1996/7

PASTURE, FORAGE AND LIVESTOCK PROGRAM

Annual Report for 1994

ICARDA

About ICARDA

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 16 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's mission is to meet the challenge posed by a harsh, stressful, and variable environment in which the productivity of winter rainfed agricultural systems must be increased to higher sustainable levels; in which soil degradation must be arrested and possibly reversed, and in which the quality of the environment needs to be assured. ICARDA meets this challenge through research, training, and dissemination of information in a mature partnership with the national agricultural research and development systems.

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, forage and pasture—with emphasis on rangeland improvement and small ruminant management and nutrition—and of the farming systems associated with these crops.

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 is offered extending from residential courses for groups to advanced research opportunities for individuals. These efforts are supported by seminars, publications, and specialized information services.

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Annual Report for 1994

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

This report was written and compiled by program scientists and represents a working document of ICARDA. Its primary objective is to communicate the season's research results quickly to fellow scientists, particularly those within West Asia and North Africa, with whom ICARDA has close collaboration. Owing to the tight production deadlines, editing of the report was kept to a minimum.

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PFLP 1994 Highlights

PFLP Research and Activities: Ongoing Projects and New Directions

Small ruminant nutrition and production (MTP 94–98, Project 15)

The work on cereal and legume crop residue intake and quality is proceeding well. Methods for predicting barley straw quality using NIRS are being calibrated. Preliminary work has been completed on milk production in underfed Awassi ewes. Sheep milk production is monitored on *Chenopodiaceae* fodder shrub plantations on arid rangeland. PFLP may expand its work in the region on milk. Surveys of small ruminant flocks in Turkey, Syria and Jordan have identified clear problems of micronutrient deficiency in the Mashreq region.

Sown pasture and forage (MTP 94–98, Project 16)

Seeding medic pod with barley is an attractive option for medic pasture establishment and high crop residue value, especially if the farmers produce their own pods. This is a major aspect of the participatory approach with farmers in Syria and Morocco. Medic pods are also used for marginal land rehabilitation in the El Bab district in northern Syria.

In Algeria, comparisons between pasture legume/cereal rotation and highly valued weedy fallow/cereal rotation continue to produce useful information on seed bank build-up, as well as composition of pasture species in the pasture and fallow phase.

An overview is presented on pasture and grain legume biodiversity in the highlands of west Asia. Also included is earlier work on maximizing the growth and nitrogen of rhizobium under cold conditions when water is not the limiting factor. Finally, data on legume micronutrient nutrition—such as zinc and its interaction with nitrogen and phosphorus—are reported. This relates to similar micronutrient deficiencies observed in small ruminants fed on pasture legumes and crop residues in the WANA region.

Marginal land and rangeland (MTP 94–98, Project 17)

PFLP has focused its marginal land activities on farmers who have volunteered for a rehabilitation exercise on highly degraded hills in northern Syria. With farmer collaboration, we have initiated ICARDA marginal land regeneration procedures involving a small amount of phosphate and reseeding with local species. We intend to use small ruminants to reseed pastures with seeds ingested on better pastures, an interesting low cost/low input concept very attractive to the farmers who are able to control the grazing of their marginal village land.

For the degraded arid rangeland and steppe country of WANA, PFLP has reintroduced the pitter-seeder concept, where we seed directly into a micro-water catchment to facilitate plant establishment and survival. We have built a prototype pitter-seeder using local agricultural machinery parts at the Maragha Steppe Directorate Station, and are initiating direct rangeland seeding with fodder shrubs such as *Atriplex* and *Salsola* spp.

Socioeconomics (MTP 94–98, Project 21)

Our participatory approach and on-farm work can only be carried out with a thorough understanding of the human environment. This work, conducted in Bedouin and settled farmer communities, aims at improving our approach to local community motivation and socioeconomics. The role of Bedouin women in labor and decision making processes is defined. The dynamics of an agro-pastoral population and its impact on the extension of barley cultivation in the steppe are reviewed.

Finally, we clarify how public policy and land tenure systems in the steppe affect the future of rangeland natural resources.

Outreach

PFLP strengthens its outreach with the support of ICARDA regional coordinators in:

- Algeria: continuing small ruminant integration in the cereal/legume rotation at El Khroub (Constantine).
- Morocco: developing informal pasture seed production with farmers.
- Lebanon: establishing small ruminant integration in the cereal/legume rotation at the AUB Farm, and supporting the UN Integrated Rural Development Program in the Bekaa Valley.
- Jordan: initiating marginal land reseeding.
- Balochistan: launching a rangeland monitoring and shrub establish-

ment mini-project.
- Turkey: initiating a rehabilitation project of commonly grazed village pastures using a participatory approach.

All these activities are carried out in collaboration with the national agricultural research programs.

Other News from PFLP

As of September 1994, the PFLP Feedstuffs Laboratory is totally operational after damage from a December 1993 fire. After several months of interruption, routine work has resumed with new equipment.

Tim Treacher leaves, Euan Thomson returns

PFLP's Small Ruminants Project, a vital part of WANA farming systems, continued to face storms and dust.

Dr. Tim Treacher completed his appointment after four years of loyal service to PFLP and ICARDA. During his assignment, Tim developed a strong research component for the management of cereal crop residue in collaboration with Mr. Safouh Rihawi (PFLP, Research Associate and PhD student, Reading University), Dr. Tony Goodchild (PFLP, Small Ruminant Nutrition Scientist) and Dr. E. Owen (Animal Nutritionist, Reading University, UK). This research was supported by a GTZ special project through the end of 1994. Tim also developed a convincing training plan with the small ruminant scientists of Jordan, Iraq and Turkey through the ICARDA Mashreq regional program in Amman. With the same program in Jordan, he launched a successful series of on-farm trials aimed at synchronizing lambing and improving the nutrition of ewes and lambs. Dr. Tim Treacher left ICARDA in May 1994.

In September 1994, we secured the return of Dr. Euan Thomson, upon completion of his duties in Quetta (Arid Zone Research Institute, Pakistan) with a US-MART aid project in Balochistan. Dr. E. Thomson's new assignment is to expand ICARDA's small ruminant network in WANA.

Staff movement and visiting scientists

Michel Obaton, Director of Research on sabbatical from the Institut National de la Recherche Agronomique, Laboratoire des Symbiotes des Racines, (Montpellier, France) joined the PFLP microbiology group in

March 1994. The purpose of his sabbatical was to develop a research project on the growth and nitrogen fixation of annual pasture legumes under cool and cold Mediterranean winter environmental conditions. This follows up earlier work conducted in southern France by Michel Obaton and Gus Gintzburger on *Medicago rigidula* and its associated rhizobium to secure vigorous growth and continuous nitrogen fixation in annual legumes, thus ensuring quality feed for sheep flocks throughout the Mediterranean winter. Michel, working in close collaboration with Dr. Luis Materon and his team, has screened the ICARDA PFLP rhizobium collection to find the most efficient annual medic combination to grow (and possibly fix nitrogen) under low winter temperatures when water is not the limiting factor. This topic is of relevance to most WANA farming systems where feed calendars indicate a winter and early spring deficit.

Dr. Haruhiro Fujita (JIRCAS, Japan), visiting scientist on land resources information, expanded his GIS activities in Jebel Abdel Aziz and recruited Mr. Masahiro Hirata and Mr. Hitoshi Shinjo, two Japanese PhD volunteers who worked through JICA, to assist in his research. Mr. Hirata will study range resources and small ruminant flock movements in the Jebel Abdel Aziz region. Mr. Hitoshi will measure run-off and erosion on test sites of the Jebel.

Mr. Shabab Nasser concluded his MSc thesis—Agricultural system analysis in dryland areas, El Hassakeh Province (Syria)—with Dr. Tom Norblom and the University of Damascus.

Ms. Andrea Pape (Hohenheim University, Germany) completed her MSc thesis—The Contribution of women to labor and decision making processes in Bedouin families: an example from Syria. She immediately started a PhD project with Dr. Tom Nordblom (PFLP Socioeconomist, Project 21)—Economics of barley/livestock systems in the El Bab district of Aleppo province (northern Syria).

Ms. Undine Opitz (Justus-Liebig University, Giessen, Germany) embarked on her PhD project with Dr. E. Thomson (PFLP, Livestock Scientist, Project 15) and Dr. S. Christiansen (PFLP, Grazing Management Scientist, Project 16)—Increasing small ruminant productivity in the El Bab Mantika in north Syria.

Internally Managed External Review (IMER) of PFLP Activities

The review process of the research and training program of ICARDA contains many elements. A key component is the Internally Managed External Review. This year, PFLP agreed to submit its activities to the IMER process after the general 1993 External Program and Management Review. ICARDA began implementation of the IMER system in its 1994–1998 Medium Term Plan. MTP 94–98, executed through the Project Management System, describes the proposed research in 23 projects. Each year, for the duration of this plan, a group of related projects will be evaluated by a panel of renowned external scientists. Evaluation of all projects must be completed by 1998.

For PFLP (Projects 15,16,17), the IMER panel members include:

- Dr. M. Bounejmate, Head Forage and Pasture Lab., Rabat, INRA Morocco.
- Dr. E.C. Correal, Fodder Shrubs and Pasture Lab., CIDA, Murcia, Spain.
- Dr. G.E. Pollot, Small Ruminant Geneticist, Wye College, London, UK.

All were familiar with ICARDA operations, programs and projects. The review process took place June 7–9, 1994. The reviewers met with the PFLP scientists and attended their presentations and discussions.

In their report, the IMER panel wrote (page 2): "There is no doubt of the high level of integrity and commitment of the PFLP staff to ICARDA, the region and the research program....[PFLP] is to be commended for its work under very difficult conditions and any comments in this report which may appear unfavorable or critical should be set against the admiration for the achievement of the team."

The IMER panel stressed the need for ICARDA to "...clearly formulate a research strategy for livestock or increased livestock research as directed by the EPMR..." and to urgently improve the experimental animal and parasitology facilities at Tel Hadya. Other comments on PFLP activities state that "...the proposed [PFLP] research program is modest but probably achievable within the capacity of PFLP, given current staffing, including the replacement of the Animal Production scientist. This replacement is an unknown quantity at present (June 94), but depending on his/her expertise, interest and level of activity could strongly influence the future livestock element of PFLP (and ICARDA)."

PFLP Project Management Implementation

The Project Management approach continued to be implemented at the program level as recommended by the ICARDA Board of Trustees. The PFLP project structure developed in the 1994—1998 Medium Term Plan is an anticipated response to the BOT expectation. Note that the 1994 PFLP annual report is presented by project activity (15, 16, 17, 21).

New Directions in PFLP

PFLP is entering the active phase of its participatory approach, with on-farm activities and expansion of interaction with farmers and pastoralists within a group of villages in the El Bab district (northern Syria) and at Maragha (Aleppo Steppe Directorate). This requires intense support from local extension services, and close collaboration with local authorities.

PFLP is moving into arid rangeland research after hesitating for several years to approach this difficult environment. Barley cropping is expanding onto the steppe and contributing to range resource degradation as it becomes an essential feed resource for small ruminants. Small ruminants and migrating pastoralists are the essential links between cropping zones and rangelands. ICARDA cannot continue to ignore this important issue, especially when desertification and natural resource degradation continue their pernicious expansion. Arid rangeland management and rehabilitation will be the major focus of PFLP activities in the future.

Do not hesitate to contact our program if you need supplementary information on our research and activities, or if collaboration is foreseen.

