure in natural populations by routine molecular methods of analyzing genetic variation. We report here the results of the first phase of such an analysis, in which we examined the chromosomal genetic structure of 232 *Rhizobium meliloti* isolates, primarily from natural populations in southwest Asia, where there is high species diversity of hosts of *R. meliloti*. The nominal species *R. meliloti* has two distinct chromosomal lineages, one of which is specifically adapted to the soils and native annual medic species of the eastern Mediterranean basin. Comparable studies of the genetic structure of the symbiotic megaplasmid within these lineages should reveal whether or not their chromosomal and plasmid phylogenies are cognate.

Introduction

The symbiotic nitrogen-fixing soil bacteria of the genus *Rhizobium* (family Rhizobiaceae) have been an important subject of agricultural research for the past century (Fred *et al.* 1932). This early agronomic interest in *Rhizobium* resulted in a species-level classification of strains based on variation in host range among common legume species (Burton 1972). Plant species susceptible to nodulation by the same strains of rhizobia constitute a cross-inoculation group, and strains capable of nodulating plants within a group are considered nonspecific.

The species *Rhizobium meliloti* is defined by an ability to stimulate development of root nodules in symbiotic association with plant species of three related genera native to southwest Asia—*Medicago*, *Melilotus* and *Trigonella*) (Bolton *et al.* 1972; Burton 1972;

Jordan 1984). Since strains of *R. meliloti* are found only in soils where these legumes have grown previously, it is presumed that they are indigenous to the same localities as their legume hosts.

The classical cross-inoculation group concept of species limits in *Rhizobium* is wholly inadequate for describing genomic relatedness among this important and highly diverse group of bacteria (Wilson 1944; Pinero *et al.* 1988). Problems with the use of this concept in defining species limits in *Rhizobium* are related to two central issues. First, the genes encoding host specificity in *Rhizobium* are plasmid-borne (Banfalvi *et al.* 1985) and, hence, are of questionable value for estimating chromosomal relatedness. This conclusion is substantiated by observations that rhizobial symbiotic plasmids (pSym) may be self-transmissible (Brewin *et al.* 1980) and that identical pSym plasmid genotypes have been found on different chromosomal backgrounds in natural populations (Schofield *et al.* 1987; Young and Wexler 1988). Second, in spite of the fact that phenotypic traits are widely used to establish genetic relatedness in bacteria, dependence on such characteristics has led to numerous anomalous associations between genetically distant taxa (Fox *et al.* 1980). Based on our assessment of these two issues, we conclude that species limits within the genus *Rhizobium* need to be redefined on the basis of chromosomal relatedness.

Described in this report is an analysis of the chromosomal genetic structure within diverse natural populations of *R. meliloti*. The results of this analysis are intended to serve as a basis for the future examination of the population genetic structure of the symbiotic megaplasmids in this species. This sequential approach has been used previously, but only in studies limited to local populations (Schofield *et al.* 1987; Young and Wexler 1988). To our knowledge, ours is the first use of this approach to characterize extensive populations representing an entire species of soil bacteria.

Collection of Isolates

Two hundred isolates were obtained from geographically and ecologically diverse locations in southwest Asia by the use of both annual and perennial *Medicago* species as trap hosts; 115 isolates were cultured from annual species of *Medicago* grown in previously uninoculated soils of Syria, Turkey and Jordan; 85 isolates were recovered from perennial *Medicago* species (primarily *M. sativa* or alfalfa) in northern Nepal and Pakistan. The trap hosts and geographic origins of these isolates are listed elsewhere (Eardly *et al.* 1990). Additionally, 32 isolates of diverse global origins were examined, including 10 commercial inoculant strains from the collection of the senior author and 22 isolates from the global collection of the Laboratorie de Biologie Moleculaire des Relations Plantes-Microorganismes, CNRS-INRA, Castanet-Tolosan, France (Casse *et al.* 1979).

Analysis of Chromosomal Genotypes

Multilocus Enzyme Electrophoresis (MLEE)

The genetic structure of the native populations was examined by an analysis of electrophoretically demonstrable allelic variation at 15 metabolic, presumably chromosomal enzyme genes: 6-phosphogluconate dehydrogenase, malate dehydrogenase, 3-hydroxybutyratedehydrogenase,beta-galactosidase,aconitase,glyceraldehyde-phosphate dehydrogenase, glucose-6 phosphate dehydrogenase, isocitrate dehydrogenase, leucine aminopeptidase, phosphoglucose isomerase, leucyl-alanine peptidase, indophenol oxidase, hexokinase, adenylate kinase and phosphoglucomutase. The methods used for enzyme extraction, electrophoresis, staining and data analysis are described elsewhere (Selander *et al.* 1986; Eardly *et al.* 1990).

A comparison of the allele profiles of the 232 isolates revealed 60 distinctive multiloci genotypes, or electrophoretic types (ETs). These are listed in Figure 1 with the number of isolates representing each ET. Fourteen of the fifteen enzyme loci assayed were polymorphic (only indophenol oxidase was invariable). A cluster analysis of the ETs revealed two primary phylogenetic divisions (denoted as A and B in Fig. 1), separated at a genetic distance of 0.84 and a secondary branch from division A at a genetic distance of 0.64 (denoted as A2 in Fig. 1).

Included in subdivision 1 of division A were 43 of the 60 ETs identified; these 43 ETs were represented by 209 of the 232 strains examined. The most frequently observed genotype, ET1, belonged to this subdivision; it was represented by 70 isolates, including the type strain of *R. meliloti* (ATCC 9033) and five commercial inoculant strains of alfalfa. Strains of ET1 were obtained from eight species of *Medicago* at localities on five continents. Other common ETs were 3, 7, 26 and 36, which were represented by 28, 17, 14 and 18 isolates, respectively.

The secondary branch of division A, which is identified in Figure 1 as A2, was represented by the single Australian isolate CC2013. This strain was unusual in that it possessed unique alleles at four loci, and it is also able to effectively nodulate the highly strain-specific legume species *Trigonella suavissima* (Brockwell and Hely 1966), which is native to Australia (Vincent 1962).

Division B included 16 ETs (Fig. 1), each of which was represented by only one or two isolates. With the exception of the two strains of ET 57, all isolates of ETs of division B were recovered from annual medics in the eastern Mediterranean basin. One of the strains of ET 57 (CC169) is symbiotically efficient with most annual medic species and is used as a seed-inoculant strain for these species in the eastern Mediterranean region (Materon and Cocks 1987). Interestingly, strain CC169 was isolated in Australia in 1979 (Casse *et al.* 1979) and the other strain representing ET 57 was isolated by O.N. Allen in the USA, probably in the 1930s (E.B. Roslycky, Agriculture Canada, Ontario, pers. comm.). Since there are no indigenous *Medicago* species in either of these countries, we

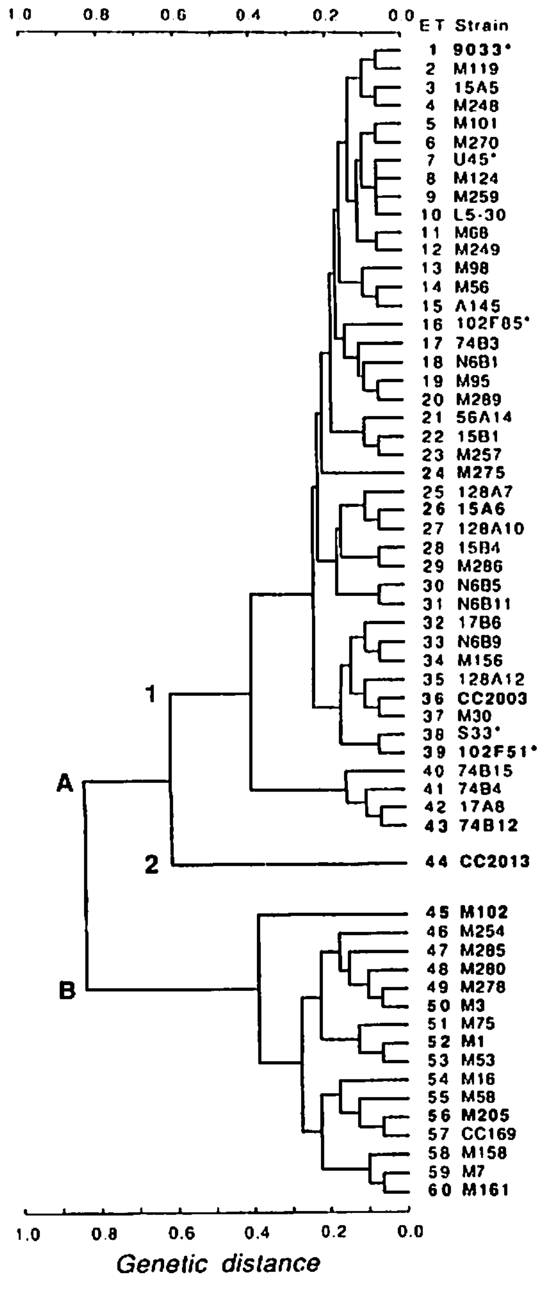


Fig. 1. Genetic relationships among 50 ETs of *R. meliloti* estimated on the basis of electrophoretically detectable allelic variation at 14 enzyme loci. A representative isolate is listed for each ET. Strains used in *Bam*HI RFLP analysis of the rRNA operons (Fig. 2) are denoted in bold type; commercial inoculant strains are marked with an asterisk.

conclude that this particular ET was probably introduced as an inoculant culture or, perhaps, as a soil contaminant.

rRNA Operon Restriction Fragment Length Polymorphism

Genetic relatedness among isolates of the primary phylogenetic divisions revealed by MLEE was assessed by an analysis of *Bam*HI restriction fragment length polymorphisms (RFLPs) in rRNA operons by Southern hybridization (Southern 1975). This method was a modification of that described by Grimont and Grimont (1986), in which we used a 3.8-kb cloned *Escherichia coli rrnB Pvu*II fragment as the hybridization probe (a gift of J. Zengel and L. Lindahl) rather than the commercial rRNA probe used in the original protocol. Twelve representative isolates were analyzed, one from each of 12 branches of the MLEE dendogram at a genetic distance of 0.20 (Fig. 1). Total genomic DNA extracted by standard methods (Heath *et al.* 1986) was digested overnight with *Bam*HI. The digests were then subjected to electrophoresis, blotted on to a nylon membrane and hybridized with the nick-translated ^{32}P-labeled probe (Maniatis *et al.* 1982).

The results of the RFLP analysis confirmed the phylogenetic subdivisions revealed by the MLEE analysis (Fig. 2). The presence of the three consistent, easily observable bands in these patterns indicates that this method will be particularly useful for subdividing complex rhizobial population samples into discrete chromosomal genotypes for further analyses.

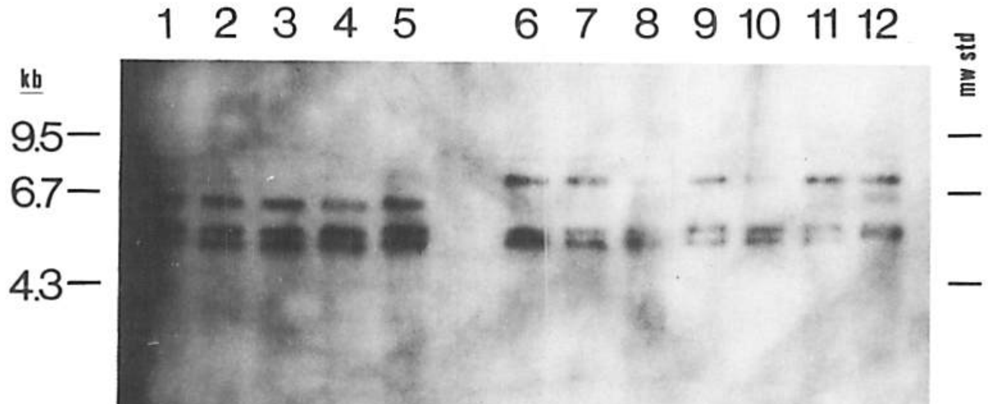


Fig. 2. Southern blot of *Bam*HI-digested chromosomal DNA from 12 *R. meliloti* strains probed with a rRNA operon restriction fragment from *E. coli*. Lanes 1-5 and 6-12 are strains representing divisions B and A, respectively (Fig. 1). Lanes: 1, M161; 2, M205; 3, M1; 5, M102; 6, 74B12; 7, 102F51; 8, CC2003; 9, 15A6; 10, ATCC 9930; 11, M275; 12, CC2013. Positions of molecular

Species Limits and Geographic Distribution of *R. meliloti*

By the criterion conventionally applied in defining species limits among the Enterobacteriaceae and certain other bacteria (Brenner 1981), and on the basis of strong correlations between MLEE data and DNA/DNA hybridization data (Gilmour *et al.* 1987), we conclude that the two primary divisions of *R. meliloti* represent distinct evolutionary species. Subdivision 1 of division A included 43 ETs represented by 207 strains from the eastern Mediterranean basin, northern Pakistan, Nepal and various other localities worldwide. The widespread use of certain strains of ETs in this division for laboratory research and for alfalfa seed inoculants accounts for their global geographic distribution.

We suspect that the single isolate of subdivision 2 of division A (CC2013; ET 44), which is ecologically peculiar in being able to nodulate *T. suavissima*, represents an old phylogenetic lineage allied with the lineages that include the other 43 ETs in division A. However there is the possibility, albeit remote, that it is an unusual hybrid formed by extensive chromosomal recombination between strains of the two divisions, or between a strain of division A and some other form of *Rhizobium*.

The observation that virtually all of the division B strains originated in the eastern Mediterranean basin suggests that they may be specifically adapted for symbiotic relationships with native annual medic species. This interpretation is supported by previous field studies in this region, where annual medic species fixed more nitrogen when inoculated with a strain of division B (CC169; ET 57) than when inoculated with a strain of division A (U45; ET 7) (Materon and Cocks 1987).

This observed correlation between chromosomal genotype and host reproductive growth habit is not absolute, however. For example, one strain in division A (CC2003) is symbiotically effective on the annual medic species *Medicago laciniata* and ineffective on alfalfa. In contrast, another more typical strain of the same ET (strain 311; ET 36) is symbiotically effective on alfalfa and presumably ineffective on the highly strain-specific *M. lacinita* (Brockwell and Hely 1966). Because most symbiotic traits in *R. meliloti* are encoded by genes on megaplasmids, one possible explanation for the unusual symbiotic behavior of strain CC2003 is that it possesses an unusual pSym genotype. We intend to test this hypothesis by an RFLP analysis of the pSym megaplasmids in several symbiotically diverse strains of ET 36.