Acknowledgments

To GTZ-BMZ for supporting the PFLP Small Ruminant projects, and to JIRCAS and JICA for their continuing support to ICARDA activities and in seconding Dr. H. Fujita (JIRCAS Land Resources Information Scientist), Dr. Nishikawa (JICA Veterinarian, Specialist in Small Ruminant Blood Parasites), and two JICA volunteers to PFLP.

—G. Gintzburger Program Leader (Pasture, Forage and Livestock Program)

Small Ruminant Nutrition and Production (MTP 94–98/Project 15)

Forage Legume Quality

Calibration of Near Infrared Reflectance Spectroscopy of Forage Legume Hay and Straw for Various Measurements of Tannin Content

Our consultant, Dr. H.P.S. Makkar from Hohenheim University, measured various anti-nutritional factors in 41 samples of freeze-dried green forage material (n=17) and straw (n=24) from accessions of the genera *Lathyrus* and *Vicia*. The results (Table 2) were used to calibrate NIRS (Table 1). All data were treated identically before performing an automatic regression with NSAS software; in this process, data were transformed to a second derivative, using a gap of 0 nm and a segment of 20 nm.

Table 1. Standard deviations and R-squares of calibration (not prediction) of NIRS for Total Phenolics (TotPhe), Tannins, Condensed Tannin (CondTan), percentage increase in HFT gas test when PEG is added (HFTinc), ADF, NDF and Crude Protein (CP).

Measurement	Standard deviation	R-square of calibration				
		$n_\lambda=1$	$n_\lambda=2$	$n_\lambda=3$	$n_\lambda=4$	$n_\lambda=5$
TotPhe	7.58	0.641	0.902	0.926	0.941	0.945
Tannins	5.34	0.465	0.669	0.709	0.760	0.773
CondTan	8.90	0.558	0.854	0.926	0.939	0.950
HFTinc	1.963	0.444	0.509	0.518	0.559	0.557
ADF	10.11	0.904	0.930	0.943	0.955	0.956
NDF	11.82	0.929	0.943	0.946	0.950	0.951
CP	4.763	0.889	0.908	0.916	0.921	0.923

Acceptable calibrations were obtained for all measurements except HFTinc, and are potentially useful for screening germplasm. Detailed calibrations will be published elesewhere.

Units are mg/g DM (except for HFTinc, ml/100 ml). n_λ=number of wavelengths.

Table 2. Species means of reference laboratory analyses of green forage and forage legume straw.

Measurement	*Lathyrus sativus* straw	*Vicia ervilia* straw	*Vicia narbonesis* forage	*Vicia sativa* straw	forage	straw
n(samples)	5	1	1	9	16	9
TotPhe	13.2	6.5	14.3	9.8	22.9	10.9
Tannins	4.3	1.8	6.2	3.7	12.2	4.8
CondTan	1.4	4.6	4.2	1.3	16.8	4.1
HFTinc	0.84	1.10	-1.78	0.82	4.14	1.85
ADF	422	552	270	366	206	390
NDF	618	759	411	554	358	580
CP	66.4	43.5	149.3	67.2	157.7	63.4
ME(HFT)	7.82	6.70	8.53	8.43	9.71	7.30

Measurement units are the same as in Table 1, with the addition of ME(HFT), the metabolizable energy (MJ/kg) predicted from the Hoheneim Gas Test (HFT) and proximate analyses.

The reference data show interesting features. Tannins are between one half and one third of total phenolics, and probably all are condensed tannins. The highest tannin levels were found in *Vicia sativa*, which was the only case in which the HFT could be improved by PEG. In straw, all estimates of phenolic compounds were about half the value found in forage. In *V. narbonensis*, the forage was more fibrous, had a lower ME and lower phenolics than *Vicia sativa*, but crude protein was almost the same. The composition of its straw including phenolics and fiber fractions was, however, closer to that of *V. sativa*.

—H.P.S. Makkar (Hohenheim University, Stuttgart, Germany),
—H. Nakkoul and A. Abd El Moneim (Germplasm Program, Legumes),
—F.J. El Haramein (Germplasm Program, Cereals),
—I. Said and A.V. Goodchild.

Prediction Methods for Barley Straw Quality

Reference Set of 42 Samples of Barley Straw

Unless otherwise stated, the reference set is identical to the one used in the section *Predicting the voluntary intake of barley straw with Near Infrared Reflectance Spectroscopy (NIRS)* in the 1992 PFLP Annual Report. The samples were harvested in six years (1985, 1986, 1988, 1989, 1990, 1992) and covered 13 genotypes. The 1986 samples included three leaf and four stem, in addition to whole straw. Thirteen cultivars were represented; their voluntary DM intake in Awassi sheep averaged 17.3 (SD=7.29) g/kg body weight. For ease of description, leaf and stem were treated in the same manner as samples grown in different years.

Palatability Measurement by the Paired-preference Test

Farmers in the WANA region value those varieties of straw preferred by sheep. Straw variety preference was measured as the relative quantity that sheep ate when presented simultaneously with 20 g each of two varieties (in two identical small buckets placed symmetrically to their left and right in a feeding trough). Comparing straw sample sets involves comparing, with an appropriate degree of replication, each possible sample pair. On any day, sheep (fasted overnight) participated in up to six tests spaced 25 minutes apart and usually two to five minutes in duration (depending on their average intake rate). Sometimes, to compensate for unusually high or low intake rates, the length of the test for individual sheep, or for a particular sample, was adjusted. Total intake of the two varieties had to be between 25 and 60 percent of the total offered for the result to be acceptable; if not, the test was repeated.

Palatability of the Reference Set of 42 Barley Straws

A preliminary trial tested how palatability of samples grown in different years ranked according to voluntary intake. The preference for samples grown in certain years was clear-cut; accordingly, only straws harvested in the same year (or in two similar years) were compared. There were 10 test series of pairs from similar years, and eight test series of same year comparisons, for a total of 18 sets. Each test series compared 3–13 samples of straw and lasted 0.5–2 days. Comparisons for the 42 straw samples took 15 days to complete.

The results were analyzed using the SAS Generalized Linear Model (GLM), in which each test (pair of samples) was considered as a separate block. Least squares mean relative intakes for varieties were generated. The model used was refusals=pair ID sample.

The average access time sheep were allowed was also recorded, so that partial rate of intake (g/minute) could be calculated. The mean intake or rate of intake for each variety was corrected for each series using SAS GLM, and is shown in the following table:

Genotype	No. of years (max=8)	Intake in pair-comparison test		(Partial) rate of intake, g/min	
		eaten,g	SE	mean	SE
Antares	4	13.3	1.41	4.24	0.502
ER/Apam	4	11.8	1.33	3.58	0.473
Arar	2	11.1	2.01	2.87	0.714
Arabi *abiad*	4	10.9	1.41	3.25	0.503
Arabi *aswad*	4	10.5	1.33	2.93	0.474
Badia	3	9.9	1.53	3.44	0.543
C-63	6	9.6	1.04	3.25	0.370
Tadmor	3	9.6	1.72	2.94	0.612
Rihane	3	9.2	1.69	3.13	0.603
WI-2291	1	8.7	3.34	2.85	1.189
Arta	1	7.0	3.34	2.18	1.189
Zanbaka	1	4.5	3.34	1.61	1.189
Beecher	6	3.8	1.04	1.21	0.370
Significance probability					
Genotype	(12 d.f.)	0.0002		0.0020	
Series	(17 d.f.)	0.0001		0.0001	

Consistent differences between varieties were marked, particularly for pair-comparison intake, and were statistically more significant than differences in voluntary intake measured in trials described in this and previous annual reports. The palatability ranking by variety correlated closely with the intake ranking (R^2=0.45 within years). The high palatability of Antares was consistent with its recorded voluntary intake in years with sub-optimal rainfall, reflecting its late maturation. Beecher gave a low value, as expected. The fact that Zanbaka had a lower value than Tadmor (both black-seeded landraces) was of borderline significance and needs to be confirmed. The low value for the white-seeded landrace, Arta, was not statistically significant.

These results closely echo the results obtained for voluntary intake, but used only a small fraction of the material (about 1 kg), took less time, were more precise, and unlike NIRS, required no calibration. The measurement seems relevant because it was closely related to voluntary intake, but this must be confirmed with a larger range of varieties. The low palatability of black-seeded landraces mirrored the low intake compared to other genotypes because tested was done in dry years when most other genotypes were less adapted and yielded less grain.

Palatability of 31 Samples of Barley Straw Grown in 1992

Twenty eight of 31 spring barley demonstration genotypes grown by the Cereal Program in 1992, plus two entries of Arabi *abiad* 1992 and one entry of urea-treated Arabi *abiad* 1992 were studied for palatability.

Correlation coefficients for intake in pair-comparison tests were:

- Row type (2 or 6): +0.38*
- Lateness score: -0.14^{ns}
- Height score: $+0.33^{ns}$
- Lodging score: $+0.11^{ns}$
- Percentage of whole plant:
    - stem: -0.23^{ns}
    - leaf: $+0.13^{ns}$
    - sheath: $+0.09^{ns}$
    - grain: $+0.13^{ns}$
    - awns: -0.19^{ns}

Trial of Conditions for Measuring Palatability (Nine Genotypes)

A small pair-preference experiment in sheep was performed during days 17–19 of the adaptation period in the barley grain quality. Palatability estimates were made of 19 samples of straw (nine genotypes grown in two locations, plus control). The trial design allowed us to measure the ability of sheep fed different diets to rank the 19 straws in the same order as the experimental average. The diets were 700S:700G, 100S:700G and 100S:1400G, where S represents the quantity of straw and G represents the quantity of grain (in grams).

The amount of feed offered had a significant effect on preference between varieties of straw. Sheep fed the smallest amount of food (100S:700G) were about half as likely to show a preference than sheep offered larger quantities of food (700S:700G or 100S:1400G). This stresses the importance of not letting sheep get too hungry before palatability trials.

The Ideal Way to Express Palatability

This is a broad topic, and one or more of the following criteria are used:

- Precise and repeatable palatability estimation irrespective of test conditions.
- Ability to distinguish samples.
- Usefulness in predicting nutritive value, alone or in conjunction with other tests.

The only testing conditions used so far are those described above, and work will continue.

Our primary interest is data transformations and statistical model modifications that will give the greatest F-value in samples. When users have no access to a Generalized Linear Model, techniques that minimize the F-value for sample pairs are also of value.

Results, though still in the draft stage, show that testing conditions have little effect on the proportion of the total intake coming from each sample as a measure of intake in the GLM. In replicated trials computing requirements are reduced and precision is generally increased by using the GLM model intake=sample pair-of-varieties, rather than intake=sample test.

It may be possible to analyze carefully planned and laid out pair-comparison trials as a series of chain blocks (Cochran and Cox 1957).

—A. Goodchild, A. Termanini and L. Jaffel.

Barley Straw Quality

There is More to Barley than Big Ears: Genotype–Environment Interactions Affecting the Nutritional Value of Straw

Abstract of seminar presented by A.V. Goodchild for the ICARDA in-house seminar series, April 20, 1994.

Historically, barley breeders have tended to concentrate on maximizing grain production, and protecting it from biotic and abiotic stresses. Although grain yield is important, barley straw accounts for one third of the metabolizable energy for sheep. Straw quality is lowest when growing conditions are good. The voluntary straw intake of a 50 kg Awassi sheep in a very wet year (such as 1987/88) was as low as 550 g/d containing 3 MJ ME (half the sheep's requirement to maintain body weight). In a drought year (such as 1988/89) the straw yield was much lower, but voluntary dry matter intake was as high as 1600 g/d containing 15 MJ ME (enough to support 1.2 kg/day of milk). The variation in voluntary intake between varieties is less (variation coefficient about 15 percent), but varieties rank differently in drought than in wet conditions. Exotic varieties, particularly those of the six-row type, tend to have lower intakes in favorable (wet) years than landraces; they also yield slightly more grain. Both of these trends are reversed in unfavorable years, and we have found a significant genotype x year interaction for voluntary intake.