Agricultural Significance

In the arid eastern Mediterranean basin, attempts are being made to develop cropping systems that utilize indigenous annual species of *Medicago* for livestock production (Materon and Cocks 1987). Inoculant strains of *R. meliloti* for agricultural use have traditionally been selected by an arduous trial-and-error method in which isolates of an undefined genetic background are evaluated. By identifying a variety of phylogenetic lineages that may be expected to vary in phenotypic traits, the genetic framework provided in Fig. 1 should increase the efficiency of this selection process. Results of such screenings also may further define the host-microsymbiont affinity groups suggested by our genotypic analysis.

References

Banfalvi, Z., E. Kondorosi and A. Kondorosi. 1985. *Rhizobium meliloti* carries two megaplasmids. Plasmid 13:129-138.

Bolton, J.L., B.P. Goplen and H. Baenziger. 1972. World distribution and historical developments. Pages 1-34 *in* Alfalfa Science and Technology (C.H. Hanson, ed.). ASA Monograph No. 15. Am. Soc. Agron., Madison, Wisconsin, USA.

Brenner, D.J. 1981. Introduction to the family Enterobacteriaceae. Vol. II Chap. 88 *in* The Prokaryotes (M.P. Starr, H. Stolp, H.G. Truper, A. Balows and H.G. Schlegel, eds.). Springer-Verlag, Berlin.

Brewin, N.J., J.E. Beringer, A.V. Buchanon, A.W.B. Johnston and P.R. Hirsch. 1980. Transfer of symbiotic genes with bacteriocinogenic plasmids in *Rhizobium leguminosarum*. Journal of General Microbiology 116:261-270.

Brockwell, J. and F.W. Hely. 1966. Symbiotic characteristics of *Rhizobium meliloti*: an appraisal of the systematic treatment of nodulation and nitrogen fixation interactions between hosts and rhizobia of diverse origins. Australian Journal of Agricultural Research 17:885-899.

Burton, J.C. 1972. Nodulation and symbiotic nitrogen fixation. Pages 229-246 *in* Alfalfa Science and Technology (C.H. Hanson, ed.). ASA Monograph No. 15. Am. Soc. Agron., Madison, Wisconsin, USA.

Casse, F., C. Boucher, J.S. Julliot, M. Michel and J. Denarie. 1979. Identification and characterization of large plasmids in *Rhizobium meliloti* using agarose gel electrophoresis. Journal of General Microbiology 113:229-242.

Eardly, B.D., L.A. Materon, N.H. Smith, D.A. Johnson, M.D. Rumbaugh and R.K. Selander. 1990. The genetic structure of natural populations of the nitrogen-fixing bacterium *Rhizobium meliloti*. Applied and Environmental Microbiology 56:187-194.

Fox, G.E., E. Stackebrandt, R.B. Hespell, J. Gibson, J. Maniloff, T.A. Dyer, R.S. Wolf, W.E. Balch, R.S. Tanner, L.J. Magrum, L.B. Zablen, R. Blackmore, R. Gupta, L. Bonen, B.J. Lewis, D.A. Stahl, K.R. Luehrsen, K.N. Chen and C.R. Woese. 1980. The phylogeny of prokaryotes. Science 209:457-463.

Fred, E.B., I.L. Baldwin and E. McCoy. 1932. Root nodule bacteria and leguminous plants. University of Wisconsin Press, Madison, Wisconsin, USA.

Gilmour, M.N., T.S. Whittam, M. Kilian and R.K. Selander. 1987. Genetic relationships among oral Streptococci. Journal of Bacteriology 169:5247-5257.

Grimont, F. and P.A.D. Grimont. 1986. Ribosomal ribonucleic and acid gene restriction patterns as potential taxonomic tools. Annales de l'Institut Pasteur Microbiologie 137:165-175.

Heath, L.S., G.L. Sloan and H.E. Heath. 1986. A simple and generally applicable method for releasing DNA from bacterial cells. Applied & Environmental Microbiology 51:1138-1140.

Jordan, D.C. 1984. Family III. Rhizobiaceae. Genus I. *Rhizobium*. Pages 235-242 *in* Bergey's Manual of Systematic Bacteriology, Vol. 1 (N.R. Krieg and J.G. Holt, eds.). Williams & Wilkins, Baltimore, Maryland, USA.

Maniatis, T., E.F. Fritsch and J. Sambrook. 1982. Molecular cloning—a laboratory manual. Cold Spring Harbor Laboratory, Cold Soring Harbor, New York, USA.

Materon, L.A. and P. Cocks. 1987. Constraints to biological nitrogen fixation in ley farming systems designed for west Asia. Pages 93-105 *in* Microbiology in Action (W.G. Murrell and I.R. Kennedy, eds.). John Wiley & Sons, New York, USA.

Pinero, D., E. Martinez and R.K. Selander. 1988. Genetic diversity and relationships among isolates of *Rhizobium leguminosarum* biovar *phaseoli*. Applied & Environmental Microbiology 54:2825-2832.

Schofield, P.R., A.H. Gibson, W.F. Dudman and J.M. Watson. 1987. Evidence for genetic exchange and recombination of *Rhizobium* symbiotic plasmids in a soil population. Applied & Environmental Microbiology 53:2942-2947.

Selander, R.K., D.A. Caugant, H. Ochman, J.M. Musser, M.N. Gilmour and T.S. Whittam. 1986. Methods of multilocus enzyme electrophoresis for bacterial population genetics and systematics. Applied & Environmental Microbiology 51:873-884.

Southern, E.M. 1975. Detection of specific sequences among DNA fragments separated by gel electrophoresis. Journal of Molecular Biology 98:503-571.

Vincent, J.M. 1962. Australian studies of the root-nodule bacteria. Proceedings of the Linnean Society of New South Wales 87:8-38.

Wilson, J.K. 1944. Over five hundred reasons for abandoning the cross-inoculation groups of the legumes. Soil Science 58:61-69.

Young, J.P.W. and M. Wexler. 1988. Sym plasmid and chromosomal genotypes are correlated in field populations of *Rhizobium leguminosarum*. Journal of General Microbiology 134:2731-2739.

Needs and Priorities for Further Collection of Annual Medic Germplasm

R. Reid[1], J. Konopka[2] and J.R. Rihan[3]

[1] *Pastures and Field Crops, Department of Primary Industry, Kingsmeadows, Tasmania 7249*

[2] *International Board for Plant Genetic Resources, 00145 Rome, Italy*

[3] *Department of Biology, University of Southampton, UK*

Abstract

Medicago is recognized as one of the most important genera of pasture plants in the world. Distribution patterns are fascinating, complex and not well researched. This paper reviews the distribution of medic species, and reports on the establishment of a Mediterranean pasture and forage legume database. The authors concede that there may be need for future collection trips, especially when germplasm from particular areas has been neglected or overlooked. Another justification is the acquisition of germplasm that will help solve immediate problems. A third reason is to collect in an area threatened with disappearance because of destruction of the natural habitat. The three major collections of annual medic are held at the Department of Agriculture, South Australia, ICARDA and collectively in Europe. Duplication of accessions in collections is a general problem and may represent about one-third of the medics held around the world. Better coordination and communication are needed to improve accounting and evaluation. Finally, cooperation will be useful to direct collections to high priority regions or to concentrate on vulnerable taxa in risk of disappearing.

Introduction

The genus *Medicago*, comprising about 55 species native to the Old World, is arguably one of the most important sources of pasture plants in the world. The center of diversity is probably the eastern Mediterranean region, with natural distribution occurring across Europe, north Africa and much of western and southern Asia. European settlement of the Americas, southern Africa and Australasia brought about both the unintentional and deliberate introduction of some species into new lands where they have become important in pastoral and ley farming systems.

The value of the genus within the Mediterranean region has long been recognized by livestock farmers but it is only in recent years that interest has focused on the deliberate sowing of annual medics to improve grazing quality. It is probably true to say that the first attempt to collect wild germplasm for deliberate introduction and evaluation on a significant scale was undertaken by Australian scientists who were seeking to expand the range of germplasm available to them. As a consequence of this collecting effort, the germplasm assembled by a series of collectors has not only supplied a number of pasture cultivars but also has exhibited a range of variability that has stimulated further collecting.

A working group on forages for the Mediterranean and adjacent semiarid areas was convened in Limassol, Cyprus in 1985 as part of a forage plan of action, which was approved by the International Board for Plant Genetic Resources (IBPGR) in 1983. The existing collections were reviewed and a number of recommendations were made in relation to the genetic resource requirements of the forages of the region.

In discussing priorities the working group noted that in many cases the distribution patterns of the species were inadequately known, and where they were better known the corporate knowledge had been built up from *ad hoc* short visits to likely areas. It was agreed that a better approach was necessary and the IBPGR was urged to carry out a number of surveys on several of the major priority genera to include data from flora, herbarium specimens, published papers and passport data in existing collections. It was further agreed that a number of species required priority action on the basis of their agronomic potential and the risk of genetic erosion (IBPGR 1985).

IBPGR undertook a survey of all existing collections of Mediterranean forages and established a database; further, a herbarium-based ecogeographic survey of the priority *Medicago* species was commissioned. From these studies a number of conclusions can be drawn as to the future needs and priorities after further collection of the annual medics.

Database and Ecogeographic Survey

IBPGR invited 25 institutions known to have significant holdings of Mediterranean forage germplasm to send copies of their inventories, with the accompanying passport data, so that a central database could be established. Nineteen institutions responded, with 16 eventually contributing data. (Unfortunately, some important collections are missing.)

The format of the data received reflected the diversity of the documentation systems (descriptors, hardware, software) used in the germplasm centers and a great deal of effort went into data transformation. Virtually every record had to be rearranged in some way. All accessions were screened to ensure that they had been collected within the Mediterranean and the adjacent semiarid/arid areas; breeders' lines and advanced cultivars were excluded. Only those accessions with a unique number were accepted. (Some inventories had many duplicate numbers.)

Whilst this study was not limited to *Medicago* the results apply equally well. At last, from the accessions reported, only 70% had accompanying location data and less than 25% could be accurately mapped. The information on the site characteristics was even worse with important data such as soil texture or soil type being reported in only 1% of the accessions. Table 1 illustrates the situation, with a total of 21 406 records examined, and clearly highlights the descriptors that genebank curators are interested in.

Table 1. Percentage of records with data entry for some selected database fields.

Field name	Records (%)
Institute	100
Donor code	100
Accession no.	92
Genus	100
Species	85
Country	87
Site	70
Latitude	46
Longitude	24
Altitude	52
pH	11
Parent rock	16
Rain	30
Soil texture	1
Herbarium	3
Other no.	52
Collector no.	26

The second study involved the collection of data from the labels of herbarium sheets, with the identification of the specimen being determined and/or checked at the same time. The study was limited to 7 perennial species and 13 annual species as recommended by the IBPGR working group.

Information was recorded from all countries bordering the Mediterranean and also Jordan, Iraq and Iran. Only data from specimens from the southern parts of France were entered into the database. All information relating to the location, habitat and collectors' data (date, name, number) was taken and additional morphological measurements were made if the specimen appeared unusual in some way. Eight herbaria were visited by one of us (J.R.R.) and 3458 specimens recorded. Finally, the geographic coordinates for 2687 of the specimens examined were obtained so that the distribution records could be digitally mapped.

There are records from 26 countries subdivided into 356 regions and data from 37 taxa in the 20 species. As it is not expected that every taxon will occur in every region, these figures appear to be a reasonable representation of the distribution. It is likely that the full distribution of some species and the complete list of taxa for some regions is not yet fully represented in the database. There are still some regions that have no records in the database and it is expected that additional records will gradually change the overall pattern.

In the database the oldest record is dated 1790 and the most recent is from 1987; of the total, 74% date from after 1900 and 47% are of specimens collected since 1939. Thus the information in the database could be considered to be reasonably current.

Taxonomy

Consideration of the distribution of taxa, generic, specific or subspecific, demands that the entities to be mapped should first be clearly determined taxonomically. The first requirement is that an unambiguous taxonomy exists and second that the determinations within that taxonomy should be accurate. The more divergent views there are on the taxonomy, the less certain will be the meaning of the determinations (Williams 1984).

To maximize the morphological resolution of the information the genus is discussed at the lowest possible taxonomic level, species, subspecies or variety as applicable. A more complete list of the synonyms of the annual species can be found in Heyn (1963). After a review of recent taxonomic literature it was decided to use the specific names as used by Lesins and Lesins (1979) and to subdivide the annual species into the varieties used by Heyn (1963).

A nomenclatural anomaly arises because although *Medicago aculeata* (of Heyn 1963) becomes *Medicago doliata* in Lesins and Lesins (1979), the new combinations needed for the varieties of *M. aculeata* under *M. doliata* are not listed by Lesins and Lesins (1979). So, to avoid this anomaly, the name *M. aculeata* is still used here, along with the variety names under *M. aculeata*. (The discussion will be further complicated by a majority of genebanks listing accessions under both specific names.)

A number of natural hybrids have been recorded in the wild; particularly well represented in the collections are the complexes of *Medicago rotata* × *Medicago blancheana* and *Medicago littoralis* × *Medicago truncatula* var. *tricycla*.

Geographical Distribution

The distribution map (Fig. 1) shows the general distribution of annual and perennial species of *Medicago* in Europe, north Africa, southwest Asia and central Asia. The

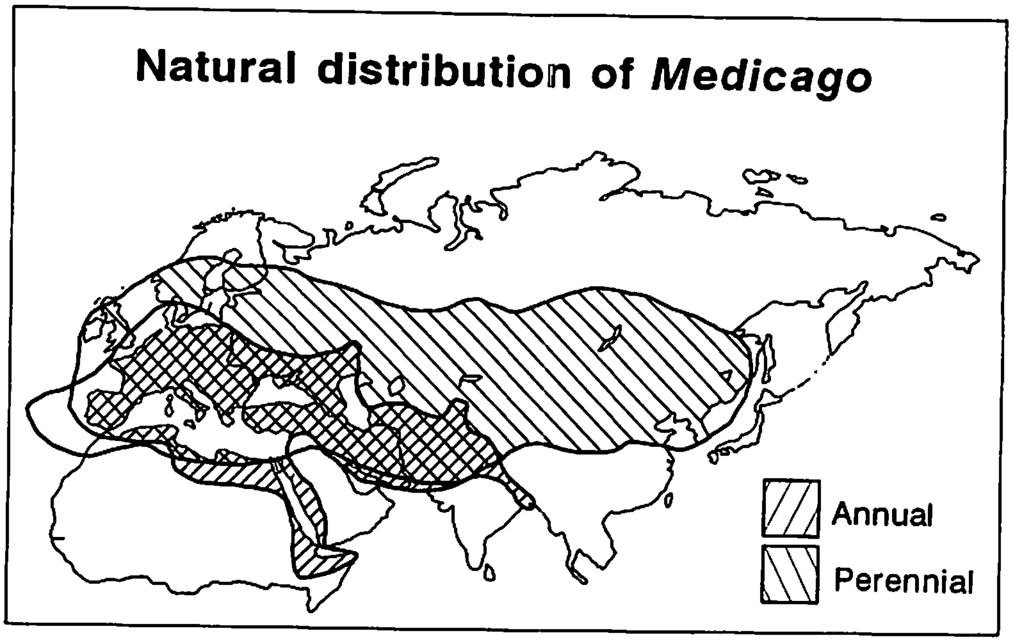


Fig. 1. Natural distribution of *Medicago* species in North Africa, Europe and Asia.

majority of the annual species are found in areas with a Mediterranean type climate (hot dry summers, cool wet winters). A few annual species are found in the cool temperate region of northern Europe and one (*Medicago laciniata*) even finds its way into the summer rainfall regions of east Africa and north India.