Within exotic six-row varieties, a late variety (Antares) shows higher than average intake, and an early variety (Beecher) shows lower than average intake. Straw intake generally increases when diet is supplemented with soybean meal, cottonseed cake or urea; an exception to this is Beecher, which rarely shows a response to protein supplements. Within two-row varieties, landraces have higher quality in wet years than exotics. However, landraces, particularly tall black-seeded selections, have the least yield depression in drought and the least quality improvement.

Voluntary intake is a valuable indicator of quality, since it varies more than digestibility, with which it is correlated. Voluntary intake of digestible organic matter is a consistent indicator of body weight change.

Differences in voluntary intake are best predicted by Near Infrared Reflectance Spectroscopy. Only sample pair-preference by sheep can rank intake nearly as well—followed distantly by nitrogen, detergent fibers, and fermentation by rumen microbes using the *in sacco,* Hohenheim Gas Production, or Tilley and Terry *in vitro* techniques.

We need to determine what characteristics are picked up by NIRS and palatability measurements, particularly those which are not explained by microbial digestion in the rumen or by nitrogen content. We hypothesize that physical characteristics (such as mechanical resistance to mastication or the presence of sharp structures) and chemical characteristics (such as unpleasant taste) depress intake. We need to determine the structural and biochemical bases for differences in microbial digestion. Although in some cases straw quality is associated with late maturity or shortness (with adverse effects on grain or straw yield), we try to avoid these traits and concentrate on biochemical and mechanical traits that affect straw quality without compromising yield. Confirmation is also needed that NIRS can predict animal performance (growth or lactation) from straw fed to appetite.

The seminar concluded that it is best to select for straw quality only in years with good growing seasons. In drought years, because straw quality is high and can be further elevated by traits related to poor adaptation, it is appropriate to select mainly for grain and straw yield.

Effect of Year-to-year Environmental Variation on Barley Straw Quality

Abstract of a paper presented by A.V. Goodchild at the ICARDA Agro-ecological Characterization Workshop, Aleppo, 19–22 April 1994.

It is known that straw quality is increased by drought. In barley, inhibition of growth by water stress makes plants less mature (leafier and shorter) at harvest, and interrupts nutrient translocation to the seed. The voluntary intake (by a 50 kg Awassi sheep) of straw dry matter in a very wet year (such as 1987/88) can be as low as 550 g/d, and in a drought year (such as 1988/89) as high as 1600 g/d. The prediction of straw quality from weather factors is valuable for agro-economic modeling.

ICARDA has voluntary intake data on straw for a wide range of winter-planted barley varieties, as well as meteorological data including rainfall, minimum temperature (MINT) and maximum temperature (MAXT). Nine years (1982–1986, 1988–1990, and 1992) of mean straw intakes and monthly weather data means were analyzed by SPSS stepwise multiple linear regression. The procedure selected MAXT and MINT in the spring months (positive sign), rain in the spring months (negative sign) and MINT in some of the winter months (negative sign). The latter was interpreted as a positive effect of frost on intake. Two more climatic variables were introduced, based on spring temperature (mean of MINT and MAXT for March, April and May) and spring rain (total for February and March); these variables were the first chosen by the stepwise regression procedure and had positive and negative signs, respectively.

In a published study (Van Oosterom *et al.* 19--), the yield of grain at ICARDA was negatively correlated to temperature and frost, and positively correlated to rainfall. This is broadly the reverse of the effect on quality reported above, except that winter rain affected grain yield but not quality. The conclusion is that high winter rainfall increases the number of tillers, and that spring climate affects the yield per tiller. Therefore the grain yield of each tiller, rather than the grain yield per hectare, is correlated to straw strength and quality, so that an increase in the number of tillers caused by winter rain helps offset the total rainfall effect on straw quality.

Intake and Digestibility of 32 Barley Straw Genotypes: Year 1/Preliminary Results

The ICARDA Spring Barley Project developed a set of 31 barley genotypes for demonstration purposes. We conducted intake and digestibility trials with these 31 entries, plus Arabi *abiad* (previously used in feeding trials).

The trial started with the 1993/94 growing season. On December 23–24, 1993, the 32 varieties were planted using 20 cm row spacing and a sowing rate of 100 kg/ha. The layout was alpha-lattice with four replicates and four blocks per replicate, totaling 128 plots. Plot size was 50x6 m, so that each genotype was grown on 0.12 ha, of which 0.11 ha was harvested June 1–15, 1994.

Crop growth observations were carried out through late May. Three quadrat samples (each 0.4x0.6 m) were taken from each plot between May 27–28 at a height of five cm to measure straw, grain and awn yields. A subsample of straw was taken from each plot to estimate the proportion of leaf (including leaf-sheath) in the straw.

The straw from each plot was chopped in a commercial movable hammer mill (hired from Mr. Mohamed El Yassim of El Ais village). As far as possible, straw from each field replicate was fed in the corresponding replicate of the feeding trial. Within each replicate, there were four blocks of eight straws; these were randomly allocated to eight sheep, similar in age and intake.

Animal Trials

The feeding trial was conducted with groups of 32 castrated sheep in four replicates. In each replicate the experimental straw was fed for five weeks. There were two groups of castrated sheep, one used for replicates one and three, the other for replicates two and four. The schedule for each replicate, beginning two weeks before the experimental straws were introduced, was:

- *Covariance:* 14 days
  Sheep housed in large individual pens, fed *ad libitum* with standard barley straw.

- *Adaptation:* 7 days
  Sheep moved into digestibility crates, each of the 32 sheep fed *ad libitum* with one of the 32 experimental straws.
- *Digestibility:* 10 days
  Sheep fed as for the adaptation period, feces collected and a 1/10 subsample analyzed in the lab.
- *Protein supplement:* 9 days
  Sheep fed 3.0 g cottonseed cake per kg body weight, followed by experimental straw fed *ad libitum.*
- *Urea supplement:* 9 days
  Sheep fed 1.0 ml of 350 g/liter urea solution per kg body weight, sprayed on top of experimental straw fed *ad libitum.*
- *Recovery:* 21 days
  Sheep kept in a bare exercise paddock and offered 200 g/d barley grain and vetch hay to appetite.

With all diets, sheep were fed 20 g of a mixed mineral supplement consisting of: fertilizer-grade calcium diphosphate (12 g), common salt (6 g) and a commercial vitamin-mineral supplement (2 g). *Ad libitum* means that sheep were fed *at least* 1.2 times as much straw as the average straw intake for the previous three days.

Preliminarly Results

The results presented here are based on the assumption that dry matter intake=(quantity offered-quantity refused)x0.92. Results will be revised following recalculation based on the DM content of feed and refusals.

Nutritive value, as indicated by voluntary intake, varied significantly by variety: $P<0.001$ for the whole trial and $P<0.05$ or 0.01 for the various supplements. Body weight gain seemed to be measured imprecisely, varying between 3.3 kg loss and 4.5 kg gain, possibly due to the effect on gut fill rather than tissue gain.

Plant characteristics between varieties that varied most significantly were: lodging, head weight, height and lateness. Lateness was not significant to any measure of nutritive value. Tendency to lodge was positively correlated ($P<0.05$) only if no supplement was fed. Stem height was negatively correlated with nutritive value.

Grain yield varied significantly by genotype ($P<0.01$), and was positively correlated with voluntary intake, particularly when nitrogen supplements were fed ($P<0.05$). A similar but stronger phenomenon was seen with the harvest index (grain weight÷total biological yield, $P<0.01$ or 0.001). Grain weight per head (higher in six-row varieties) had only a small negative relationship with intake, and then only when no supplement was fed. Leafiness and straw yield were only beneficial (insignificantly) when supplement was not fed.

Both nitrogen and the ratio of N to an indicator of digestibility (1-ADF) were highly correlated with voluntary intake. In straw, however, a high N or N/(1-ADF) *did not imply a smaller response to N supplementation.* Good body weight gain, despite imprecise measurement, was associated with failure to respond to nitrogen supplements (cottonseed cake or urea) rather than to the straw nitrogen content.

These results will be augmented with *in vivo* measurements of digestibility. Similar experiments (in the next two seasons) will yield further animal intake and weight gain data, from which more precise estimates of varietal merit and possible season x variety interaction will be calculated.

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Table 1. Means, ranges and standard deviations of characteristics, and significance of varietal differences.

Characteristic	Unit	Mean	Std. Range	dev.	Genotype effect Variance ratio	Genotype effect Significance probability
Stem height	mm	658	520–833	76	10.5	<<0.0001
Lodging (at harvest)	%	22	0–95	31	31.9	<<0.0001
Lateness score	% green	1.8	0–17	3.2	8.06	<<0.0001
Grain* yield	kg/ha	2982	1976–3931	528	2.25	0.0014
Straw* yield	kg/ha	3493	2736–4756	475	1.80	0.016
Total biological yield	kg/ha	6859	5526–8655	861	1.61	0.041
Leaf as propn of straw*	g/g	0.498	0.453–0.578	0.030	2.63	0.0002
Grain as propn of TBY	g/g	0.432	.352–.520	0.045	3.48	<<0.0001
Grain weight per head	g	0.873	.537–1.578	0.273	17.23	<<0.0001
Straw weight per head	g	1.027	.557–1.681	0.244	1.93	0.0083
Nitrogen	g/kg DM	4.51	3.75–6.45	0.53	2.68	0.0002
Acid detergent fibre	g/kg DM	411.9	366–430	14.7	2.45	0.0007
Acid detergent lignin	g/kg DM	58.4	48–73	5.3	2.18	0.0029
N: (1—ADF/1000) ratio	g/kg	7.64	6.4–10.1	0.78	2.67	0.0002
Daily straw DM intakes, g/kg body weight:						
whole trial (days 8–35)		18.17	11.2–21.8	2.30	2.43	0.0009
no supplement (days 8–17)		16.17	12.7–20.2	1.87	2.14	0.0036
with cottonseed cake (days. 23–26)	20.45	12.3–24.8	2.89	1.70		0.031
with urea (days 32–35)		19.27	6.9–24.3	3.73	2.73	0.0044
Body weight change	g/day	30.2	(93)–128	37.9	1.57	0.277

* does not include awns

Table 2. Correlation between varietal characteristics and straw intake or weight gain.