The medics in general are well adapted to neutral and alkaline soils, slightly acid silicaceous sands, occasionally moderate acid loams with free lime, but never to soils that are strongly acid with high exchangeable aluminum. They are characteristically found in open situations such as steppe, pasture or fallow fields and very rarely under forest shade.

We have examined the distribution of the species on a geographical and, where possible, an ecological basis. The data sources are shown in Table 2. Table 3 lists all the taxa mapped and summarizes the geographical and ecological data. The Mediterranean climatic zones are mapped in Fig. 2.

Medicago radiata occurs from western Anatolia through to inland Syria, Jordan, Iraq, Iran and on into central Asia. The habitat is recorded in dry areas, often rocky hillsides, and a wide range of soils which are usually derived from limestone or sandstone. The altitude range is given as from 250 to 1750 m elevation. The broad climatic classification is given as Continental Mediterranean and this species clearly has ecotypes that are adapted to both very hot summers and extremely cold winters.

Table 2. Source data for geographical and ecological distribution.

Herbaria

1. The British Museum of Natural History, London, UK
2. The Royal Botanic Garden, Edinburgh, UK
3. Conservatoire et Jardin Botanique de la ville de Geneve, Switzerland
4. The Hebrew University, Jerusalem, Israel
5. Royal Botanic Gardens, Kew, London, UK
6. Jardin Botanico, Madrid, Spain
7. Institut de Botanique, Montpellier, France
8. Universidad de Sevilla, Sevilla, Spain

Institutions which provided forage germplasm data

1. Agricultural Research Institute (ARI), Cyprus
2. CSIRO - Division of Plant Industry, Introduction Section, Canberra, Australia
3. Welsh Plant Breeding Station, Aberystwyth, Wales, UK
4. Greek Genebank, Thessaloniki, Greece
5. Israel Genebank (GB), Bet Dagan, Israel
6. Consiglio Nationale delle Ricerche, Istituto del Germoplasma, Bari, Italy
7. Station d'Amelioration des Plantes, Maugio, INRA, Montpellier, France
8. Institut de Biocenotique Experimentale des Agrosystemes (UACNRS), Universite de Pau, France
9. University of Birmingham, UK. (Data on IBPGR 1986 Sicily collecting mission)
10. Servicio de Investigacion Agraria, Badajoz, Spain
11. Estacao Nacional de Melhoramento de Plantas, Elvas, Portugal
12. Genetic Resources Information Network, USDA, Beltsville, USA
13. Royal Botanic Gardens, Kew, Wakehurst Palace (Seed Handling Unit), UK
14. International Centre for Agricultural Research in the Dry Areas (ICARDA), Aleppo, Syria
15. International Livestock Centre for Africa (ILCA), Addis Ababa, Ethiopia
16. Institut fur Pflanzenbau und Pflanzenzuchtung (FAL), Braunschweig, Germany
17. Centre de Production des Semences Pastorales El Jadida, Morocco
18. INRA (GEVES), La Miniere, Guyancourt, France
19. Plant Breeding Acclimatisation Institute, Razikow, Poland

Medicago rotata (two varieties, *rotata* and *eliezeri*, are recognized) is found in Cyprus, Syria, Lebanon, Israel, Jordan and southeast Turkey. It is found from 230 m below sea level in the Jordan Valley to 1675 m elevation in Lebanon, usually in rocky sites based on limestones, although a number of records report it growing on heavy alluvial soils.

Table 3. Geographic and ecological characteristics of 13 annual species of *Medicago*.

Species	Latitude range (°N)	Climatic zone†	Soil‡ reaction	Altitude (m)
aculeata	27-46	W-C	ANB	0-2000
littoralis	28-46	W-T	A	0-1700
murex	32-45	W-C-T	ANB	0-1050
noena	35-41	C	A	700-1000
polymorpha	27-46	W-C-T-CC	ANB	0-1900
radiata	29-44	C	A	250-1750
rigidula	30-46	W-C-T-CC	AN	0-1500
rotata	31-37	W-C	AN	(-)230-1675
rugosa	28-44	W	AN	30-1000
scutellata	32-46	W	AN	0-1200
tornata	28-46	W-CC	AN	0-1700
truncatula	27-46	W	AN	0-1250
turbinata	31-46	W-C	AN	0-1500

† W = warm Mediterranean, T = temperate, CC= cool, C = continental.
‡ A = alkaline, N = neutral, B = acid.

Medicago noeana is endemic to eastern Turkey and northern Iraq, with records from nearby areas in Syria and Iran. It is usually found from 700 to 1000 m elevation on calcareous rocky slopes. Apparently not a common species, it occupies a fairly narrow ecological niche.

Medicago rugosa is found all around the Mediterranean although nowhere is it very common. It is often recorded as growing on heavy clay soils and found from 30 to 1000 m elevation. Its distribution pattern would indicate a preference for the 'warm mediterranean' climate.

Medicago truncatula (varieties: *truncatula*, *longiaculeata* and *tricycla*) is found all around the Mediterranean but with a tendency to the west. It occurs mainly on calcareous soils, although also on basalt, usually up to 850 m elevation but occasionally at 1250 m elevation in southern Spain.

Medicago littoralis (varieties: *littoralis* and *inermis*) is widespread around the Mediterranean and is considered to be very common on sand dunes and beaches. It has been recorded up to 1700 m elevation in north Africa and Spain. Geographically it is somewhat disjunct in its distribution, being common around the southern shores of the Caspian Sea.

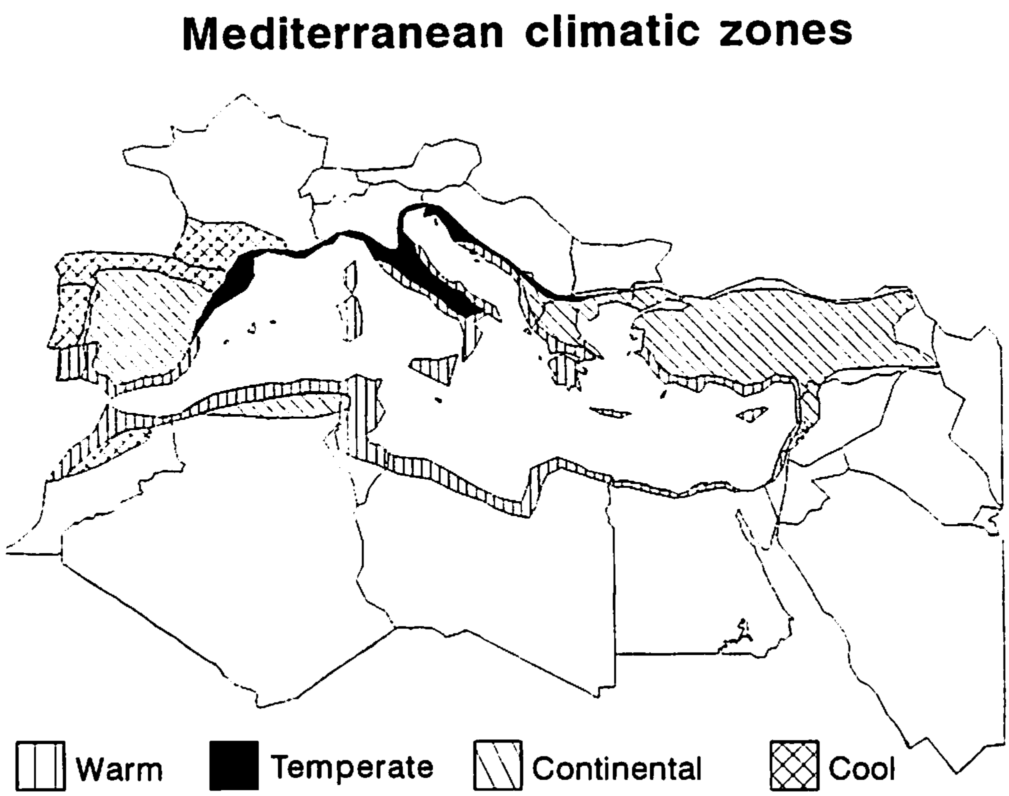


Fig. 2. Climatic zones of the Mediterranean region.

Medicago tornata is a very polymorphic species in which four varieties are recognized (*tornata, spinulosa, rugulosa* and *aculeata*). Some varieties of this species are very similar to those of *M. littoralis* and *M. truncatula* and it can be difficult to distinguish between them. *Medicago tornata* is essentially western Mediterranean in distribution and is found from 0 to 1200 m elevation (1700 m in north Africa) mainly on sand or silicaceous soils but also in marshy coastal meadows.

Medicago scutellata also is found all around the Mediterranean, usually near sea level, but it has been recorded up to 1200 m elevation (especially in Cyprus and north Africa). Records indicate that it has a preference for soils derived from limestone and often on disturbed sites.

Medicago polymorpha has three varieties (*polymorpha, vulgaris* and *brevispina*). It is widely distributed throughout the Mediterranean region and clearly tolerates a wide variety of habitats, seemingly being more tolerant of cold and excess moisture than most of the annuals. It ranges from below sea level bordering the Caspian Sea in Iran to over 1900 m in southern Spain.

Medicago aculeata has been divided into two varieties on the basis of presence or absence of spines. It is found all around the Mediterranean but principally in the west. It is recorded from sea level up to 2000 m and usually on soils derived from limestone. Herbarium records often describe it as "rare".

Medicago turbinata is divided into three varieties (*turbinata*, *aspiculata* and *aculeata*) but many herbarium specimens are difficult to identify to this level. It is found essentially on the south and southeast coasts of the Mediterranean, usually from sea level to around 800 m elevation (1500 m in southern Italy) and is invariably associated with calcareous soils.

Medicago murex (including *M. lesinsii*) is found all around the Mediterranean but already is more abundant in the west. It has been collected up to 1050 m elevation in Algeria but is usually found considerably lower than this. The soil preference is seemingly very varied and occasionally mildly acid soils are described. Although it does not appear to prefer a maritime habitat it is often found relatively near the sea.

Medicago rigidula is a very variable species, divided into four intergrading varieties, and it has proved difficult to assign many of the specimens to a variety with certainty. According to Heyn (1963) this species is most common in the western Mediterranean but this has not been confirmed by the study of the distribution records. It is found in virtually every country in the region from sea level up to 2800 m but more commonly between 300 and 1500 m elevation. Calcareous soils are seemingly preferred but it also has been recorded from basalts and sandstone-derived soils.

Discussion

Although only those species that have the greatest agronomic potential are discussed here, it should be recognized that other taxa may become equally important in the future. Any discussion on the distribution of a taxon at the continental or country level will result in only the broadest of conclusions. As a method of determining the distribution of a taxa with the eventual aim of collecting germplasm, it can only be recommended when nothing, or very little, is known of the occurrence of the taxon. Considering the genus *Medicago* it is probably true to say that, for example, Albania or the more remote parts of Iran, Afghanistan and the Soviet Union require exploratory collections.

The pattern of distribution exhibited by a taxon is complex and involves a great many selection pressures. Climate and soil type are fairly obvious, but so also are grazing conditions and specific rhizobial requirements. In more recent times changing agricultural practices and historical seed introduction also have become important.

Present germplasm requirements are probably best served by a more detailed level of study, that of the miniregion or land system. A recent example of the land system approach is illustrated by a collecting mission to Sicily and the Eolian Islands in 1986. The mission aimed at collecting a range of forage legumes, particularly *Medicago* and *Trifolium* species, and at recording the habitat where the material occurred.

The sampling strategy employed was that of examining all the land systems of the island. By studying all available climatic, edaphic, geological and vegetational data pertaining to the area in preparation for the mission, the collectors were able to select sites that were representative of all the land systems. Over 200 sites were explored and documented.

Annual medics were collected from a variety of both cultivated and uncultivated situations, ranging from coastal sites to the mountains, from weedy fallows in cereal areas to subalpine pastures at high altitudes. Usually, several species were found together. The most abundant and widespread species were *M. orbicularis*, *M. polymorpha* and *M. truncatula*, with the latter two exhibiting considerable phenotypic variations. Among the rarer species collected were *M. muricoleptis*, *M. tuberculata*, *M. tornata* and *M. tenoreana*. *Medicago minima* var. *minima*, which according to the "Flora d'Italia" is not present in Sicily, was collected at two locations. The collections are summarized in Table 4 (Auricht 1986).

The miniregion is well illustrated by the recent work of Ehrman and Cocks (1990) who sampled the genetic diversity of annual legumes in Syria (including *Medicago*) with a view to its conservation, and they described the distribution of species in terms of climate and soil with a view to gaining information that would assist in selecting useful material. A total of 207 sites in western and northern Syria were sampled; seed, soils and climatic data were obtained and an environmental classification established.

The researchers were able to conclude that both climate and soil control the distribution of many species. As might be expected in the Mediterranean basin, rainfall seems to be the most significant climatic factor with many species restricted to areas with excess of 400 mm. However, high rainfall and low incidence of frost are related in Syria and previous work (Cocks and Ehrman 1987) has demonstrated that frost frequency dictates the distribution of many species. In Syria, coastal areas receiving relatively high rainfall have species that occur there and nowhere else owing to the warm winters that are experienced.

Location of Collections and their Specificity

The world's three major collections of annual *Medicago* germplasm are held at the Department of Agriculture, South Australia, ICARDA and collectively in Europe. A number of other significant collections are found in individual countries.