Characteristic	Straw intake whole trial (days 8–35)	Relative straw intake cf. no supp. (no supp.) (days 8–17)	with cotton seed cake	with urea	Daily body weight gain
Stem height	-0.43*	-0.26	-0.32	-0.51**	-0.04
Lodging at harvest	0.20	0.35*	0.07	-0.37*	-0.02
Lateness score	-0.12	-0.21	-0.05	0.26	0.05
Grain yield	0.36*	0.22	0.42*	0.37*	-0.14
Straw yield	0.15	0.27	-0.03	-0.27	-0.02
Total biol. yield	0.36*	0.33	0.27	0.10	-0.11
Leaf : straw	0.32	0.35	-.01	0.18	0.07
Grain ¸ Tot.Biol.Yield	0.27	0.04	0.48**	0.57***	-0.21
Grain weight per head	-0.14	-0.23	0.01	0.19	0.03
Straw weight per head	-0.38	-0.32	-0.37*	-0.20	0.23
Nitrogen	0.54**	0.63***	-0.02	0.00	-0.05
Acid detergent fiber	-0.43*	-0.48**	0.02	-0.10	0.00
Acid detergent lignin	-0.23	-0.06	-0.32	-0.32	0.04
Body weight gain	-0.03	0.15	-0.42*	-0.36*	[1]
N ¸ (1—ADF/1000)	0.51**	0.60***	0.00	-0.03	-0.06

*, $P<0.05$; **, $P<0.01$; ***, $P<0.001$

Voluntary Intake and Digestibility of Barley Straw Varieties Harvested in 1992 with Three Levels of Urea Supplementation

ICARDA's Seed Production Unit produced five varieties of barley for distribution in 1992. These were: Tadmor and Zanbaka (selections from the black-seeded Arabic *aswad* landrace), Arta (a selection from the white-seeded Arabic *abiad* landrace), and Rihane 03 and WI 2291 (exotic six-row and two-row varieties). We tested their voluntary intake and digestibility in castrated Awassi sheep (six were allocated to each variety of barley straw). There was a covariance period of 24 days, followed by two intake and digestibility trials, each lasting 21 days (11 days adaptation and 10 days fecal collection). For each variety of straw, each of the six sheep was fed a different sequence of urea supplementation treatments for the two intake and digestibility trials. The urea levels were 0, 5 or 10 g/kg fresh straw (equivalent to increasing the crude protein content by 16 or 32 g/kg dry matter).

Sheep	a	b	c	d	e	f
First trial	0	5	10	0	5	10
Second trial	5	10	0	10	0	5

The urea was given as a solution sprayed onto the straw.

Results

Dry matter intake and digestibility per kg body weight are shown in Table 1.

Table 1. Effect of urea level and variety on the voluntary intake and digestibility of straw dry matter harvested in 1992 (g/kg body weight).

	Urea level, g/kg DM				Significance	
Variety	0	5	10	SE(mean)	0 vs. 5	5 vs. 10
Arta	11.1	14.5	15.3	0.63	$P<0.01$	ns
WI2291	10.7	15.0	14.5	1.29	$P<0.1$	ns
Rihane 03	11.4	11.6	12.3	0.76	ns	ns
Tadmor	9.9	10.7	9.7	0.89	ns	ns
Zanbaka	10.8	11.6	10.7	0.55	ns	ns

Variety	Dry matter digestibility, g/g	Digestible DM intake, g/kg body weight
Arta	0.431	5.81
WI2291	0.468	6.34
Rihane 03	0.473	5.43
Tadmor	0.437	4.67
Zanbaka	0.427	4.77
SE of means	0.0215^{ns}	0.586*
Urea level		
0	0.431	4.68
15	0.450	5.63
30	0.461	5.90
SE of means	0.0106($P<0.1$)	0.240^{ns}

Urea x variety interactions not significant ($P>0.1$)

Table 2. ***In sacco*** **dry matter disappearances (g/g) and laboratory analyses (g/kg).**

Variety	*In sacco* dry matter loss: 0 hours	8 hours (washings)	24 hours	48 hours	72 hours
Arta	0.248	0.399	0.541	0.667	0.720
WI2291	0.197	0.298	0.554	0.667	0.728
Rihane 03	0.205	0.307	0.524	0.644	0.680
Tadmor	0.201	0.300	0.527	0.648	0.689
Zanbaka	0.181	0.263	0.468	0.570	0.638
Variety	**Total nitrogen fiber**	**Neutral detergent fiber**	**Acid detergent (Tilley & Terry)**	**Digestible OM in DM *in vitro***	
Arta	3.10	782	470	432	
WI2291	3.50	753	415	514	
Rihane 03	4.10	810	458	475	
Tadmor	5.10	702	368	457	
Zanbaka	3.30	752	462	446	

There was little difference between varieties in unsupplemented straw intake. The intake increase when urea was supplemented was significant ($P<0.1$ or 0.01) in only two varieties, and response to the higher level of urea (10 g/kg DM) was no greater than to the lower level (5 g/kg DM). The characteristic most closely correlated with response to urea was *in sacco* disappearance at 72 hours ($r=+0.85$, $P<0.1$). Crude protein was not significantly related ($r=-0.58$).

This suggests that benefit from urea supplementation to straw depends on the balance between fermentable energy and nitrogen in the straw. To illustrate this: the ratio between crude protein and 24-hour *in sacco* loss was 36 and 40 for Arta and WI2291 (varieties with a significant urea response) but 49, 60 and 44 in Rihane, Tadmor and Zanbaka (varieties with no significant response to urea).

The total dietary nitrogen level was probably no more than 0.7 g per MJ metabolizable energy in varieties not responding to urea supplementation, and lower than the recommended minimum level for optimum microbial growth in the rumen (1.34 g *degradable* N/MJ [ARC 1984]). Since animals were not gaining weight it is possible that a large part of the microbial protein digested in the small intestine was converted to urea in the body and diffused into the rumen. Such urea recycling requires that sheep control the excretion of urea in the urine; studies of the relationship between rumen ammonia, blood urea and urinary urea in Awassi sheep could reveal a highly beneficial breed trait.

—*A. Goodchild and A. Termanini.*

Reference

ARC (UK Agricultural Research Council). 1984. Report of the protein group of the ARC Working Party on the nutrient requirements of ruminants. Commonwealth Agricultural Bureaux. Slough, England.

Using Sheep Preference, Near Infrared Reflectance and Laboratory Tests for Predicting Voluntary Intake from Small Samples of Barley Straw

Breeding cereals with straw that has a high voluntary DM intake (VDMI) could maximize the value of straw in ruminant diets without the risk and cost of chemical treatment. Following are some low-cost rapid tests which breeders can use to predict the voluntary DM intake of small samples of straw.

For the reference set of 42 samples of barley straw, we performed the following laboratory tests:

- Gas production (Hohenheim HFT test) at 4, 6, 8, 12, 24, 30, 36, 48, 54, 60, 72, 96 hr from straw.
- Gas production at the same times from the NDF of straw.
- *In sacco* loss of DM and NDF at 0, 8, 24, 48, 72 hr.
- Energy required for grinding.
- N, NDF, ADF, *in vitro* DMD.
- Four promising second derivatives of the near infrared spectrum (1236, 1606, 1668, 1680 nm).

We also offered straw pairs to sheep in the preference tests described above. Statistical analysis was by the SAS generalized linear model procedure with type II error.

Findings (see table):

1) When VDMI was predicted from any one laboratory test by linear regression, residual standard deviation (RSD) varied 3.02–7.29.
2) Predictions of VDMI using a combination of year effect and any one laboratory test improved the RSD to 1.53–1.95.
3) Predictions of VDMI were better using a combination of year effect and sheep preference (RSD=1.47).
4) Predictions of VDMI using a combination of year effect, preference and one laboratory test were no better than the latter, except for NIRS D2OD at 1236 nm or *in sacco* DM loss at eight hours ($P<0.001$ or 0.05; RSD=1.33 or 1.38). Using NDF rather than DM for estimating

gas production or *in sacco* disappearance, or using the parameters of asymptotic regressions, did not improve predictions.

We conclude that laboratory methods to predict differences in voluntary DM intake between cultivars must be used in their proper context. When one corrects for year-to-year variation in DMI, gas production methods lose their predictive ability in favor of *in sacco* methods. Near Infrared Reflectance shows considerable promise, and preference tests, although requiring more time and more straw (e.g., one kg) than laboratory tests, may be accurate enough to contribute to NIRS calibrations for predicting VDMI.

Laboratory test	Regression model: Intake=...	Standard error of prediction	Significance of year	Significance of test	Significance of palatability
DM loss *in sacco*					
all times	Test alone	4.15 to 5.80			
	Year and test	1.64 to 1.83			
	Yr,test,palat.	1.38 to 1.47			
first 8 hr	Test alone	4.87		****	
	Year and test	1.64	****	***	
	Year,test,palat.	1.38	****	*	*
first 24hr	Test alone	4.15		****	
	Year and test	1.66	****	***	
	Year,test,palat.	1.47	****	ns	*
NDF loss from DM *in sacco*					
all times	Test alone	4.47 to 7.18			
	Year and test	1.80 to 1.98			
	Year,test,palat.	1.39 to 1.44			
Gas production (Hohenheim HFT)					
all times	Test alone	3.48 to 4.66			
	Year and test	1.82 to 1.90			
	Year,test,palat.	1.49 to 1.51			
first 12hr	Test alone	3.48		****	
	Year and test	1.82	****	†	
	Year,test,palat.	1.50	****	ns	***
first 24hr	Test alone	3.54		****	
	Year and test	1.82	****	*	
	Year,test,palat.	1.50	****	ns	***
first 72hr	Test alone	3.96		****	
	Year and test	1.86	****	†	
	Year,test,palat.	1.50	****	ns	***
HFT gas production from NDF					
all times	Test alone	3.93 to 6.43			
	Year and test	1.87 to 1.92			
	Year,test,palat.	1.50 to 1.51			

Laboratory test	Regression model: Intake=...	Standard error of prediction	Significance of year	test	palatability
Grinding energy (kJ/g)					
	Test alone	3.29		****	
	Year and test	1.93	****	ns	
	Year,test,palat.	1.45	****	ns	***
Nitrogen	Test alone	3.02		****	
	Year and test	1.59	****	***	
	Year,test,palat.	1.42	****	*	†
Neutral detergent fiber					
	Test alone	4.06		****	
	Year and test	1.77	****	**	
	Year,test,palat.	1.49	****	**	ns
Acid detergent fiber					
	Test alone	3.58		****	
	Year and test	1.85	****	*	
	Year,test,palat.	1.49	****	**	ns
In vitro DM digestibility					
	Test alone	5.04		****	
	Year and test	1.80	****	*	
	Year,test,palat.	1.46	****	**	ns
NIRS (D2OD, 4 points)					
	Test alone	4.96 to 7.29			
	Year and test	1.53 to 1.95			
	Year,test,palat.	1.33 to 1.49			
at 1236nm	Test alone	4.96		****	
	Year and test	1.53	****	****	
	Year,test,palat.	1.33	****	**	**

[1] Residual standard deviation of VDMI (g DM/kg body weight) predicted using the test
[2] Significance probability: ns, †, *, **, ***, **** denote $P>0.1$, <0.1, 0.05, 0.01, 0.001, 0.0001
[3] RSD of VDMI within year = 1.95
[4] RSD of VDMI predicted by preference within year = 1.50

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Barley Grain Digestibility: Effect of Feeding Level and Barley Variety on Digestibility of Barley and Barley Straw

High levels of barley grain are fed to lactating and fattening sheep in many Middle Eastern countries. Barley-based diets should contain at least a small quantity of roughage to maintain health; lack of roughage can directly affect milk production (see elsewhere in this report). On the other hand, dietary cereal starch can reduce cellulose digestibility in straw, and in high-grain diets; feeding more than a minimum level of straw may be wasteful.

There is substantial variation in the nutritive values of barley grain itself. In Britain, MAFF (1992) reports that metabolizable energy values in 45 lots of barley varied between 12.1 and 14.3 MJ/kg dry matter, with a mean of 13.3 and a standard deviation of 0.50. Protein was more variable: 100–171 g/kg DM (mean 129 SD 14.6) and acid detergent fiber 43–91 g/kg DM (mean 55 SD 10.7). In the Middle East, quality variability is likely to be higher, as drought reduces grain filling (thereby increasing fiber and protein) and probably reduces ME. For example, barley grain harvested at Tel Hadya in 1993 contained over 170 g crude protein/kg, but the 1994 harvest contained 103–114 g/kg. We wanted to confirm relationships between fiber content and digestibility in common varieties of barley grain.