The chief purposes of a germplasm collection are not only to preserve for future generations the genetic diversity they will need, but also to acquire new genetic material

Table 4. Number of *Medicago* species collected and seen, altitude and soil pH at site and notes on species distribution in Sicily.

Species	Collected	Seen	Altitude range (m)	pH range	Species distribution
aculeata	38	1	20-1190	7.0-9.0	Widespread in Sicily, also on Lipari pastures
arabica	29	0	60-935	6.5-8.5	Mostly in N mtns. and 3 islands, not high altitudes
ciliaris	33	3	40-990	8.0-9.0	Not on islands or NE mtns., hot cereal areas
intertexta	11	1	50-630	8.5-9.0	Only in W Sicily in hot cereal areas, clay soils
littoralis	2	0	0-210	7.5-7.5	Will be mixed with *M. truncatula*
minima	41	2	2-1430	6.5-9.0	SE, N mtns. and 4 islands, rocky slopes
minima, ssp. *mini*	2	0	810-1270		Nedrodi's only, high rainfall
murex	58	3	2-1190	6.5-8.5	Widespread throughout
muricoleptus	3	0	2-1050		N side of Nedrodi's alpine zone to coast
orbicularis	104	7	2-1430	6.5-9.0	Extremely widespread throughout
polymorpha	113	8	2-1430	6.5-9.0	Extremely widespread throughout
rigidula	21	0	60-1430	8.5-9.0	Mostly in N mtns., avg. to high altitude, precip.
rugosa	26	1	60-1050	6.5-8.5	Extensive in SE and N mtns. (not NE or islands)
scutellata	24	1	40-1050	6.5-9.0	Throughout cereal areas incl. Lipari, not NE mtns.
tornata	16	1	20-1050	6.5-8.0	All but 2 sites on islands, high summer temps.
truncatula	79	4	2-1050	6.5-9.0	Widespread throughout
turbinata	4	0	20-520	8.5-8.5	Three sites in SE, one in NE

that will solve immediate problems. In the collecting process it is self-evidently important to observe the plants in their native habitats and to note their edaphic, climatic and ecological relationships. This is important when we are looking for plants that may prove useful in areas other than their country of origin or when plants are sought to fill a particular environmental niche (e.g., gypseous soils, cold tolerance, etc.). The major part of the collecting of the annual medics has been targeted at providing this problem-solving germplasm and yet for the majority of the collections the quality of the passport data and even the number of total accessions reported leaves a great deal to be desired.

We have estimated that there are 25-30 000 accessions of annual medics held in various genebanks throughout the world. Of these we can confidently expect approximately one-third to be duplicate holdings; thus 20 000 are likely to be unique accessions.

The response to the IBPGR request for information on the various collections gave some 11 757 accessions of which, again using the one-third duplications estimate, at least 8000 are probably unique. This leaves approximately 12 000 accessions that we were unable to include in our analysis of the distribution of the genus.

Furthermore, of the material that was eventually available for analysis, less than one-fifth could be mapped with any degree of confidence (Table 5). The accompanying environmental information is at best probably only 5%, thus it can be deduced that great difficulties will be experienced in attempting to make judgements about the ecological conditions of the germplasm. The species held in the three major collections are listed in Table 6.

Unfortunately, there has been some inflation of the various collections caused by duplication of accessions. There are two major problems, each of which has become increasingly serious with the intensification of germplasm collecting and exchange activities. These are:

1. Loss of information on the history and origin of germplasm accessions received as donations from other institutions, due to insufficient recordkeeping or insufficient data transfer from the donor to recipients of samples.
2. Lack of clear identification of germplasm accessions as joint collections when materials are collected by two or more institutions.

For example, if the University of Southampton, the South Australian Department of Agriculture and the Aegean Regional Agricultural Research Institute in their respective listings do not clearly identify the 190 *Medicago* accessions collected during the joint southeast Turkey mission in 1988, this collection runs the risk of being triplicated on a total inventory basis with unforeseeable additional multiplication risks once these materials start to be distributed to other institutions.

Table 5. Summary by source of annual *Medicago* mapped until June 1989.

Source	No. of accessions
Pre-1987	
Australia - CSIRO	4496
Spain - Zaragoza	56
France - INRA, Geves	122
Great Britain - Kew	8
Greece - Thessalonika	24
IBPGR - 3 missions	667
Syria - ICARDA	332
Israel - Genebank	206
Italy - Genebank, Bari	92
Portugal - ELVAS	47
USA - Fort Collins	891
Total	6941
1987-1988	
Syria - ICARDA	3382
Spain - EPINIALO, Badajoz(ECP/GR)	1244
IBPGR - Turkey	190
Total	11757

It is clear that a major reform is needed in this respect and it is herewith suggested that the institutions that hold the principal annual *Medicago* collections should thoroughly check the origin of their accessions and complete the documentation of passport data. Eventually collections should be divided into:

1. Germplasm material whose source can be traced back to the accession number of its original collection. In germplasm collections, the original identification number may be that issued by the collecting institution or in other cases that of the national germplasm institution of the material's country of origin. All subsequent numbers assigned to the germplasm material are synonyms that may be desirable but not essential to cite in other germplasm inventories, exchange of material or scientific publications. The significance of the principle of always referring to germplasm material by its original accession number (PI, CPI) cannot be overemphasized for the orderly development of inventories.
2. Germplasm material that cannot be traced to the original accession number and which consequently may be represented in the form of more than one introduction.

Table 6. Annual species of *Medicago* in the major collections, June 1989.

	Collection		
Species	IBPGR Database	ECP/GR	ICARDA
Hybrid	629	-	53
aculeata	144	4	191
arabica	194	31	10
aristensis	1	-	-
blancheana	43	14	98
ciliaris	88	4	-
constricta	79	36	76
coronata	32	18	27
disciformis	57	19	12
doliata	54	30	-
glandilosa	1	-	-
granadensis	14	4	2
intertexta	107	25	57
laciniata	361	11	77
lanigera	-	-	-
littoralis	685	26	150
lupulina	93	37	3
marina	1	4	-
minima	355	47	109
murex	233	15	15
muricoleptis	-	1	5
noena	21	1	47
orbicularis	541	193	294
papillosa	1	-	-
polymorpha	900	341	547
praecos	33	9	26
radiata	37	7	105
rigidula	428	32	732
rotata	108	18	123
rugosa	103	23	37
sauvagei	-	-	3
scutellata	92	37	46
shephardii	-	2	-
soletrolii	9	-	2
tenoreana	6	-	-
tornata	148	25	103
truncatula	870	104	547
tuberculata	1	-	-
turbinata	72	32	81
Other spp.	399	90	39
Total	6941	1238	3572

It would be highly desirable if such a coordinated checking on the originality of the collections would also result in a coordination of responsibilities regarding maintenance, conservation and identification of annual *Medicago* germplasm.

Priorities for Future Collections

As for the future needs for annual *Medicago* collections, it is convenient to distinguish three aspects:

1. Need to collect and preserve genetic materials that are in danger of disappearing as a consequence of the destruction of the natural environment.
2. Need to collect genetic material in particular areas that in the past have been neglected or overlooked.
3. Need to increase the variability of collections from particular areas or species that on the basis of previous evaluation work have proved to be particularly promising, and/or to obtain germplasm that will solve immediate problems.

The Limassol meeting recommended that, besides IBPGR being asked to collate the data from existing collections and conduct a basic ecogeographic survey of the annual medics, a number of areas should be collected as a matter of high priority. These areas were Sicily, Turkey, the Aegean Islands and Iran.

A mission took place in Sicily in 1986 with three groups (S. Australia, W. Australia, IBPGR) joining an Italian national program, Istituto Sperimentale per le Colture Foraggere, to collect a broad spectrum of forage legumes. A total of 620 samples of annual medics were obtained.

A specific mission, again to collect a broad spectrum of forage legumes in southeast Turkey, was undertaken in 1987 by the Aegean Regional Agricultural Research Institute, Izmir and supported by personnel from the University of Southampton, South Australia and IBPGR. The Aegean Islands were the target of a successful mission by Gillespie (1989) and a mission to collect all species of *Medicago* will take place in Iran in 1989.

Genetic Conservation

Throughout the Mediterranean zone and particularly in low-rainfall areas, there is severe genetic erosion due to overgrazing, degradation of the native flora, use of herbicides and changing farming practices. Many of the medics are especially threatened by herbicides because they are commonly weeds of wheat and barley fields and the modern farmer will spray these crops for weed control.

Grazing pressure has been intense in north Africa and southwest Asia for centuries but the recent increase in livestock populations has accelerated the degradation enormously and all indigenous forage species are threatened. Apart from high-altitude areas protected by winter snow cover, at the present rate of decline by the year 2000 there will be few areas from which good pasture and forage-crop legume collections can be made (Carter 1978). Mathison (1983) has given many specific examples of the causes of depletion and in which countries it is occurring.

It is not yet possible to assess the regional impacts of the forthcoming global change in climate. There does, however, seem to be general agreement that there will be a raising of the sea level and that midlatitude, midcontinental drying during the summer will occur. Thus the more humid areas of the Mediterranean area will have a reduction of rainfall and the semiarid regions will become even drier; in effect, a gradual northern movement of the existing climatic zones. The whole concept of *in situ* conservation will have to be re-examined and priorities for collection continually assessed. Even the smallest predicted rise in sea level of 0.3 meters over the next 20 years will mean that many coastal taxa will disappear.

Genetic conservation can be of considerable importance in areas with a rapidly expanding agricultural frontier and a more direct and immediate loss of germplasm occurs where man-made structures alter the environment. In Turkey, the government is implementing a major hydroelectric and irrigation project (Guneydogu Anadolu Projesi or GAP) in Urga, Gaziantep, Adiyaman and Maras provinces. The project will lead to the flooding of tens of thousands hectares in the Euphrates and Tigris basins and will have wide-reaching ecological effects. This very real threat of genetic erosion in the center of diversity of so many forage legumes has led to a number of collecting missions being successfully carried out.

Neglected Regions and Species

Within the region of interest there are self-evidently significant areas that have had little or no exploratory work. At the country level, Albania is clearly conspicuous, but probably no more so than Yugoslavia, Bulgaria and Lebanon. Some countries have had numerous missions but there is still further collecting to be done within them.

Turkey is a very large country both physically and floristically and as it is the center of diversity of so many forage legume species, there should be an ongoing program of collections for some time to come. Some areas can be ascribed particular importance; the extreme southeastern area (Surt Bitlini, Var and Hakkari provinces) is of high interest, also the extreme northeast area (Kars and Artivian provinces) and the humid Black Sea coast.

Many of the species examined in some detail in this paper are widely distributed around the Mediterranean and grow in a range of mainly marginal habitats, but in almost every species there are exceptions to this generalization. A large number of accessions come from road and trackside habitats and in a ruderal species this may be an accurate reflection of their distribution, rather than a comment on the collecting techniques of plant collectors.

The herbarium study revealed some interesting varieties and novel genotypes from what were clearly the extremes of a taxon's distribution. Examples include *M. radiata*, normally associated with areas west of longitude 28°, recorded from northern Tunisia; *M. scutellata*, usually occurring near sea level, recorded up to 1200 m elevation in Algeria; *M. littoralis*, again usually found close to sea level, recorded up to 1700 m in Spain; also in Spain, *M. truncatula* from 1250 m.

In relation to ecological conditions, ecotypes that are found in atypical situations are again of interest. Examples include *M. tornata*, found in marshy meadows in southern Spain; *M. littoralis* growing on sand dunes in the arid, extreme south of Tunisia; *M. truncatula* in southern Libya and *M. polymorpha*, which seemingly is found in sites characterized by extreme moisture.

In certain areas where a previous collection has indicated that ecotypes with valuable characteristics are present, more intensive collections are desirable to fully exploit these resources. This already has been done in Sardinia and the Cyclades Islands of Greece (Gillespie 1989).

Undoubtedly, it would be desirable to collect germplasm of those taxa which in the *Medicago* collections so far are absent or represented by only a few genotypes, which include *M. aristensis*, *M. lanigera*, *M. lesinii*, *M. marina*, *M. muricoleptis*, *M. papillosa*, *M. sauvagei*, *M. tenoreana* and *M. tuberculata*.

Further Variability

There is some need for further collection of annual *Medicago* germplasm to increase the variability of material that has a recognized potential for cultivar development by selection or breeding. This is dependent on the already existing variability, the identification of limiting factors, information from evaluation programs by agronomists and breeders, and on the understanding of the natural distribution and adaptability of the species.

Knowledge of the genetic resources of *Rhizobium* is quite limited and we are only now beginning to understand the complexities of *Rhizobium* ecology. Although we understand the processes of nodulation and nitrogen fixation very well, there is still argument on the relative merits of rigid strain specificity vs promiscuity. At the very least a rudimentary collection of *Rhizobium* species with effective strains is needed for each legume species (Mathison 1983).

The Limassol meeting recommended that it is essential to collect *Rhizobium*, especially in the case of new taxa and where there are known difficulties with modulation. Further, it is desirable to increase collections of *Rhizobium* to the point of having a representative collection of strains and to preserve a *Rhizobium* pool. Only about 6% of the total accessions reported to IBPGR had indicated that a *Rhizobium* sample had been collected. Allowing for a very low rate of successful isolation it would appear that this aspect of plant collection is considered to be of low priority among collectors.

In defining the need for further collections on the basis of identified limiting factors, there are naturally considerable differences between organizations which are determined by specific interests and mandates. For example, ICARDA's search for productive and adapted pasture legumes reflects the wide environmental problem of the entire Mediterranean region, from the virtually frost-free coastal areas of north Africa to the dry, cold winter areas of southwest Asia. The success of the plant introduction program in finding suitable ecotypes of *M. rigidula* for ley farming systems in western Syria, and the promise of selected ecotypes of *M. polymorpha* in low-rainfall marginal areas, has been a great stimulus in the continuing search for adapted material for environments where no other legumes can be recommended.

In southern Australia, the annual *Medicago* work is concentrated on cultivar development in the ley farming system where emphasis is placed on the value of medics as the nitrogen supplier for utilization in cereal production. The climate of southern Australia has resulted in cultivars being developed from species essentially of coastal origin, but recent trends in soil acidification have resulted in a search for species from inland, acid soils. Tolerance to naturally acid soils is particularly important in western Australia. Because of the importance of wool production in Australia, the selection of spineless or short-spined medic types is an essential prerequisite for the development of successful and acceptable varieties (Gillespie 1989).

Conclusions

The present undertaking of attempting to set the needs and priorities for the further collecting of annual medic germplasm has proved to be extremely difficult. The paucity of reported information on the existing collections, both in terms of numbers of accessions and the associated passport data, has of necessity meant that a great deal of speculation has been involved in our deliberations. Without the full cooperation of all the genebanks and in turn the support of their respective parent organizations, future collecting priorities will continue to be met by *ad hoc* decisions and individual needs.

The immediate priority is not one of further collection but of an accounting and evaluation of what has already been collected; and to this end all the genebanks should first ensure that their collections are adequately documented and the data are available for exchange in computerized form. The documentation should at the very least include all the available relocation data and a minimum of site characteristic data, e.g., altitude, soil type, pH. To obtain a global picture, it is necessary to integrate genebank data into one database. Such a system already has been initiated by IBPGR and efforts should be directed toward completing this database as soon as possible. Only when it is possible to analyze such data will we be able to discuss both the geographic distribution and ecological amplitude of a taxon and assess the real need for conservation of those taxa and habitats that require it. The reported herbarium study and limited passport data from the existing collections have given us part of the picture. It now remains for the collectors to tell us where they have been and what they have collected.

Acknowledgements

We gratefully acknowledge Mr Alfred Mayer who compiled the IBPGR Mediterranean Forage Database.

References

Auricht, C.G. 1986. A forage collecting and ecogeographical surveying mission in Sicily during June and July 1986. M.Sc. Thesis, University of Birmingham.

Carter, E.D. 1978. A review of the existing and potential role of legumes in farming systems of the near east and north African region. A report to ICARDA, Waite Agricultural Research Institute.

Cocks, P.S. and T.A.M. Ehrman. 1987. The geographic origin of frost tolerance in Syrian pasture legumes. Journal of Applied Ecology 24: 673-683.

Ehrman, T.A.M. and P.S. Cocks. 1990. Ecogeography of annual legumes in Syria. 1. Distribution patterns. Journal of Applied Ecology 27:578-591.

Gillespie, D.J. 1989. A report on the collection of annual legumes in southern Italy and some Greek islands. Australian Plant Introduction Review 20:1-15.

Heyn, C.C. 1963. The annual species of *Medicago* Scripta Hierosolymitana. University of Jerusalem Press.

IBPGR. 1985. Forages for Mediterranean and adjacent arid/semi-arid areas. Report of a working group held at Limassol, Cyprus, April 1985. IBPGR, Rome.

Lesins, K.A. and I. Lesins. 1979. Genus *Medicago* (Leguminosae): a taxogenetic study. Dr W. Junk Bv Publishers, The Hague.

Mathison, M.J. 1983. Mediterranean and temperate forage legumes. Pages 63-81 *in* The Genetic Resources of Forage Plants (J.G. McIvor and R.A. Bray, eds.). CSIRO, Melbourne, Australia.

Williams, R.J. 1984. Natural distribution of *Stylosanthes*. *In* The Biology and Agronomy of *Stylosanthes* (H.M. Stace and L.A. Edge, eds.). Academic Press, Australia.

Management of Genetic Resources of Annual *Medicago* in the Mediterranean Basin

C.M. Francis
Department of Agriculture, South Perth, WA 6151, Australia

Abstract

In the Mediterranean basin, all but one known species of annual *Medicago* are found, but not all species have agronomic potential. Attention must necessarily focus on agronomically desirable species represented in regional surveys; these key species vary from country to country. They should be selected from well-grazed regions and form the basis of active working collections in different countries. The potential for development of ecotypes of key species should be assessed, primarily in their regions of origin. Long-term base collections should contain reference samples of accessions from all participating countries and include the best potential species and others whose value is less obvious. Long-term storage facilities are required for base collections, which should be duplicated and located with institutions whose longevity is assured. A third type of collection, the ***in situ*** gene bank, is of most immediate use. Collections from areas of dense medic populations, after removal of undesirable types, can be the source for seed increase of regionally adapted genotype mixtures for on-farm use. The ***in situ*** gene banks can be created and managed to provide readily useable genetic resources of *Medicago* species.

Introduction

The Mediterranean basin is the center of origin of *Medicago* species and carries the world's greatest diversity. In all, 27 species are represented (Heyn 1963). In zones of low to medium rainfall (250-400 mm), generally the regions where cropping is common, most soils are alkaline, loamy and very often limestone based. This combination of soil type, pH and farming system make *Medicago*, with its inherent adaptive character, the logical choice as the pasture species most likely to succeed. The high content of hard seeds and adaptation of the species and associated *Rhizobium* to alkaline soils are a feature of *Medicago* species that make them well suited to regions where rotation with cereals is planned.

Recent selection of medic species and rhizobia from Sardinia (Francis and Gillespie 1979; Howieson and Ewing 1986) does provide the opportunity for wider distribution of *Medicago* species, like *Medicago polymorpha* and *Medicago murex*, on to moderately acid soils. In Mediterranean regions, however, acid soils are mainly associated with high-rainfall, often mountainous country unsuited to crop production.

The countries of the Mediterranean have a diverse range of altitude (hence winter cold), rainfall and soil type. Grazing pressure, while high on the average, will also play a major part in the pattern of distribution of the best-adapted species, as measured by those most commonly occurring at moderate to high density in grazed situations. The species will vary from country to country and between regions in individual countries. It is this endemic variation that is, and should be, the source of the ecotypes or mixtures of ecotypes on which to base the development of ley farming systems.

This paper proposes a system for identification of the best species for conservation and further development to serve the needs of the Mediterranean countries.

The fundamental issues are:

1. The survey and collection of the genetic resource.
2. Conservation and utilization of the genetic resource. In this context, three types of gene bank can be identified:

    (a) long-term base collection in a linked international network,
    (b) national, active collection of key species,
    (c) *in situ* gene banks, important sources for initial pasture development in all countries.

In addition to these gene banks, appropriate *Rhizobium* collections may need to be established in parallel.

Survey and Collection of Medics

Most, if not all, countries in the region have undertaken or sponsored collections of medics. Although perhaps not as comprehensive as the IBPGR-sponsored mission in Libya (Gintzburger 1980), most or all countries are in a position to identify species distribution. As a consequence, the species most likely to persist can be identified, because in being commonly endemic they are already adapted to the environment. Also, where a species occurs commonly it can be assumed that there also must be an associated effective population of rhizobia in those soil types.

Population studies can be used to identify the common species and to relate their distribution to major environmental features. Differences between countries in species distribution often are evident. Table 1 shows, for instance, different key species in several countries.

The ubiquitous nature of *M. polymorpha* should be noted. This species is common to all countries and nonspined or short-spined pod types (*brevispina*) should always be selected for further evaluation, if possible.

Table 1. Distribution of *Medicago* species in five Mediterranean regions (occurrences as percentage of collection sites).

Species	Cyprus	Morocco	Libya	Turkey	Sardinia
aculeata		55			
arabica			3	14	
constricta	15			4	
intertexta	15	3		3	
littoralis	52	4	58		5
minima	14	15	19	2	9
murex		7			26
orbicularis	8	12		32	9
polymorpha	71	72	6	39	43
rotata				5	
rigidula				43	9
scutellata	10				
tornata		15	12		3
truncatula	57	47	36		25
turbinata	9			5	1
Sites	71	121	217	90	162

Documentation of rainfall, soil characteristics, grazing pressures and altitude will enable the analysis of species relationships to major climatic regions, geographical features or soil types. Excellent examples of this are provided by the studies of Abdelguerfi *et al.* (1989) in Algeria, Piano *et al.* (1982) in Sardinia and Ehrman and Cocks (1990) in Syria. Figure 1 shows the influence of soil type on *Medicago* distribution in Sardinia. Species like *M. truncatula* and *M. orbicularis* are common on calcareous soils while the neutral or mildly acidic basalt-based soils are dominated by *M. arabica*, *M. polymorpha* and *M. murex*. Other relationships have been derived for Morocco (C.M. Francis and M. Bounejmate, unpublished data). In Morocco the altitude relationship (Table 2) must reflect a degree of cold tolerance. This is expressed in this instance in the more common occurrence of *M. aculeata* at higher altitudes relative to species such as *M. truncatula*, which unlike the 'coastal' species *M. tornata* has apparently evolved toward the selection of at least a few cold-tolerant ecotypes. An analogous situation appears to occur in Algeria (G. Gintzburger, pers. comm.) where a number of ecotypes of *M. truncatula* adapted to the high plateau have been selected.

Plant collection data can thus be used broadly to identify regionally important species. Their density will be the prime measure of their adaptive success. Even so, there are a number of species that should be excluded from the ley farming systems, which will normally entail close grazing by sheep and frequent cropping. Collection experience, research and some assumptions have been used to provide a checklist of species to

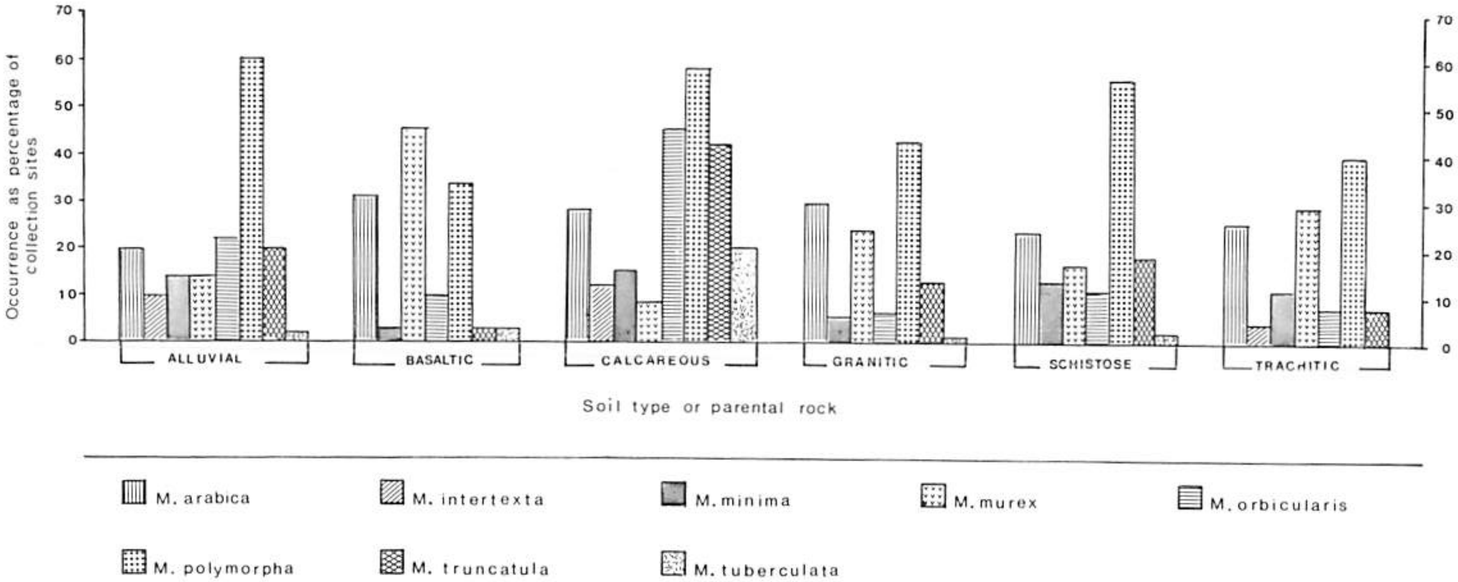


Fig. 1. Distribution of medic species on soils of Sardinia.

Table 2. Distribution of *Medicago* species by altitude (as percentage of collection at that altitude) in Morocco.

Species	< 500	Altitude 500 - 1000 m	> 1000
aculeata	14	27	35
minima	1	6	16
polymorpha	33	30	27
tornata	16	2	-
littoralis	5	-	-
truncatula	23	21	11

include in working collections. Such species should comprise only those endemic to the region and be chosen from groups a, b or c. Species not occurring at all, or only rarely, are unlikely to be well adapted. Their successful introduction into ley farming systems in the region is at best doubtful, particularly as compatible rhizobial populations probably will not be present. Although it might be argued that suitable rhizobial strains can be introduced with the seed, as in Australia where medics were not endemic, a general need for inoculation would nevertheless be a considerable disadvantage, as it adds considerably to the cost and complexity of successful establishment of medic pastures in developing countries.

Other than in base collections there is little point in holding more than token numbers of the pioneer (or rare) species of group d (Table 3), which are often excessively spiny. Species of group c, with typically large pods and seeds, are likely to be of limited value under heavy grazing. On hard-surfaced, heavy soils, however, species like *M. aculeata*, *M. scutellata* and *M. intertexta* may be well adapted and need to be included in an initial species mixture, as large seed size appears to have some selective advantage on clay and poorly structured soils. Working collections should therefore concentrate on evaluation of ecotypes of group a and on those members of groups b and c of likely value in more restricted ecogeographic localities.

Selection for grazing-tolerant ecotypes (prostrate growth habit, small seeds, small pods and high hard seed content) may need to be undertaken in view of the advantages these characteristics are likely to confer in heavily grazed systems (Cocks 1988). Small-seeded species are often adapted to low-rainfall regions (Table 3). In these regions, grazing pressures are often extreme and small seeds should mature rapidly when hard seed content is adequate in small-seeded medics (<1 mm diam).

Table 3. *Medicago* species of the Mediterranean countries: adaptive features.†

Feature/species	Distribution†	Soil texture	pH‡	Min. rainfall	Seed wt. (g/1000)
a. Key species					
polymorpha (*brevispina*)	OM ± cold tolerant	variable	a-b	250	2 - 5
truncatula	OM	loams	b-B	225	3 - 5
rigidula	OM, IT, cold tol.	loam-clay	B-b	250	2.5 - 6.5
littoralis (or hybrids§)	OM	sandy	b-B	175	2.5 - 4
b. Regional potential					
noeana	EM, cold tolerant	loam-clay	b-B	400	ca. 4
murex	OM, acid soils	sand-loam	A-N	400	4.5 - 8
tornata	WM, coastal, rare EM	sandy	N-B	2001.5 - 6	
rugosa	OM, low frost risk	clay-loam	B-b	350	5 - 14
rotata	EM ± cold tolerant	loams	b-N	350	7.5 - 10
solerolii	S France, Algeria, Tunisia	sand-loam	a-b	400	ca. 7
c. Large pods and seeds					
aculeata (mixtures only)	OM + cold tolerant	clay-loam	B-b	350	7 - 15
scutellata	OM (not dense)	clay-loam	B-b	350	15 - 30
intertexta	WM (not dense)	clay	B-b	400	14 - 20
ciliaris	OM, IT (not dense)	clay	B-b	350	12 - 15
blancheana	EM ± cold tolerance	clay-loam	b-N	400	ca. 10

turbinata	NM, EM, IT, Greek Is., ± cold tolerance	clay-loam	b-B	350	8 - 9
orbicularis	OM + cold tolerant	loam-clay	b-B	250	5 - 7
<u>d. Unproductive, rare or spiny</u>					
polymorpha (spiny)	OM	variable	a-B	250	2 - 6
minima	OM, cold tolerant	loam-clay	B-b	225	1 - 1.5
arabica	OM (high rainfall)	sandy loam	A-b	500	2.5 - 4
laciniata	SM, EM, IT (deserts)	variable	b-B	100	1 - 2
radiata	EM, cold tolerant	variable	b-B	150	1.5 - 2.5
tenoreana	NWM	loam-clay	b-B	300	1.5 - 3
praecox	NM, rare EM	sandy loam	a-b	250	2 - 3
disciformis	NM, EM, Greek Is.	loam-clay	N-B	350	3 - 4
coronata	N, EM, IT	loam-clay	b-B	250	ca. 0.7
heyniana	Karpathos	?	?		ca. 5
sauvagei	Morocco	loam-clay	b-B		ca. 5.5
constricta	EM, Greek Islands	variable	N-B	350	5 - 6
muricoleptis	Sicily, Italy	clays	b-B	400	ca. 7.5
granadensis	EM ± cold tolerant	clays	N-B	400	ca. 10

† OM = omni-Mediterranean; EM = east Mediterranean; WM = west Mediterranean; NM = north Mediterranean; SM = south Mediterranean; IT = Irano Turanian.