We performed two experiments with Awassi sheep in digestibility crates, each in three replicates. The first experiment determined whether barley grain depressed the digestibility of straw in mixed diets, whether levels of barley in feed affected total ration digestibility and whether barley variety affected digestibility. The second experiment investigated the effects of urea supplementation on the voluntary intake of different mixtures of barley grain and straw.

Barley Grain Digestibility and Its Effect on Straw Digestibility

The treatments were:

1. Barley straw alone, 700 g/day.

2. Barley straw, 700 g/day, with:
    2a. barley grain a, 700 g/day
    2b. barley grain b, 700 g/day
    2c. barley grain c, 700 g/day

3. Barley straw, 100 g/day, with:
    3a. barley grain a, 700 g/day
    3b. barley grain b, 700 g/day
    3c. barley grain c, 700 g/day

4. Barley straw, 100 g/day, with:
    4a. barley grain a, 1400 g/day
    4b. barley grain b, 1400 g/day
    4c. barley grain c, 1400 g/day

The first two barley grain varieties were selections from Syrian two-row landraces: (a) Arabic *aswad* (black-seeded) and (b) Arabic *abiad* (white-seeded). The third variety (c) was Rihane, an exotic six-row variety. There were three sheep for each of the 10 treatments, allocated in a randomized block design.

Animals were gradually introduced to barley grain for nine days, followed by a seven day adaptation period and a 12-day digestibility trial (in which intake and fecal output were measured). Barley grain was fed in separate containers one hour before straw. Refusals, if any, were measured the following morning.

In the treatment with the highest level of barley, most sheep refused some grain. Intake and dry matter digestibility were as follows:

Diet	Straw DM	Barley grain		Feces	DM digestibility	
	intake g/d	*Variety*	DM intake g/d	DM, g/d	Whole diet	Barley (by difference)
1	525	(none)	0	328	0.264	-
2a	507	*Aswad*	644*	457	0.585	0.837
2b	510	*Abiad*	644*	413	0.625	0.907
2c	525	Rihane	644*	450	0.587	0.847
3a	92*	*Aswad*	644*	181	0.752	0.820
3b	92*	*Abiad*	644*	175	0.780	0.853
3c	92*	Rihane	644*	184	0.771	0.843
4a	92*	*Aswad*	960	217	0.768	0.820
4b	92*	*Abiad*	1280	300	0.775	0.813
4c	92*	Rihane	1177	264	0.776	0.813
SE	10.9		51.3	35.8	0.0298	0.0244

(continued)

Diet	Straw DM intake g/d	Barley grain Variety	DM intake g/d	Feces DM, g/d	DM digestibility Whole diet	Barley (by difference)
Means:						
1	525	(none)	0	328	0.264	-
2	514	all	644*	440	0.599	0.863
3	92*	all	644*	180	0.768	0.839
4	92*	all	1139	260	0.773	0.816

* Sheep consumed all that was offered

Diets containing Arabic *aswad*, Arabic *abiad* or Rihane grain had average dry matter digestibilities of 0.701, 0.727 and 0.711, respectively, (SE 0.0158) with no significant difference ($P>0.5$). The calculated grain digestibility in high-grain diet four was lower than in medium-grain diet three, as expected since the high-grain sheep suffered from intermittent diarrhea. The difference was not significant ($P>0.1$).

The straw digestibility in diet two (with equal quantities of straw and grain fed) was 0.299 (SE 0.0144), calculated from the difference in straw intake and fecal dry matter between this diet and diet three. The calculated straw digestibility was not less than that of unsupplemented straw (0.264 SE 0.0240, no significant difference). It seems that if barley grain had a depressing effect on straw digestibility it was counterbalanced by other benefits. Barley grain has a higher crude protein/metabolizable energy ratio (c. 9 g/MJ) than barley straw (c. 5 g/MJ) and would improve nitrogen supply to rumen microbes.

Body weight gains, though not statistically significant, were slightly higher in barley-fed groups.

Urea Effect on Intake of Barley Straw

Following the collection period and a six-day gradual treatment change, a second trial began in which all sheep were fed 400, 800 or 1200 g/d Arabic *abiad* barley grain with barley straw *ad libitum* for 10 days. Urea, in a 350 g/liter solution, at a rate of 0, 7 or 14 g/kg (to increase the crude protein equivalent of the diet by 20 or 40 g/kg) was sprayed on the ration. Animals were chosen to balance for barley varieties fed in the previous trial. After six days, intakes stabilized, and the following responses were observed:

Diet	Urea level in diet as fed, g/kg	Barley intake as fed, g/d	Straw intake as fed, g/d
1.1	0	0	635
1.2	7	0	674
1.3	14	0	579
2.1	0	400	537
2.2	7	400	647
2.3	14	400	535
3.1	0	800	327
3.2	7	800	313
3.3	14	800	356
4.1	0	980*	60
4.2	7	765*	341
4.3	14	919*	286

* 1200 g were offered

When no more than 800 g barley was offered, sheep consumed it all. Larger quantities of barley resulted in varying intakes, and many sheep refused about half the barley offered. The intake of barley straw decreased as the quantity of barley eaten increased, so that straw intake=652-0.366 barley intake(*SE 0.0605****)

Straw intake was not consistently increased by urea at any level of barley intake. This suggests that the crude protein:metabolizable energy of any straw and barley mixture is adequate to maximize straw intake. Other indicators of adequacy of dietary protein supply, such as rumen parameters or rate of microbial protein synthesis, were not measured.

—A. El Awad, A. Goodchild and A. Termanini.

Reference

MAFF (Ministry of Agriculture, Fisheries and Food). 1992. UK Tables of Feed Composition and Nutritive Value for Ruminants. Second Edition. Chalcombe Publications. Canterbury.

Effects of Urea Treatment Supplementation and Coarse Milling on Nutrient Intake of Sheep Fed Barley and Wheat Straw

Two experiments were carried out, similar in design to the experiment described in the 1992 PFLP Annual Report. That experiment found that chopping (as practiced by farmers) reduced the extent to which sheep selected their diet, but did not increase intake or reduce digestibility, probably because most particles were greater that one mm in diameter (see PFLP Annual Report for 1992). Both urea treatment and urea supplementation increased voluntary intake, digestibility and nitrogen content compared with straw fed with minerals. Treatment gave the greatest improvement per kg straw, but supplementation (because 60 percent less urea was used) gave the greatest improvement per kg urea.

Barley straw was used in the second experiment of the series and wheat straw in the third. As before, the experiments had a 3x2 factorial design. The factors were the method of using urea (treatment [T] vs. supplementation [S] vs. none [C]), and mechanical treatment (long vs. milled straw). The grinding coarseness was similar to that found in previous years (40 percent of straw allowed to pass a 1.0 mm screen). There were five replicates in each of two experiments, using 30 mature castrated Awassi males weighing about 45 kg.

Straw treatment followed the method of M. Hadjipanayiotou (personal communication). Each kg of straw was mixed, in large black heavy-gauge polyethylene bags, with a solution of 50 g urea in 0.5 kg water (Experiment 1) or 50 g urea in 0.5 liters of water (Experiment 2). After three winter months the bags were opened and the straw laid out in the shade to release gaseous ammonia and moisture. The untreated straw was supplemented with urea to give a dietary nitrogen content equal to that of air-dried treated straw.

Each straw type was fed to each sheep at a rate of 1.2 times the mean intake in the previous three days. Urea supplement, if fed, was sprayed on the straw by syringe at a solution of 333 g/l. All sheep were fed 20 g/day of a mixed mineral supplement. Sheep were fed a uniform diet (*ad libitum* barley straw) to allow intake correction by covariance (if needed), followed by a 15-day adaptation period, and then a 10-day fecal collection period. Feed, refusals and feces were analyzed, and results will be published in a separate paper.

Table 1. Composition of sheep diets in Experiment 2 (g/kg DM).

Treatment	Code	Organic matter	Crude protein	Neutral deterg. fiber	Acid deterg. fiber
Barley straw treated with urea					
Long straw	T-long	893	102	759	437
Milled straw	T-tibn	892	90	754	454
Barley straw supplemented with urea					
Long straw	S-long	886	87	762	431
Milled straw	S-tibn	896	83	785	422
Unsupplemented barley straw					
Long straw	C-long	886	31	765	432
Milled straw	C-tibn	898	28	781	423

Five sheep per treatment.

Table 2. Daily intake and digestibility of organic matter (OMD) or of dry matter (DMD), digestible intake and live weight change in Experiments 2 and 3.

	Experimentt 2 (barley straw)			Experiment 3 (wheat straw)		
CODE	DM intake (g)	OMD (g/kg)	DOM intake (g)	DM intake (g)	DMD (g/kg)	DDM intake (g/kg$^{0.75}$)
T-long	1338	647	871	1027	600	31.9
T-tibn	1174	621	718	951	560	27.3
S-long	1103	594	653	882	560	25.2
S-tibn	1062	541	574	871	510	22.4
C-long	771	540	413	861	520	23.1
C-tibn	676	536	382	830	450	20.0
SE of mean	?	?	?	89	20.9	2.70
Significance[1]	**	***	***	ns	***	**

[1] Significance of differences between the means of C, S and T.
Length of chop not significant in any case. [ns], $P>0.05$; **, $P<0.01$; ***, $P<0.001$.

The diet actually consumed by the sheep in Experiment 2 is shown in Table 1. The crude protein (nitrogen x 6.25) contents of the S and T treatments were not significantly different, and were 61 g/kg DM higher than in the unsupplemented group. Unlike in the reported 1992 experiment, urea treatment had little effect on the neutral and acid detergent fiber content of straw.

The higher crude protein content and lower NDF content in the diets of sheep fed long straw partly reflects their selective behavior when fed these straws. As a result, intake and digestibility tended to be slightly (but insignificantly) higher in long straw than in equivalently-treated chopped straw. This was also true in the third experiment.

With barley straw (Experiment 2), voluntary DM intake increased from 724 to 1082 g/day with urea as a supplement, and was a little greater (1256 g/day) with urea treatment (SE of C, S or T means 54). The respective digestible organic matter intake was 398, 614 and 794 g/day. With wheat straw (Experiment 3), responses to urea supplement were smaller (DM intake increased from 846 to 876, DDM intake from 21.6 to 23.8) than responses to urea treatment (989 and 29.6). In both experiments, nearly three times more urea was used to treat than used to supplement a kg of straw. For these particular straws and experimental conditions, to increase the digestible intake of straw the most efficient use of urea was as a supplement for barley straw and as a treatment for wheat straw.

—*A. Termanini and A. V. Goodchild.*

Effects of Underfeeding Awassi Ewes in Late Pregnancy and Early Lactation on Body Weight Changes and Milk Production

Responses of Awassi ewes to nutrition in late pregnancy and lactation. El Awad, Goodchild, Treacher, Bahhady and Gürsoy.

In the Middle East and parts of Turkey, Awassi sheep traditionally graze rangeland for most of the year, and lambing is spread throughout the winter. Grazing is poor during late pregnancy and early lactation and today's farmers feed sheep on straw, cereal grains and other supplements. Farmers rely on the Awassi's capacity to mobilize body reserves at these times. In countries where there are land pressures, and feed grain is imported, farmers are increasingly feeding low-roughage diets during lactation.