‡ Soil pH: A = acid, < 6; a = slightly acid, 6-7; N = neutral; b = slightly basic, 7-8; B = basic, > 8.

§ Hybrids (*M. truncatula* and *M. littoralis*).

Conservation of Seed Resource

Base: Long-term Collections

These should be widely representative of the species and varieties of the participating countries and be available to all for research in small quantities on request. Such collections require a long-term storage facility. It is logical to develop only two such collections. South Australia already has the world's largest collection of over 17 000 medic accessions with long-term facilities and would, given some financial support, contribute seed on request.

A duplicate collection is most logically located with institutions such as universities whose long-term future is assured. Bari, where a large collection is already in place, would seem a logical candidate. IBPGR could provide assistance with compilation of country-by-country accession lists and passport data with the cost of growing and providing fresh seed for working collections.

Active: Working Collections

Countries should individually house their own working collection of 'key' species chosen. Long-term storage facilities are not required in this instance. Unscarified medic seed will remain almost fully viable for more than 10 years at 15°C (50% RH) and for at least 20 years if stored as pods in the same conditions.

The emphasis must be on an active collection, constantly in use in the quest for the improved genotypes. Local ecotypes of locations within the country should be held for agronomic assessment. Available plant collection data should of course be used as a guide to species likely to be best adapted to the various test sites, which need careful characterization in terms of soil characteristics, rainfall and winter temperatures. All countries should have such a working collection which need not be unduly extensive. Fresh seed must be produced at intervals to service the research programs, which ought have a 'rolling' number of ecotypes (say 50, including a mixture) grown over several sites and seasons. The first medics tested would logically be those genotypes selected from dense medic areas (i.e., *in situ* gene banks).

In situ Gene Banks

These are localized areas of dense medic populations. Despite the heavy overgrazing occurring in most countries, pockets of high density do exist, most often typified by some degree of grazing control, e.g., recent enclosures on farmer's land. These will logically be representative of the regional diversity and hold the key to rapid introduction of pastures based on the use of locally adapted ecotypes.

In situ gene banks have been used in Syria to select the *M. polymorpha* variety Tah (Cocks *et al.* 1986), in Morocco for *M. truncatula* and *M. aculeata* (M. Bounejmate and P.E. Beale, pers. comm.) and Iran for collections of *M. polymorpha* and *M. rigidula*

(Nazari-Dashlibrown and Francis 1988). The *in situ* gene banks comprise, if not a mixture of species, then at least a range of varietal diversity of a particular species. Simply bulking the populations, perhaps after hand selection of clearly undesirable burr forms, provides a mixture adapted to the region, including the soil microflora; a good start indeed in selection of medics for the ley farming system of a given region.

The *in situ* gene banks can be managed and manipulated. In different regions, small areas (0.5-1.0 ha) of moderate medic density, if fenced and fertilized, can provide an *in situ* gene bank often after only one season.

It is also of interest to theorize over the use of enclosures for sheep camps during the summer. It may be that the sheep will act as 'biological seed collectors', depositing undigested seeds in the camp during their overnight stay. These seeds should be representative of ecotypes able to withstand intensive summer grazing because their seed has the ability to escape digestion by the sheep. Most countries should identify localities of fairly recent enclosure or otherwise create them, because such *in situ* gene banks are likely to be fundamental to development of successful mixtures of medics for ley farming systems, at least in the short term.

Acknowledgements

My thanks to Dr Efisio Piano for permission to reproduce original data and to ICARDA for the opportunity to participate in this workshop.

References

Abdelguerfi, A., J.Y. Chapot and A.P. Conesa. 1989. Contribution à l'étude de la repartition des éspèces spontanées de luzernes annuelles en Algerie, selon certains facteurs du milieu. Fourrages 113:89-106.

Cocks, P.S. 1988. Seed production and seed survival under grazing of annual medics (*Medicago* spp.) in north Syria. Journal of Agricultural Science, Cambridge 110:455-463.

Cocks, P.S, H. Sawmy, Y. Swedan and B. Mawlawi. 1986. Medics on farmer's fields—adaptation of ley farming to northern Syria. Pasture, Forage and Livestock Program Ann. Rep. ICARDA, Aleppo, Syria.

Ehrman, T.A.M. and P.S. Cocks. 1990. Ecogeography of annual legumes in Syria. 1. Distribution Patterns. Journal of Applied Ecology 27:578-591.

Francis, C.M. and D.J. Gillespie. 1979. Ecology and distribution of subterranean clover and *Medicago* species in sardinia. CSIRO Plant Intro. Review 10:1.

Gintzburger, G. 1980. Forage legumes in Libya. IBPGR Plant Genetic Resources Newsletter 43:7.

Heyn, C.C. 1963. The annual species of *Medicago*. Scripta Hierosolymitana. University of Jerusalem Press.

Howieson, J.G. and M.A. Ewing. 1986. Acid tolerance in the *Rhizobium meliloti* - *Medicago* symbiosis. Australian Journal of Agricultural Research 37:55-64.

Nazari-Dashlibrown, P. and C.M. Francis. 1988. Value and potential of medic based ley farming in Iran. Technical Report. Forestry and Range Organization, Shamarin, Iran.

Piano, E., M. Sardara and S. Pusceddu. 1982. Observations on the distribution and ecology of subterranean clover and other annual legumes in Sardinia. Revista di Agronomia 18: 273-283.

Part 4. New Structures for More Efficient Work

A New Approach: Crop Networks

P.M. Perret
International Board for Plant Genetic Resources, 00145 Rome, Italy

Abstract

A brief summary of the development of genetic resources activities during the last 20 years outlines the need for a closer dialogue between curators and users. IBPGR's previous action is mentioned and some discussions follow on its limitations in supporting prebreeding activities. The IBPGR program to stimulate the establishment of eight crop networks is then presented and described, taking as an example the *Beta*, barley and wild *Arachis* networks. The goal of IBPGR in launching this pilot program is summarized.

Genetic Resources: Evolution in the Last 20 Years

Activities for the collection and conservation of crop genetic resources have been undertaken at least since the beginning of this century (by Vilmorin, Vavilov, etc.). Nevertheless, we can note a tremendous explosion since 1969 because of the invasion of southern corn leaf blight in US maize fields. The severe yield loss of corn, due to the predominance of the T cytoplasm susceptible to a new race of *Helminthosporium maydis*, raised awareness of the dangers of genetic uniformity in modern cultivars. In addition the success of the green revolution was accelerating the genetic erosion of landraces and primitive cultivars.

Numerous institutions were created with the primary purpose of conserving germplasm for the future and also to make it immediately available to users. We can give as an example numerous genebanks at a national level (USA, Australia, USSR); regional level (CATIE, Costa Rica; Nordic Gene Bank, Sweden) and finally, at an international level, the genetic resources units of the CGIAR centers. IBPGR, created in 1974 for stimulating and coordinating genetic resource work, often has been instrumental in the establishment of these genebanks.

Many collecting missions, essentially for landraces and primitive cultivars, were undertaken during the last 20 years, so that there are now around 2.5 million samples kept in more than 600 collections/institutions across 109 countries. Unfortunately, the knowledge necessary for the proper management of genebanks has not been progressing at the same rate as the accumulation of material in collections. For example, the knowledge of DNA damage during storage or of germination and dormancy mechanisms is not sufficiently advanced to allow adoption of the best conservation and monitoring techniques in genebanks. The main challenges that lie ahead, however, consist of a more comprehensive understanding of genetic diversity, especially at the crop level, which will allow *inter alia* a proper identification of samples, meaningful collecting of the remaining material before its disappearance, the application of adequate regeneration methods and, above all, making collected material available to users.

The Gap between Users and Curators

There was a general belief in the 1970s that a more intense use of genetic resources in research and especially in breeding programs would be a natural consequence of its availability in collections/genebanks. Without denying a marked increase in genetic resources use in the last 20 years, facts show that too much of the accumulated material has not yet been studied and/or utilized. This may result in policy maker and public disinterest with a subsequent reduction of funds for genebanks, just at a time when a significant increase of funding will be needed for the better maintenance and enhancement of genetic resources.

A significant paper published by Duvick (1984) placed the problem of use of genetic resources in its correct context by pointing out that the narrowing of the genetic base of our modern farm crops is sometimes overrated because the genetic diversity in time (the continuous replacement of cultivars by new ones) is not taken into account and the genetic reserves in the hands of breeders (advanced cultivars in trials, breeding lines as well as breeding pools) are totally underestimated. His survey of five crops showed that hidden genetic diversity in this breeding material was such that most breeders could find the desired sources of resistance to diseases, pests or adaption to stresses. Being aware, nevertheless, of the absolute necessity to enlarge the genetic diversity of our crops for the continued success of modern plant breeding, he criticized the insufficient description of genetic resources collections and advocated the development of prebreeding activities.

Numerous papers (Frankel and Soule 1981; Brown 1983; Frankel and Brown 1984; Holden 1984) examined the insufficiencies and constraints of genetic resources collections in responding to the expectations of users and called for the establishment of narrow links between curators and users, although few of them proposed concrete action. Frankel, with the new concept of core collections, and Holden, proposing some guidelines on the basis of the ECP/GR experience (ECP/GR, see below), are notable exceptions. Peeters and Williams (1984), focusing on documentation of genebanks and basing their review on literature as well as on a survey of opinions of diverse experts, stated that "the information which is currently provided (by genebanks) is generally not the information which is required" and that "the data are often too incomplete to be of any significance to the breeder." They concluded that a new approach to information capture in genebanks is required but did not propose significant and concrete lines of action except the establishment of core collections.

In summary, all these papers were pleading implicitly or explicitly for closer contact and interaction between curators and users, and also among curators to rationalize the management of their collections.

IBPGR's Early Action

Details of IBPGR activities in furthering the study, collection, preservation and documentation of the genetic diversity would be too lengthy and without purpose in an introduction to crop networks. Of direct concern to this paper is the last part of our mandate[3] calling for a catalytic role in what is defined as "a viable network of institutions for the conservation of genetic resources."

IBPGR, since its creation, has always benefitted from the expertise, advice and contributions from hundreds of scientists around the world and it is this informal network of specialists which has allowed IBPGR, at least during the first decade, to play its coordinating role quite successfully. Five crop advisory committees were established for wheat, rice, maize, sorghum and millet, and the genus *Phaseolus* in close collaboration with the CGIAR centers responsible for these crops; namely CIMMYT, ICARDA, IRRI, CIMMYT, ICRISAT and CIAT. Numerous working groups were set up (e.g., for *Hevea*, cotton, cacao, *Vitis*, tropical and subtropical forages, forages for the Mediterranean and adjacent semiarid areas).

It was also under the advice of these crop advisory committees and working groups that collecting priorities and base collections were established. The greatest attention in the 1970s was given to the long-term conservation of germplasm. Base collections are founded as a means of ensuring long-term storage. Seeds are stored in below-freezing temperatures at 4-7% moisture in air-tight packages and monitored for viability so that regeneration can be undertaken if seed germination falls below a defined threshold (generally 86%). The base collections are not used for general distribution; that is, the purpose of active collections. At this time, there are 39 base collections representing all major and some minor crops. This is sometimes known as the IBPGR network of base collections. This description is somewhat misleading since the institutes holding base collections have only committed through a letter of agreement with IBPGR to conserve germplasm of specific crops in long-term storage. Their responsibilities are confined, at least until now, to conservation *per se* and not to documentation, characterization, maintenance and distribution of the accessions. Their roles are basically static and do not imply a responsibility for active and clear linkage with active collections (except of course when the active collection is located in the same institute). What confirms this analysis is that in actuality few active collections have duplicated their material in the base collection designated by IBPGR. There are, of course, a few notable exceptions, including the genetic resources units of the CGIAR centers which act as base collections.

---

[3] The mandate of IBPGR is to further the study, collection, preservation, documentation, and utilization of the genetic diversity of useful plants for the benefit of people throughout the world. IBPGR shall act as a catalyst both within and outside the CGIAR system in stimulating the action needed to sustain a viable network of institutions for the conservation of genetic resources of these plants.

In 1983 the Board, aware of the inherent limitations of this structure, decided to launch a study to prepare outlines of a new network of active collections. This policy decision materialized in 1988 as a pilot program to stimulate the implementation of crop networks.

IBPGR Dilemma: to Stimulate Evaluations or Not

Since its creation, the Board considered that evaluation and enhancement of plant material were clearly outside its mandate; therefore, it committed very little funding to this activity. Such a policy may appear rational and fully justified, considering that CGIAR centers have a mandate for major crops of the world, and that IBPGR action in prebreeding/evaluation could be limited at the best in view of its restricted budget and staff. There was a concern that IBPGR not duplicate efforts of international or national programs.

Nevertheless, the second external review of the IBPGR in 1985, assessing the need for characterization, evaluation and documentation of the germplasm, noted that it was imperative to find ways to link genebanks to national breeding programs and that to do this effectively would require that IBPGR explore its role in germplasm evaluation and in prebreeding. The examination of these matters culminated in the organization of a workshop on the use of plant genetic resources in Montpellier in September 1986 in which these issues remained unsolved although some recommendations, for instance those related to the core collection concept, were adopted (Brown 1988).

A New Approach

The continual increase of genetic resources activities around the world has gradually shifted the role of the IBPGR Field Program from a leading role in collection, documentation and characterization to coordination of a complete array of genetic resources activities. To be effective, this coordination requires active participation of all concerned parties, good information services, consultation and dialogue. The continuous strengthening of IBPGR scientific expertise allows IBPGR to confine itself more to an advisory role.

The crop, or more precisely the crop gene pool, is the common denominator in a dialogue between curators and users. A pilot program of self-sustaining crop networks was approved by the IBPGR Board in 1988. Considering the limitations of IBPGR to directly support enhancement of genetic resources, either through funds from its core budget or through its staff time, it was agreed that such activities would be best handled by curators and users. In accordance with this new approach, crop networks must be self-sustaining.

Practically speaking, IBPGR cannot support all targets agreed upon by networks. This means that each network should define the specific situation of the crop (extent of collections, breeding achievements, knowledge of evolution of the crop) to guide its work. IBPGR will play an active role in all aspects linked to conservation and genebank management. IBPGR attempts to assist the crop networks in following the process from conservation to use of germplasm by acting as an intermediary between the international community, which may provide necessary additional funds, and the community of curators and users. In addition, any technical constraints faced by the crop networks or requests for research whose results may be applied to other crops will be actively tackled by IBPGR.

In the selection of crops for which networks could be developed, consideration has been given to a reasonable spread between the following:

- Different crop groups (cereals, legumes, roots and tubers, fruits, vegetables, forages, industrial crops)
- Tropical and temperate crops
- Seed and vegetatively propagated crops
- Crops within and outside the mandate of other centers in the CGIAR system.

Sixteen crops were short-listed. Finally, eight crops (barley, maize, groundnut, sweet potato, banana, okra, medic and beet) were selected in consideration of the criteria mentioned above and also with the belief or the hope that networks for each of these crops could be established in a relatively short period of time. There would be no point in testing out the concepts on a pilot scale if no response could be measured in a relatively short time span.

The ECP/GR

The operations of the European Cooperative Program for the Conservation and Exchange of Crop Genetic Resources (ECP/GR), put under the aegis of IBPGR in 1983, did contribute to the elaboration of the crop networks concept. This program focuses on six crop groups, each with a defined plan of action which is executed through goodwill and contributions-in-kind from participating institutes.

The activities of the Forages Working Group will be briefly mentioned because of direct relevance to the pasture and forage legume network. The Forages Working Group, which met for the first time in February 1984, recognized that the prerequisite to further collaborative action was the inventory of accessions existing in European collections. Consequently, 11 European institutes accepted responsibility to collate existing passport data, each for a specific crop or group of crops. INIA, Badajoz, the European database for annual medics (as well as for *Trifolium subterranean*), published the last version of their catalogue in February 1989. All data from European databases are available to any *bona fide* user on request.

Parallel to the establishment of the databases, many collecting missions considered as urgent were undertaken, some with IBPGR support, others as a contribution-in-kind from other countries. Two lists of reference varieties, one for northern and middle European forages and one for Mediterranean forage legumes, were implemented. These reference varieties are used more frequently in the process of evaluation to allow better comparison of data.

In its last meeting (Montpellier, January 1989), the group opened new areas of collaboration, one of them being the establishment of core collections for forage crops across European institutes. One of the purposes of these core collections is to concentrate on regeneration of the most meaningful accessions. A small committee has been established to outline this project at the Welsh Plant Breeding Station, Aberystwyth, UK in July 1989.

Crop Networks

Beta

Thirty-one participants from 19 countries attended the International *Beta* Genetic Resources Workshop, which was held at the Center for Genetic Resources in the Netherlands. All curators of major *Beta* collections were present as well as breeders and researchers from the private or public sector. The collaborative activities that were agreed upon at this first meeting are quite comprehensive. Many operations are already underway because the network benefitted from the previous work of the ECP/GR; notably the existence of the International *Beta* Database, which had already registered and sorted out passport data of nearly all *Beta* collections.

To ensure the follow-up of their recommendations, the Workshop elected a *Beta* coordinating committee (BCC) of three scientists having responsibility for the IDBB. Members agreed that the network should maximize return of resources that are already committed. They recognized, however, that resources greater than those presently available would become necessary with the development of the network program. They recommended that these resources should be sought first by the BCC from national funding bodies and, if necessary, from industry or regional/international organizations.

The BCC met early in June 1989 to focus on the need to enlarge genetic diversity used in sugar beet breeding programs. This enlargement depended on the availability of sugar beet populations in which genes of numerous wild/landrace accessions had been introgressed (prebred). The BCC agreed that around half a dozen populations, each with different characters, should be prepared. At least one or two of these prebred populations should be specifically constituted for breeding characters of importance to developing countries.

The constitution of these populations needed the International *Beta* Database, the full collaboration of all *Beta* curators and better coordination of ongoing research on *Beta*.

It is hoped that the *Beta* network will become totally self-sustainable. IBPGR funding was used for the organization of the first workshop meeting and the first meeting of the *Beta* coordinating committee; however, future IBPGR support will be limited to priority collecting missions that cannot be undertaken by national institutions and to the facilitation of contacts when required by the BCC.

Groundnut

A workshop of 11 scientists and curators was convened at CIAT, Colombia, 28 February to 2 March 1989 to develop a collaborative program on wild *Arachis* genetic resources. Immediate action resulting from this meeting is the inventory of all wild *Arachis* accessions held by North Carolina State University, continued support of priority collecting missions by IBPGR, and the finalization of a descriptor list complete to the level of species. This will be a valuable help to curators, who have many undescribed accessions in their collections.

The groundnut subnetwork for wild species reflects the case of a crop that is under the mandate of a CGIAR Institute, but for which IBPGR, at the request of ICRISAT and other members of the meeting, will take coordinating responsibility at least for the early stages of the subnetworks development, whereas in the case of the maize network, for which activities will not be developed in this paper, CIMMYT has assumed from the beginning a leading coordinating role.

Barley

As it is impossible to invite all barley curators and users at once, representatives of major barley collections were invited to strengthen the collaboration between themselves and to explore strategies for the building up of an international barley network with full participation of all concerned specialists. The meeting called for the organization of regional meetings: South America, South Asia and Southwest Asia, North Africa and Near East—and continuation of the activities of the European Barley Working Group —to discuss further the objectives of the international barley crop genetic resources network. The International Barley Symposium to be held in Sweden, in July 1991 will represent a milestone in the implementation of the international network.

Conclusions

The primary objective of a crop network is to create a dialogue between all concerned parties on the genetic resources of a specific crop. Through stimulating the development of such networks, IBPGR is aiming at:

1. Ready provision of information on the crop gene pool through global and/or regional databases.
2. Security of germplasm samples for long periods in the base collections.
3. Availability of samples for evaluation and use to all *bona fide* users from the active collections and more interaction between curators and users.

References

Brown, A.H.D. 1988. The case for core collections. Pages 136-156 *in* The Use of Plant Genetic Resources (A.H.D. Brown, O.H. Frankel, D.R. Marshall and J.T. Williams, eds.). Cambridge University Press, UK.

Brown, W.L. 1983. Genetic diversity and genetic vulnerability. An appraisal. Economic Botany 37:4-12.

Duvick, D.N. 1984. Genetic diversity in major farm crops on the farm and in reserve. Economic Botany 38:161-178.

Frankel, O.H. and A.H.D. Brown. 1984. Plant genetic resources today: a critical appraisal. Pages 249-256 *in* Crop Genetic Resources: Conservation and Evaluation (J.H.W. Holden and J.T. Williams, eds.). George Allen and Unwin, Winchester, MA, USA.

Frankel, O.H. and E.M. Soule. 1981. Conservation and Evolution. Cambridge University Press, UK.

Holden, J.H.W. 1984. The second ten years. *In* Crop Genetic Resources: Conservation and Evaluation (J.H.W. Holden and J.T. Williams, eds.). George Allen and Unwin, Winchester, MA, USA.

Peeters, J.P. and J.T. Williams. 1984. Towards better use of genebanks with special reference to information. FAO/IBPGR Plant Genetic Resources Newsletter 60:22-31.

Part 5. Poster Presentation

Preliminary Observations on Seed Coat and Hardseededness in Six Pasture Legumes

L. Russi
ICARDA, Aleppo, Syria

Introduction

Ley farming is the rotation of self-regenerating annual species of *Trifolium* and *Medicago* with cereals. Central to ley farming is the presence of a persistent soil seed bank of legume seeds which allows a pasture regeneration after the preceding cereal crops. Although embryo dormancy has been observed in the Mediterranean climate of Western Australia (Quinlivan 1971), the dormancy mechanism by which legumes survive in the soils in northwest Syria, for example, is entirely due to the hard seed coat (Russi 1989).

Hard seeds develop during the process of ripening, when the seeds lose moisture (Hyde 1954), and are broken after they experience a long period of high and fluctuating temperatures (Quinlivan 1971). The continuing expansions and contractions rupture the coat, and the lens is believed to be the weakest point (Hagon 1971).

Objectives

The objectives of the study were to observe:

1. the hardseededness breakdown in some *Trifolium* and *Medicago* during summer and early autumn;
2. the morphological changes of the seed coat during summer, and
3. the relationship between seed coat structure and hard seed breakdown.

Materials and Methods

Field trials were conducted at Tel Hadya, northern Syria. Observations were taken on seeds from pure stands of three clovers (*Trifolium stellatum* L., *T. campestre* Schreb., *T. tomentosum* L.) and three medics (*Medicago orbicularis* Bart., *M. rigidula* (L.) All., *M. rotata* Boiss.) grown in 1988. Together with hard seed breakdown, assessed by germination tests at 20°C, the structure and morphology of the testa were observed by scanning electron microscopy soon after seeds were set (June) and at the end of summer (October).

Results and Discussion

In June, all species were close to 100% hard seed content (Fig. 1). No major changes were observed until the end of August, the species ranging between 97 and 99% hard seeds. Softening in *T. stellatum*, *M. rigidula* and *T. tomentosum* started at the beginning of September when the proportion of hard seeds was found to be 86, 93 and 94%, respectively. By October 16, *M. orbicularis* and *M. rotata* were the hardest (99 and 97%, respectively), significantly higher than *T. campestre* and *M. rigidula* (both at 80%), which in turn were higher than *T. tomentosum* (60%); *T. stellatum* (27%) was the softest ($P<0.05$).

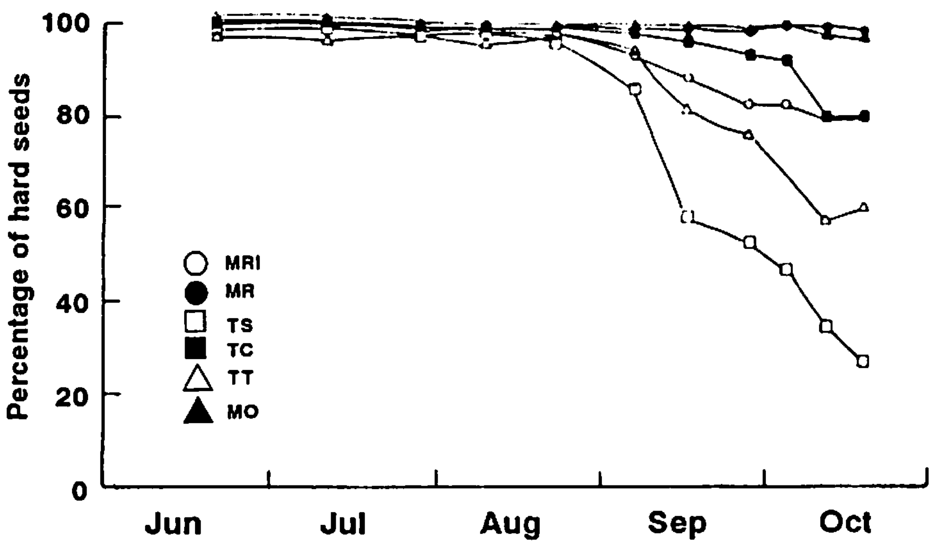


Fig. 1. Breakdown of hardseededness under field conditions during the summer of 1988 in six pasture legumes: *M. orbicularis* (MO), *M. rotata* (MR), *T. campestre* (TC), *M. rigidula* (MRI), *T. tomentosum* (TT) and *T. stellatum* (TS).

In June 1988, tiny cracks were observed over the whole seed coat in seeds of *T. stellatum*, while complete seed coats were shown by the other species.

In October 1988, the cracks shown by *T. stellatum* became deeper and larger at the lens; similar observations were detected at the lens of seeds of *M. orbicularis*, *M. rigidula* and *M. rotata* (Fig. 2a). Complete seed coats were observed in *T. campestre* and *T. tomentosum* (Fig. 2b). In these clovers it is possible that water could be taken up through the natural openings of the seed coat (micropyle and hilar fissure).

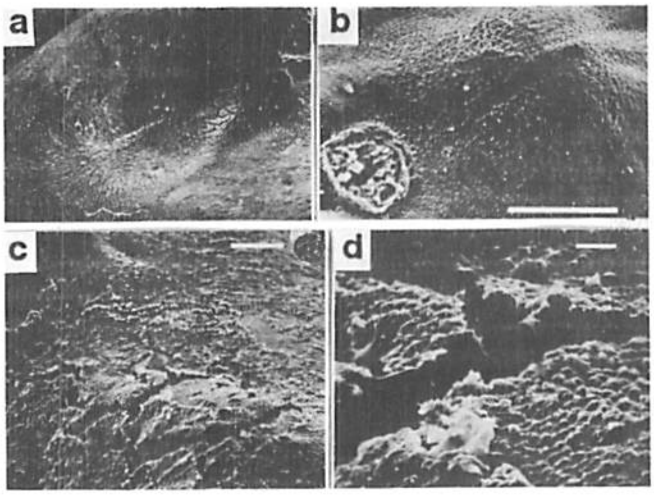


Fig. 2. Hilum and lens of seeds exposed to summer fluctuating temperatures in (a) *M. rotata* (bar=100 μm) and (b) *T. tomentosum* (bar=100 μm); (c) hard seed of *M. rotata* showing large areas of the palisade layer removed (bar=100 μm) and (d) particular of the previous seed.

In *M. rotata* the seed remains hard unless the osteosclereid layer is broken (Fig. 2c, d), according with findings detected in other species (Baciu-Miclaus 1970; Ballard 1973; McKee *et al.* 1977; Tran and Cavanagh 1980; Werker *et al.* 1973).