We conducted a factorial experiment with 48 individually penned ewes to compare responses to recent (1993) AFRC allowances with responses to the four types of underfeeding that farmers usually employ: (F1) feeding for maternal body-weight loss in the last three weeks of pregnancy; (F2) feeding to mobilize energy reserves in early lactation; (F3) feeding a reduced level of protein (similar to the older ARC 1984 allowances) in both early and mid lactation; (F4) feeding a low-roughage diet (calculated to provide 12 MJ of metabolizable energy per kg DM) in mid-lactation. Rations included cottonseed cake, barley, barley straw and minerals; a single change over design in mid-lactation was used for F4.

Ewes suckle lambs for 45 days, and hand milking starts gradually on day 32. Statistically significant performance details are shown in the table below. Underfeeding in late pregnancy (F1) had no lasting effect on the lamb or ewe. Reduction in energy levels during early lactation (F2) was equivalent to feeding 330 g less barley daily. This resulted in a smaller body weight loss than expected and a 90 g/day reduction in milk yield (the milk yield difference did not significantly persist into mid-lactation). The high-fiber diet (F4 control, 43–57 percent straw) increased the volume of milk by 10 percent and milk fat yield by 25 percent. Our results confirm the Awassi's tolerance to underfeeding during pregnancy and lactation, and emphasize the importance of dietary roughage.

Time	Effect observed	fed	Requirement under	SE of difference	Significance of probability
F1: Fed for maternal body weight loss in last 3 weeks of pregnancy					
Day -24 to-3	Body wt gain, kg	2.70	0.67	0.460	0.0001
Days 18–59	Body wt loss, kg	-2.97	-1.48	0.494	0.0046
Days 0–42	Lamb growth, g/day	262	247	8.8	0.093
Days 46–59	Milk yield, g/day	838	773	54.2	0.24
F2: Fed for 0.15 kg/d body weight loss (assuming constant milk yield) on days 18–59					
Days 18–59	Dietary ME, MJ/day	14.9	10.8		
Days 18–42	Lamb growth, g/day	236	212	9.3	0.014
Days 18–59	Body wt loss, kg	-1.29	-3.16	0.474	0.0003
Days 46–59	Milk yield, g/day	862	749	52.9	0.039
F3: Fed ARC rather than AFRC protein levels on days 18–101					
Days 18–101	Protein, g/kg DM	170.6	136.8		
Days 46–59	Milk yield, g/day	831	780	52.7	0.34
Days 60–101	Milk yield, g/day	510	477	50.9	0.52
	Milk protein, g/l	51.81	50.44	0.885	0.13
F4: Fed a low-fiber diet (ca. 10 % straw) on days 60–101 (change-over on day 81)					
Days 60–80	Milk yield, g/day	541	485	33.4	0.11
Days 81–101	Milk yield, g/day	373	346	18.4	0.16
Days 60–101	Milk fat, g/l	73.4	64.5	1.05	0.0001
	Milk protein, g/l	50.93	52.24	0.396	0.003
	Milk solids, g/l	178.6	169.4	1.24	0.0001

—A. I. El Awad, A.V. Goodchild and O. Gürsoy
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Water Consumption and Grazing Halophytic Vegetation at Maragha (Syria)

Providing adequate fresh drinking water for grazing animals is essential for proper management and utilization of halophytes—especially in arid and semi-arid areas (Squires 1981). High salt content in halophyte foliage results in a higher water requirement for grazing animals (Wilson *et al.* 1969; Wilson 1974; Hassan *et al.* 1979; Gihad 1989). Higher water intake is required for urinary excretion of excessive salt.

In Maragha (north Syria) water consumption was measured in 1994 during March 6–9, July 3–6 and September 18–21, for Awassi sheep grazing unimproved rangeland and rangeland seeded with *Atriplex halimus* and *Salsola vermiculata*. During those periods, water consumption was recorded each day (for nine paddocks) on unimproved rangeland and on shrub-seeded pasture. Each paddock was grazed continuously by eight ewes. Water was offered to the animals in troughs (two meters long with 70–95 liter capacity). The troughs had lids and were filled exactly using a measuring scale. The lid was opened and sheep allowed free access to the water. The remaining water was measured and the trough was covered until the next reading. The process was repeated twice daily—in the morning and in the afternoon—for four days.

Water consumption by grazing animals was lowest in winter and highest in summer for the unimproved and the shrub-seeded pastures (Table 5). In March there was a significant interaction of pasture x stocking rate: water consumption (liter/ewe per day) under low, medium and high stocking rates was 2.4, 2.3 and 2.2 for the unimproved range, and 2.7, 3.1 and 2.2 for the shrub-seeded pasture, respectively. In July and September, however, the water consumption (liter/ewe per day) increased several fold, being greatest on the shrub-seeded pasture at 9.3 and 9.7, compared with unimproved range at 7.3 and 6.5. In both months, the stocking rate treatments had no significant effect on water consumption. The study will be repeated a second year in 1995.

Table 5. Water consumption (liter/ewe per day) by sheep at Maragha as affected by pasture type and stocking rates at different times of the year during 1994

Type of pasture	Stocking rate Low	Medium	High	Mean
		March 1994		
Unimproved range	2.4	2.3	2.2	2.3
Shrub-seeded pasture	2.7	3.1	2.2	2.7
Mean	2.6	2.7	2.2	
SEM type of pasture		0.27		
stocking rate		0.21* (D.F. Error 8)		
pasture x stocking		0.30* (D.F. Error 8)		
		July 1994		
Unimproved range	7.7	7.1	7.0	7.3
Shrub-seeded	10.1	9.0	8.8	9.3
Mean	8.9	8.1	7.9	
SEM type of pasture		0.22 * (D.F. Error 2)		
stocking rate		0.39		
pasture x stocking		0.56		
		September 1994		
Unimproved range	7.3	6.1	6.0	6.5
Shrub-seeded	9.7	9.8	9.6	9.7
Mean	8.5	8.0	7.8	
SEM type of pasture		0.11 ** (D.F. Error 2)		
stocking rate		0.39		
pasture x stocking		0.56		

— A.E. Osman and N. Murad

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Sown Pasture and Forage Production
(MTP 94–98/Project 16)

Higher Milk Yield and Lamb Growth on Pastures Sown with Fodder Shrubs at Maragha (Syria)

Table 1. Maragha 1994 milk yield in kg per group of eight ewes (15 weeks lactation) as affected by pasture type and stocking rates.

Type of pasture	Low	Medium	High	Mean
Unimproved range	466	378	338	394
Shrub-seeded pasture	998	956	454	803
Mean	732	667	396	
SEM type of pasture		16.4 ** (D.F. Error 2)		
stocking rate		25.0 ** (D.F. Error 8)		
pasture x stocking		35.3 ** (D.F. Error 8)		

The importance of fodder shrubs in degraded rangeland rehabilitation (in arid and semi-arid areas) is well known. Large areas have been planted with shrubs and protected from grazing in several countries of the WANA region. For example, in Syria, the shrub planted area is increasing annually and is currently approximately 0.1 million hectares. The biggest remaining challenge is to manage these plantations in a sustainable way, with benefits for the environment and livestock production. In Maragha (in northern Syria, where the annual rainfall is 150 mm) a joint project with ICARDA, the Steppe Directorate of the Syrian Ministry of Agriculture and ACSAD conducted tests on varying grazing intensities on pastures established with *Atriplex* spp. and *Salsola vermiculata*. The study assessed the effect of shrubs on animal production (milk, body weight, birth rate and lamb growth rate) and on grazing availability at different times of the year. In 1994 (season rainfall 137 mm) results show that milk production during the 15 weeks of lactation in sheep grazing shrub-seeded pasture is twice as much (803 kg compared with 394 kg per group of 8 ewes) as the production of sheep grazing native unimproved pastures. The results in Table 1 show significant interaction between the type of pasture and the stocking rate: maximum milk yield from shrub-seeded pasture with low and medium stocking rates was 998 and 956 kg, respectively, compared with 466 and 378 kg from unimproved (control) pasture. Note that these results are better appreciated when expressed as yield per hectare: 55, 80 and 76 kg/ha for low, medium and high stocking rates, respectively, on the shrub-seeded pasture, and 26, 32 and 56 kg/ha for the unimproved control pasture. Lamb growth rate and final weight (after nine weeks) were also significantly higher (five percent) on the shrub-seeded pasture than on the unimproved pasture (Table 2). The available feed data (Table 3) indicate that the shrubs contribute effectively to grazeable feed throughout the year, most notably in winter and summer. In October 1994, grazeable feed was estimated at 66 kg/ha on unimproved pasture, compared with 700 kg/ha on shrub-sown pastures.

Table 2. Lamb body mass (kg) nine weeks after lambing on Maragha rangeland during 1994 (as affected by pasture type and stocking rate).

	Stocking rate			
Type of pasture	Low	Medium	High	Mean
Unimproved range	21.3	19.4	19.0	19.9
Shrub-seeded pasture	21.7	21.6	21.5	21.6
Mean	21.5	20.5	20.2	
SEM type of pasture	0.21 * (D.F. Error 2)			
stocking rate	0.42			
pasture x stocking	0.59			

Table 3. Stocking rate and pasture type affects on available[1] forage (outside cages) in April and October 1994 at Maragha, north Syria.

	Stocking rate			
Type of pasture	Low	Medium	High	Mean
	April 94			
Unimproved range	81	70	48	66
Shrub-seeded pasture	511	562	272	448
Mean	296	316	160	
SEM type of pasture[2]	29.9* (D.F. Error 2)			
stocking rate	75.8			
pasture x stocking	107.2			
	October 94			
Unimproved range	71	79	21	66
Shrub-seeded pasture	960	858	278	669
Mean	516	469	149	
SEM type of pasture	10.2* (D.F. Error 2)			
stocking rate	120			
pasture x stocking	169			

1. All herbaceous material plus leaves and twigs on shrubs but not woody parts.
2. *, ** Means are significantly different at 5 percent and 1 percent, respectively.

Note that during 1994, herbage yield (kg/ha) and grass and forb plant number (per m^2) on unimproved range showed little or no advantage over shrub-seeded pasture. On the unimproved range the April herbage yield was 66.5 kg/ha and the plant number was 724 per m^2 compared with 78.1 kg/ha and 578 per m^2 for the shrub pasture.

The seed bank data (Table 4) indicate no significant differences between native and shrub-seeded pasture. This is in contrast to the results from earlier seasons (PFLP 1992) where grass and forb seeds were significantly greater on unimproved range than on shrub-seeded pasture. If seed bank improvement continues it may result in grasses and forbs making a greater contribution to available forage, further increasing the value of shrub seeded pasture.

Table 4. Number of herbaceous species seeds and bulbs/m^2 on the top three cm of soil in two pastures, under three stocking rates, in Maragha, June 1994.

	Seed Stocking rate[1]			
Type of pasture	low	medium	high	mean
Unimproved range	1217	315	1179	904
Shrub-seeded pasture	3365	3371	842	2526
Mean	2291	1843	1011	
SEM type of pasture		1075		
stocking rate		636		
pasture x stocking		900		
	Bulb Stocking rate			
Unimproved range	1777	1344	1538	1553
Shrub-seeded pasture	1699	1093	1023	1272
Mean	1738	1219	1280	
SEM type of pasture		134		
stocking rate		462		
pasture x stocking		654		

1. Low = 2.25; medium = 1.5 and high = 0.75 ha/sheep.

—*A.E. Osman, F. Bahhady, N. Hassan and N. Murad*

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Micronutrient Deficiencies in Turkey, Syria and Jordan

In the first half of February 1994, a survey was carried out by Dr. Colin L. White of the CSIRO Division of Animal Production, Western Australia. The purpose of the six-week consultancy was to assess the micronutrient status of sheep in Syria, Jordan and Turkey. Blood samples were taken from sheep in eighteen flocks and analyzed for vitamin A, vitamin E, vitamin B_{12}, copper, selenium and zinc. Feed and pasture samples were also taken at each site and analyzed for N, Na, K, P, Ca, S, Mg, Mn, Zn, Cu, Fe, and Mo.