There is a positive relationship between the percentage of hard seeds in October and the cuticle thickness (Fig. 3). Although the cuticle alone cannot explain the different degree of impermeability found in several species, if well developed and thickened it certainly could contribute to a better protection of the layers below and could delay imbibition if cracks are thin and short.

A positive relationship also was found between the percentage of hard seeds in October and the thickness of the testa relative to seed size (Fig. 4). If cuticle thickness and testa thickness are found to play a role in hard seed breakdown of pasture legumes, the understanding of their survival strategies and population dynamics will further progress. In addition, large legume collections could be screened for hardseededness by simple measurements and such information could be used in breeding and selection programs where improved hard seed characteristics could ensure persistence of seeds in the seed bank. In some cases, it may be necessary to breed for less hardseededness, in others for more, but in both cases such a screening method is essential if rapid progress is to be made.

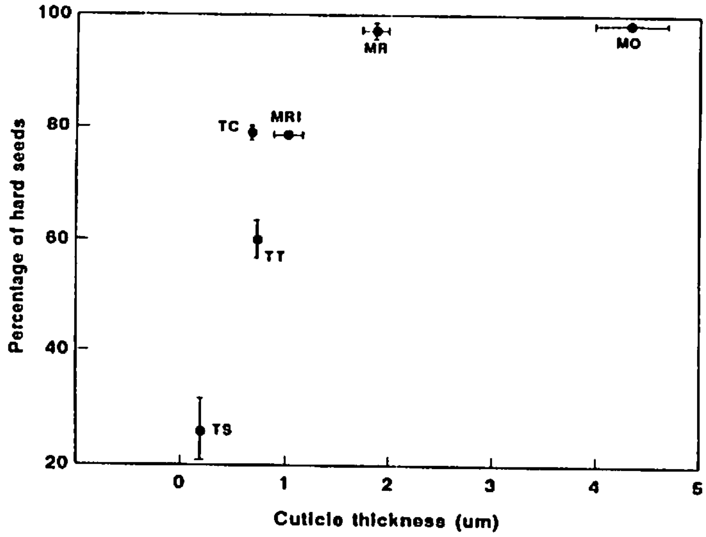


Fig. 3. The relationship between percentage of hard seeds at the end of summer and cuticle thickness in six pasture legumes. Vertical and horizontal bars represent the standard error of the mean for hard seed and cuticle thickness, respectively. *M. orbicularis* (MO), *M. rotata* (MR), *T. campestre* (TC), *M. rigidula* (MRI), *T. tomentosum* (TT) and *T. stellatum* (TS).

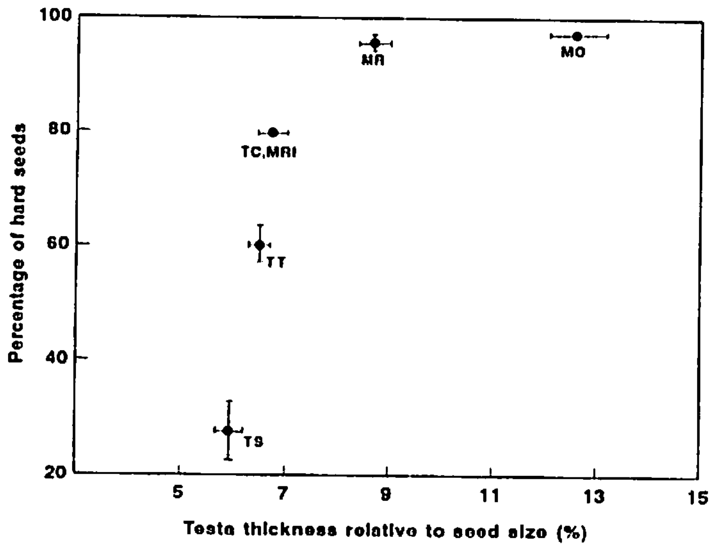


Fig. 4. The relationship between percentage of hard seed at the end of summer and testa thickness relative to seed size in six pasture legumes. Vertical and horizontal bars represent the standard error of the mean for hard seed and testa thickness, respectively. *M. orbicularis* (MO), *M. rotata* (MR), *T. campestre* (TC), *M. rigidula* (MRI), *T. tomentosum* (TT) and *T. stellatum* (TS).

References

Baciu-Miclaus, D. 1970. Contribution to the study of hard seed and coat structure properties in soybean. Proceedings of the International Seed Testing Association 35:599-617.

Ballard, L.A.T. 1973. Physical barrier to germination. Seed Science and Technology 1:285-303.

Hagon, M.W. 1971. The action of temperature fluctuations on hard seeds of subterranean clover. Australian Journal of Experimental Agriculture and Animal Husbandry 11:440-443.

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 18:241-256.

McKee, G.W., R.A. Pfeiffer and N.N. Mohsenin. 1977. Seedcoat structure in *Coronilla vaira* L. and its relation to hard seed. Agronomy Journal 69:53-58.

Quinlivan, B.J. 1971. Seed coat impermeability in legumes. Journal of the Australian Institute of Agricultural Science 37:283-295.

Russi, L. 1989. Ecological and physiological aspects of seeds of annual grasslands in a Mediterranean environment. Ph.D. Thesis, University of Reading, UK.

Tran, V.N. and A.K. Cavanagh. 1980. Taxonomic implications of fracture load and deformation histograms and the effect of treatments on the impermeable seed coat of *Acacia* species. Australian Journal of Botany 28:39-51.

Werker, E., A. Dafni and M. Negbi. 1973. Variability in *Prosopis falcata* in Israel: anatomical features of the seed. Botanical Journal of the Linnean Society 66:223-232.

Discussions and Recommendations

The workshop was generously supported by the Italian Government and IPGRI (renamed IBPGR) and attended by participants from nine WANA countries, five advanced research institutes and several international institutions (FAO, IPGRI, MIAC, SAGRIC, CIAT).

The objectives of the workshop were to:

1. Discuss research and progress of the ley farming system in the WANA region and elsewhere.
2. Formulate a strategy to implement and develop annual medic/cereal rotation systems in the Mediterranean region.
3. Define guidelines for the establishment of a network to collect and conserve genetic resources of annual *Medicago*.

The following recommendations were formulated at the conclusion of the workshop.

1. Specific target areas for ley farming should be developed. In doing so, account should be taken of climate and soil, farm size and existing farming systems. While further research is needed, the workshop considered that ley farming is likely to be most useful where farmers own livestock, use weedy fallows and cultivate shallow (less than 1 m deep) soils in low-rainfall (250-350 mm) areas.

2. The workshop highlighted the fact that good management is the key to introducing ley farming and that management systems based on Australian experience are unlikely to succeed. It recommended that appropriate management be developed in close consultation with farmers and that the concepts of farming systems research and farmer participatory research be used to the fullest extent possible.

3. The rate of population increase in WANA and its effect on traditional land use should be considered in all policy, research and extension issues. The workshop recognized that the population will more than treble by the year 2030 (when it should plateau at 1.5 billion) and this will have an enormous impact on land use. It recommended that governments influence these changes by considering land tenure, grazing rights and pricing policies.

4. It is helpful to consider ley farming as an improved weedy fallow system. Emphasis on improving existing weedy fallows should include use of fertilizer and improved grazing management.

5. The workshop participants expressed concern about the effect of imminent changes in climate and recommended that future research on the sustainability of ley farming take this factor into account.

6. The workshop recommended that training be strengthened in six areas:

   - Networks should be established on a regional (WANA) and subregional (e.g., North Africa) basis, where scientists can share experiences and coordinate their research
   - ICARDA should widen its existing training to include the training of extension agents in extension methodology and ley farming practices
   - ICARDA and FAO should continue and strengthen training in seed production
   - Specialists in ley farming should be trained to provide back-up for extension agents
   - Future research training should focus on higher level training, possibly leading to higher degrees; a training manual should be developed.

7. Extension: the workshop supported the concept that extension should be closely linked with research and that both should involve farmers. It strongly recommended that extension agents receive more field support and drew attention to the training and visiting methodology of the World Bank.

8. In developing ley farming, scientists should look beyond annual medics and subterranean clover, although it is recognized that, in the short term at least, these species are likely to be the most useful. Greater grazing tolerance in pasture legumes is needed.

9. Local ecotypes of pasture legumes should be multiplied. The workshop considered that the maintenance of seed purity is not a high priority and recommended that mixtures of several species should be used in commercial sowings.

10. The workshop recognized that availability of seeds is a major constraint. However, it recommended that more appropriate seed-harvesting technologies be developed to replace the existing, expensive suction machine.

11. Economic evaluation of ley farming is badly needed and the workshop recommended that this should be a high priority for research.

12. The workshop considered that, despite some of the outstanding problems, work on ley farming should proceed to an extension phase. It recommended that a high priority task of the networks should be to seed funding for a coordinated training and extension project to take ley farming to farmers. In doing so, full account should be taken of experience gained in the earlier work.

Participants

ALGERIA
M. Abdelguerfi*
Departement de Phytotechnie
Institut National Agronomique
El-Harrach 16200

M. Maatougui*
Station Experimentale de l'ITGC
Route de Tlemcen
BP 59
Sidi Bel Abbes 22000

AUSTRALIA
P. Beale*
7 Hemaford Grove
Gawler East, SA 5118

P.S. Cocks*
Crop and Pasture Science Dept.
School of Agriculture
University of Western Australia
Nedlands, WA 6009

E.J. Crawford*
14 Moriane Avenue
Panorama, SA 5041

C.M. Francis*
Department of Agriculture
South Perth, WA 6151

N. Halse*
156 Lockhart Street
Como, WA 6152

C. Heysen
SAGRIC International
70 Hindmarsh Square
Adelaide, SA 5000

R. Reeve*
SAGRIC International
70 Hindmarsh Square
Adelaide, SA 5000

G.D. Webber*
South Australian Department
of Agriculture
GOP Box 1671
Adelaide, SA 5001

COLOMBIA
J. Spain
Centro Internacional de Agricultura
Tropical (CIAT)
Apartado Aereo 6713
Cali

CYPRESS
I. Papastylianou*
Agricultural Research Institute
Nicosia

FRANCE
A. Conesa
Institut National de la Recherche
Agronomique (INRA)
9, Place Viala
34060 Montpellier Cedex

J.M. Prosperi*
Institut National de la Recherche
Agronomique (INRA)
9, Place Viala
34060 Montpellier Cedex

IRAN
P. Nazari-Dashlibrown
Department of Range
Forest and Range Organization
P.O. Box 19575/567
Tehran 19564

* Indicates senior author

H.S. Tabari
Ecology Garden
Nowshahr
Mazandaran

ITALY

Y.J. Adham
International Board for Plant Genetic Resources (IBPGR)
via delle Sette Chiese, 142
00145 Rome

M.N. Ben-Ali
FAO, DDC, Room D-609
via delle Terme di Caracalla
00100 Rome

S. Bullitta
Centro Pascoli-CNR
Via E. de Nicola
07100 Sassari

D. Crespo
FAO
via delle Terme di Caracalla
00100 Rome

M. Falcinelli
University of Perugia
Faculty of Agriculture
Via Borgo XX Giugno
06100 Perugia

F. Lorenzetti
University of Perugia
Faculty of Agriculture
Via Borgo XX Giugno
06100 Perugia

P.M. Perret*
International Board for Plant Genetic Resources (IBPGR)
via delle Sette Chiese, 142
00145 Rome

E. Piano*
Istituto Sperimentale per le Colture Foraggere
Lodi Sezione Operative Perferica di Cagliari
via Mameli, 118
09124 Cagliari

F. Riveros*
FAO
via delle Terme di Caracalla
00100 Rome

L. Russi
University of Perugia
Faculty of Agriculture
Via Borgo XX Giugno
06100 Perugia

D. Van Sloten
International Board for Plant Genetic Resources (IBPGR)
via delle Sette Chiese, 142
00145 Rome

LIBYA

B. El-Ouachi*
Agricultural Research Center
P.O. Box 2480
Tripoli

A. Sbeta
Agricultural Research Center
P.O. Box 2480
Tripoli

MOROCCO

C. Al-Faiz
Institut National de la Recherche Agronomique (INRA)
BP 415
Rabat

Maria Amine
Ministere de l'Agriculture et de la Reforme Agraire
Direction de la Production Végétale
Rabat

B. Boulanouar
INRA/Mid-America International Agricultural Consortium (MIAC)
Centre d'Aridoculture
BP 290
Settat

G. Jaritz*
Institut National de la Recherche Agronomique (INRA)
BP 415
Rabat

SAUDI ARABIA

A. El-Turk*
JADCO
SKAKA-JOF
P.O. Box 321

SPAIN

M. Granda*
Servicio de Investigacion Agraria
Apartado 22
06080 Badajoz

V. Moreno
Servicio de Investigacion Agraria
Apartado 22
06080 Badajoz

SYRIA

S. Christiansen*
ICARDA
P.O. Box 5466
Aleppo

J. Konopka
ICARDA
P.O. Box 5466
Aleppo

L.A. Materon*
ICARDA
P.O. Box 5466
Aleppo

B. Mawlawi
Directorate of Agricultural and Scientific Research
P.O. Box 113
Douma, Damascus

T.L. Nordblom*
ICARDA
P.O. Box 5466
Aleppo

H. Sawmy-Edo
ICARDA
P.O. Box 5466
Aleppo

Y. Swaidan
Directorate of Agricultural and Scientific Research
Forage and Pasture Department
P.O. Box 113
Douma, Damascus

W. Tawil
Directorate of Agricultural and Scientific Research
Field Crops Division
P.O. Box 113
Douma, Damascus

TASMANIA

R. Reid*
Pastures and Field Crops
Department of Primary Industry
P.O. Box 46
Kingsmeadows, Tasmania 7249

TUNISIA

A. Mersni
Agence Regionale de l'OEP
Dehmani 7170
Gouvernat de Kef

TURKEY
O. Erkan*
Department of Agricultural Economics
Faculty of Agriculture
Cukurova University
Adana

M. Savas
East Anatolia Agricultural Research Institute
P.O. Box 257
Erzurum

L. Tahtacioglu
East Anatolia Agricultural Research Institute
P.O. Box 257
Erzurum

USA
B. Eardly*
Department of Biology
Pennsylvania State University
208 Erwin W. Mueller Laboratory
University Park
Pennsylvania 16802

المركز الدولي للبحوث الزراعية في المناطق الجافة
ايكاردا
ص. ب. 5466 ، حلب، سورية

INTERNATIONAL CENTER FOR AGRICULTURAL
RESEARCH IN THE DRY AREAS
ICARDA, P.O. Box 5466, Aleppo, Syria

ICARDA-043/500/May 1993