There was symptomatic evidence (supported by laboratory analyses) of widespread deficiencies of sodium and vitamin E. There was also symptomatic and analytical evidence of copper deficiency in the Euphrates valley near Deir ez Zor, probably resulting from high sulfur intake. Selenium deficiency was identified mainly in Turkey. Zinc deficiency appeared widespread (on the basis of plasma zinc values). It appears that in many locations current feeding practices do not meet mineral and vitamin requirements, and diets are deficient in both macro- and micronutrients.

—C. White, CSIRO, Western Australia.
—F. Bahhady, A.V. Goodchild, ICARDA.

Table 1. Frequency distribution plasma micronutrient levels in sheep in Jordan, Turkey and three zones of Syria, μg/ml unless stated.

	Very defic	Low Defic	Low normal	High normal	High
Vitamin A (Retinol), μg/ml	<0.2	0.2–<0.4	0.4–<0.8	≥0.8	
Jordan, North & Central	0	0	13	17	
Syria, East & Central	0	2	27	1	
Syria, West	1	0	15	3	
Syria, Northwest	0	0	12	8	
Turkey, South	0	7	32	1	
Vitamin E (α-tocopherol), μg/ml	<0.5	0.5–<1.0	1.0<2	2–<5	
Jordan, N & C	0	4	26	0	
Syria, E & C	5	12	4	9	
Syria, W	0	6	12	1	
Syria, NW	0	2	13	5	
Turkey, S	1	4	23	13	
Vitamin B_{12} (μg/litre)	<0.3	0.3–<0.6	0.6<1.5	1.5–<3	≥3
Jordan, N & C	0	0	7	18	4
Syria, E & C	1	3	7	12	7
Syria, W	0	0	1	11	8
Syria, NW	0	0	1	7	12
Turkey, S	0	0	4	19	17
Selenium (in whole blood)	<.05	0.05–<.15	0.15–<0.3	≥0.3	
Jordan, N & C	0	0	26	4	
Syria, E & C	0	9	17	4	
Syria, W	0	9	3	8	
Syria, NW	1	18	1	0	
Turkey, S	16	9	4	10	
Copper, μg/ml	<0.3	0.3–<0.5	0.5–<1.0	1.0–<1.5	≥1.5
Jordan, N & C	0	0	7	17	3
Syria, E & C	8	3	11	7	0
Syria, W	0	0	5	13	2
Syria, NW	0	0	3	16	0
Turkey, S	0	0	28	9	2
Zinc, μg/ml	<0.6	0.6–<0.7	0.7–<0.8	0.8–<0.9	≥0.9
Jordan, N & C	5	6	9	3	7
Syria, E & C	4	2	9	140	
Syria, W	3	5	4	8	0
Syria, NW	3	45	3	6	4
Turkey, S	9	15	5	8	3

On-Farm Trials Comparing Forage Legume/Barley Rotation to Fallow/Barley Rotation and Continuous Barley in Northwest Syria

Summary

On-farm forage legume trials were conducted for seven cropping seasons in northwest Syria, where annual rainfall is about 270 mm and barley is the most common crop. Trials involved farmers in studies of the benefits of using common vetch (*Vicia sativa* [V]) or chickling (*Lathyrus sativus* [C]) instead of the fallow year in a barley/fallow rotation (F) or introducing forage legumes into continuous barley (B) monoculture. There were four rotations, BF, BB, BV and BC, with both phases represented each year. The trials were replicated on six to eight farms, depending on the year, and each site covered four ha equally divided between the two phases. Each year 30–60 kg/ha N was applied to half the barley area. Several farmers chose to graze lambs on the vetch and *lathyrus* crops in spring.

Feed yield from both rotation phases was greatest with the BV and BC rotations. Mean dry matter yields for seven years totaled for both phases of each rotation were: 2.91 (BF), 4.82 (BB), 5.02 (BC) and 5.32 (BV) t/ha, respectively, with an SE of ±0.1 t/ha. Total crude protein output was twice as high for rotations including legumes as for the average output of BF and BB. The BV rotation gave the highest output of metabolizable energy. Nitrogen application increased barley DM yields by about a ton for all rotations. There were no nitrogen x rotation interactions. Lamb weight gains averaged 194 kg/ha per year.

Farmers believe the growing of forage legumes will not become widespread until inexpensive and efficient mechanized harvesting is available to avoid the high cost of hand labor. Drought and cold tolerance, early maturation and high harvest index enhance farmer interest in forage legumes. These attributes are being studied by ICARDA's forage breeders. The grazing option is attractive because it eliminates the need for weeding and hand-harvesting, which are both expensive, and it reduces drought risk during flowering and maturity. However, a part of the forage legume area must be kept to provide seed.

Introduction

Agricultural land pressures in several parts of west Asia force farmers to use non-sustainable cultural practices, such as cereal monoculture rather than the traditional cereal/fallow rotation. Addressing these problems was, and is, important in ICARDA's research approach to integration systems involving forage and cereal crops, livestock and pastures (Carter 1978). Research and development using fallow land to grow annual forage crops started over 20 years ago in the region (Halse 1993). On-station research has shown that forage crops increase soil nitrogen and organic matter (White *et al.* 1994).

On-farm testing of forage legumes, such as vetch (*Vicia* spp.) and chickling (*Lathyrus* spp.), was essential in getting farmers to adopt these crops in west Asia. Using on-farm trials to confirm information from on-station studies was also important. ICARDA's 1980 on-farm trials showed the potential of forage legumes grown on fallow land (Thomson 1984; Thomson *et al.* 1992), and confirmed that livestock could be integrated into these trials (Tully *et al.* 1985). These early studies developed the on-farm methodology, assessed the benefits of applying phosphate fertilizer, and yielded information about the viability of the technology.

Appraisal towards the end of the first series of on-farm forage and lamb grazing trials showed a need for greater farmer involvement. For this reason, the initial project ended after six cropping seasons (Thomson *et al.* 1992) and a new project started in a similar area (Tully 1984). The new project objectives are:

1) To use on-farm trials to compare grain, straw and feed energy output from the traditional barley/fallow rotation with barley/barley and barley/forage rotations.
2) To compare the benefits of nitrogen application during the barley phase of the rotation to application following the legume, fallow or barley phase.
3) To assess the growth of lambs grazing the forage crops.
4) To monitor farmers' opinions of the new technology and its adoption potential.

This paper focuses on rotation effects on feed and lamb growth and nitrogen application benefits. Papers in progress describe the adoption potential of forage legumes and economic benefits of different rotations.

Project Background

Baseline surveys were conducted intermittently in northwest Syria between 1978 and 1983 (Tully 1984). The 1983 Tully survey showed that about half of the cultivable land was in a barley/fallow rotation. Almost no legumes were grown in the shallow (<40 cm deep) and stony soils covering roughly the southern half of the area, where annual rainfall is less than 300 mm. In the northern half of the area, where there are deeper soils combined with higher rainfall, nine percent of the land was sown to lentil, chickling and vetch.

There have been many changes since the 1983 survey. The most troubling change has been the widespread replacement of the barley/fallow system with continuous barley cultivation. This change is related to several factors:

1) Pressures are mounting to increase feed supplies, since the traditional grazing lands are producing less feed.
2) The multi-purpose nature of barley makes it attractive to farmers. It can provide green grazing in spring, it can be conserved as grain and straw for winter, and the stubble can be grazed after harvest (Jones 1990).
3) The use of tractors and combine harvesters has increased plowed and harvested areas. With little fallow land for grazing, more sheep and goat flocks are concentrated on the limited remaining grazing areas and are more dependent on barley.
4) Some farmers associate barley monoculture with a disease or nutrient deficiency that causes plants to develop normally but bear no grain at maturity. Pathologists have not yet found the cause.

At the time of the 1983 survey, it was not anticipated that in ten years the barley/fallow system would be replaced by barley monoculture. The survey recommended that forage legumes should be grown on fallow land to provide additional animal feed. The survey recognized the agronomic and economic problems associated with these legumes, including high start-up costs due to expensive seed and the need for high seeding rates for a successful crop (181, 149 and 119 kg/ha for chickling, vetch and lentil, respectively). Yields are generally low (0.4 t/ha grain and 1.0 t/ha straw) and yield variability high. Time is short for hand-harvesting the legumes before they dry up and shed leaf and seed. Successful harvesting requires a concentrated mobilization of 10–15 laborers per hectare, coinciding with lentil harvest. A non-shattering legume could increase the time available at harvest (Abd El Moneim 1993b). At present only landraces are used.

In an earlier project in the Breda area (southeast of Aleppo in a slightly lower rainfall zone) farmers preferred to use the crop for seed and straw, rather than as hay or for grazing (Thomson *et al.* 1992). The reasons were the high cost and low availability of seed, the need for straw to decrease winter feed deficits, the difficulty of making hay (Rihawi *et al.* 1987), and the lack of machinery.

Materials and Methods

Project site and climate

The project started in October 1986 near El Bab, a town in Aleppo Province in northwest Syria. Trials were replicated on six to eight farms, and the plots were located on mostly shallow (<20 cm) soils, although a few sites had medium (20–40 cm) and deep (>40 cm) soils. The shallow soils are classified as *Petrocalcic Xerochrepts*, while the deeper soils are described as *Calcixerollic Xerochrepts*. Most plots had been sown to barley during the previous year, and all farms were located within a five km radius. Crop yield and lamb performance data were collected from seven cropping seasons.

Table 1. Monthly rainfall (mm) data from El Bab during the trial.

Mo	86/87	87/88	88/89	89/90	90/91	91/92	92/93	Mean
Oct	2	63	55	5	2	22	0	21
Nov	39	53	50	38	50	27	53	44
Dec	44	57	56	43	16	70	0	41
Jan	84	68	0	39	46	20	39	42
Feb	20	63	0	56	29	65	47	40
Mar	67	83	40	22	66	0	43	46
Apr	6	78	0	4	49	0	16	22
May	0	0	0	0	17	36	16	10
Total	262	465	201	207	275	240	214	266

A rain gauge was installed on one farm. Rainfall was below the average of 266 mm in four of the seven years (Table 1). The first year was close to average; the second year had a record high rainfall. The third year had very low rainfall and very poor rainfall distribution. Rainfall in the fourth and fifth seasons was also below or about average but with better distribution. The sixth year had 36 mm of rainfall, too late in the season to be useful to barley. The final year was marked by erratic early rainfall and a low season total.

Farmer Selection and Involvement

Preparing land, sowing, fertilizing and harvesting

Tractors with ducksfoot cultivators (either belonging to or hired by farmers) and farm labor were used to prepare the land and sow crops. The seeding rate for the local barley landrace (Arabi *abiad*) was 120 kg/ha. Farmers who used forage for lamb grazing sowed 160 kg/ha uninoculated feed legume seed, if they chose to use the forage legume for seed and straw, they sowed 140 kg/ha. The latter option was preferred on deeper soils. Local landraces of vetch and chickling were used, and were sown by drill.

All fertilizer was applied in the barley phase. Triple superphosphate was hand-broadcast depending on the phosphorus content of the soils: soils with >15 ppm (Olsen P) were not fertilized; soils with 6–10 ppm were given 14.4 kg/ha P; and soils with <6 ppm were given 28.8 kg/ha P. Ammonium nitrate was hand-broadcast on half the barley crop in late winter (January or February), depending on the total nitrogen status of the soils: soils with >1500 ppm were not fertilized; soils with 1000–1500 ppm were given 10 kg/ha N; and soils with <1000 ppm were given 20 kg/ha N.

Feed legumes harvested for seed and straw were hand-pulled when close to physiological maturity, left in small piles to dry, transported, and mechanically threshed using farm labor. The local barley landrace (Arabi *abiad*) was sown and harvested similarly.

Crop rotations, experimental design and trial management

The project compared fallow (F) or barley (B) with common vetch (*Vicia sativa* [V]) or chickling (*Lathyrus sativus* [C]) in rotation with barley. The rotations were therefore BF, BB, BV and BC, laid out in a strip-split plot design with V, C and B as main plots (≈1 ha each) in the forage and cereal phases (Fig. 1). In the cereal phase, ammonium nitrate was applied in a strip halving the main plots. The fallow and continuous barley plots were located within a central strip (150x10 m) separating the forage and cereal phases of the trial. On each farm, the cereal and forage phases were not necessarily adjacent. Harvest operations were managed by the farmers in both forage and cereal phases of the trial.

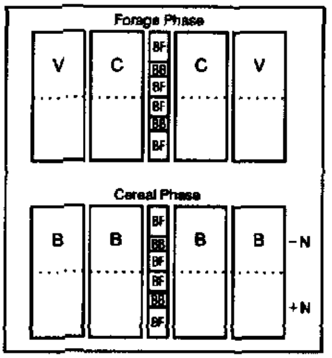

Figure 1. General representation of the plot layout with vetch (V) and chickling (C) as main plots in the forage phase, barley (B) in the cereal phase and barley/fallow (BF) and barley/barley (BB) located in a central strip between the *forage legume rotations. Nitrogen was only applied in the cereal* phase.

Measurements and procedures: herbage, grain and straw yields

Dry matter yields for hay, seed and straw were all estimated using five samples (1 m^2 per plot) that were cut or hand-pulled at ground level and dried at 60° C. Note that if farmers selected the grazing option an area of the field was protected and harvested for grain and straw yields at maturity. DM yield was converted into yield of metabolizable energy and crude protein (CP) using concentrations of ME and CP determined at ICARDA.

Grazing management

On farms that chose the grazing option, vetch and chickling plots were both grazed by a single lamb group. Each lamb received a daily supplement of 300 g barley grain.

Soil samples

Each year in October, in all treatments, soils were sampled to a depth of 20 cm and analyzed for organic matter (Olsen phosphorus and Kjeldahl nitrogen). The data obtained were used to determine fertilizer recommendations for the following season.

Interviews and economic analysis

During the cropping season, farmers were interviewed to record field operation costs and for their opinions of the feed legumes. Total sales (revenue from lambs, grain and straw) and direct costs (seed, fertilizer, cultivation, labor and harvesting) were recorded.

Statistical analysis

Analysis of variance (ANOVA) was used to evaluate error terms and effects of rotation, nitrogen, rotation x nitrogen, and interaction of the above with time components (using the methods of Yates [1954], and Cady and Mason [1964]).

Table 2. Mean dry matter yields for barley grain and straw harvested from barley/vetch, barley/chickling, barley/barley and barley/fallow rotations in 1986/87 to 1992/93. Mean nitrogen level is also shown.

	Year							
	86/87	87/88	88/89	89/90	90/91	91/92	92/93	Mean
Rain (mm)	262	465	201	207	275	240	214	266
Rotation				Barley grain (t DM/ha)				
BV	0.83	1.46	1.04	0.92	1.39	1.13	1.54	1.19
BC	1.11	1.64	1.06	0.86	1.45	1.11	1.53	1.25
BB	1.01	1.30	0.74	0.74	1.20	0.85	0.60	0.92
BF	0.95	1.38	1.20	1.13	1.48	0.99	0.74	1.12
SE				±0.079				±0.041
Rotation				Barley straw (t/ha DM)				
BV	2.20	2.68	1.93	1.60	1.85	1.16	1.52	1.85
BC	2.57	2.95	2.06	1.56	1.54	1.17	1.58	1.92
BB	2.40	1.96	1.46	1.35	1.78	0.84	0.56	1.48
BF	2.28	2.47	1.88	2.07	1.95	1.07	0.66	1.77
SE				±0.14				±0.066
Nitrogen				Barley grain (t DM/ha)				
N-	0.80	1.34	0.99	0.85	1.35	1.01	1.04	1.05
N+	1.15	1.55	1.03	0.97	1.40	1.03	1.17	1.19
SE				±0.048				±0.012
Nitrogen				Barley straw (t/ha DM)				
N-	1.84	2.25	1.71	1.42	1.65	1.01	0.98	1.55
N+	2.89	2.78	1.95	1.87	1.91	1.11	1.18	1.96
SE				±0.089				±0.025

In 1985/86, the previous crop was barley.

Results and Discussion

Barley yields

The farms (considered replications in the variance analysis) were nearly always a significant source of variation. Grain and straw yields of barley were influenced by nitrogen and rotation but there was no rotation x nitrogen interaction. Nitrogen application increased cereal grain yield by about 10 percent, but in three out of seven years there was no grain increase from fertilizer. The straw response to N fertilization was more pronounced, with a 9–36 percent increase (the largest improvement in wetter years). Overall, N increased total barley yield by an average of 0.54 t/ha (Table 2).

The barley following chickling and vetch produced nearly half a ton more total DM yield than the barley after fallow or continuous barley. Over the years of the experiment, averages suggest that nitrogen fixed in legume rotations was used by the grain and straw of the barley phase. However, rotation performance (for grain and straw yield) differed depending on year. Likewise, the efect of nitrogen on barley yield differed with time, but much of the variation was attributed to rainfall (Tables 1 and 2).

Grain and straw yields for BF rotations were greater than for BB, except in 1986/87 (note that in the first year of the trial barley was the preceding crop for all treatments). Averaged over all years, BF provided 18.5 percent higher barley grain yield and 16.4 percent higher straw yield than BB. However, in a rotation with fallow, a crop yield is obtained only once every two years. There were a few instances when the barley grain and straw yield after fallow or barley was better than after forage legumes. Most of the time barley did better after legumes (particularly towards the end of the experiment) probably due to accumulation of soil N and organic matter from the legumes (White *et al.* 1994). In 1988/89, grain yield after fallow was probably stimulated by water storage in the soil from a record rainfall the previous year.

Forage legume yield

For all trial years, vetch and chickling grain yields were not statistically different ($P>0.05$), but straw yield was half a ton greater from vetch (Table 3). Farmers using forage legumes for grain and straw preferred chickling because of its higher harvest index, as reported in similar trials (Thomson *et al.* 1992; Abd El Moneim and Cocks 1993). In Breda, where rainfall is similar but soils are much deeper, Thomson *et al.* (1992) found that vetch and chickling produced similar amounts of straw. Comparison of both trials in the same high rainfall year (1987/88) shows about 0.5 t/ha greater grain yield and 1.5 t/ha greater straw yield at Breda (for P-fertilized forage legumes).

Table 3. Mean dry matter yields for legume grain, straw and hay harvested from barley/vetch and barley/chickling rotations in 1986/87 to 1992/93.

	Years							
Rotation	*86/87*	*87/88*	*88/89*	*89/90*	*90/91*	*91/92*	*92/93*	*Mean*
Rain (mm)	262	465	201	207	275	240	214	266
			Grain (t/ha DM)					
BV	0.69	0.86	0.18	0.24	0.39	0.28	0.44	0.44
BC	0.59	1.10	0.37	0.20	0.47	0.28	0.48	0.50
SE				±0.061				±0.027
			Straw (t/ha DM)					
BV	1.98	3.44	1.05	1.42	3.09	0.66	1.10	1.82
BC	1.71	3.00	1.02	0.54	2.00	0.48	0.66	1.34
SE				±0.12				±0.047
			Hay (t/ha DM)					
BV	1.09	3.75	0.84	0.89	0.78	0.75	0.82	1.27
BC	0.89	3.16	0.77	0.51	0.47	0.44	0.49	0.96
SE				±0.101				±0.05

Farmers who harvested seed and straw for winter sheep feed found that chickling straw was better than vetch straw (sheep preferred either over lentil straw).

DM, CP and ME summed across both phases of the rotation

Total DM yield, CP and ME were affected by rotation treatment and nitrogen application, but there were no interactions. However, there were interactions of rotation and nitrogen with time.

Nitrogen fertilizer increased both DM yield and harvested CP by an average of about 10 percent (Table 4), but in low rainfall years there was no response. Seasonal variation was pronounced, however, in years with low rainfall; nitrogen remained in the soil and was probably available the following year.

Farmers appreciated the differences between fertilized and unfertilized barley. They also saw that there were big differences between continuous barley and the other options, which was the most compelling argument for a rotation system. In addition, the continuous barley fields were often subject to insect infestation, further convincing farmers of the need for a rotation system.

Table 4. Rotation and nitrogen fertilizer effect on: air dry matter yield, crude protein, and metabolizable energy (grain and straw from both phases of four crop rotations 1987–93).

	Year							
	86/87	87/88	88/89	89/90	90/91	91/92	92/93	Mean
Rain (mm)	262	465	201	207	275	240	214	266
Rotation				Dry Matter (t/ha)				
BV	5.56	8.63	4.13	4.25	6.73	3.26	4.70	5.32
BC	5.96	8.69	4.42	3.23	5.46	3.02	4.36	5.02
BB	8.15	4.81	3.53	3.90	5.93	3.30	4.10	4.82
BF	3.13	4.03	3.07	3.21	3.43	2.00	1.49	2.91
SE	±0.39							±0.096
Nitrogen								
N-	5.01	6.18	3.64	3.35	5.24	2.83	3.50	4.25
N+	6.38	6.90	3.93	3.94	5.54	2.96	3.83	4.78
SE	±0.36							±0.068
Rotation				Crude Protein (kg/ha)				
BV	217.3	338.2	137.8	146.9	243.8	135.4	197.6	202.4
BC	223.3	356.3	160.2	112.3	218.2	126.1	186.4	197.5
BB	211.6	134.6	99.9	108.6	179.6	113.9	127.6	139.4
BF	80.2	112.1	89.3	90.2	104.8	64.0	50.7	84.5
SE				±13.1				±4.09
Nitrogen								
N-	166.8	226.0	118.5	107.4	183.5	108.3	135.4	149.4
N+	199.4	244.6	125.2	121.6	189.8	111.4	145.7	162.5
SE				±11.8				±2.89
Rotation				Metabolic Energy (Megajoules x 1000) per hectare				
BV	21.39	33.76	16.15	16.50	26.24	14.15	20.36	21.22
BC	23.41	35.01	17.65	13.03	22.72	13.27	19.29	20.63
BB	31.51	19.47	14.17	15.66	25.04	14.83	16.83	19.65
BF	12.00	16.17	12.61	12.92	14.56	8.81	6.74	11.97
SE				±1.52				±0.425
Nitrogen								
N-	19.55	24.72	14.61	13.43	21.62	12.53	15.10	17.36
N+	24.61	27.49	15.68	15.63	22.67	13.00	16.51	19.37
SE				±1.39				±0.300

The mean values for the seven years of the trial suggest that BV is the most productive rotation biologically, giving 0.3 t/ha DM more than BC and 0.5 t/ha DM more than BB. The harvested protein average of BV more than doubled the total CP/ha of the BF and BB averages. The complete BF rotation gave the lowest DM yield.

Lamb fattening using forage legumes

Table 5 shows the lamb average live weight gains during legume grazing for seven years on five farms (generally having shallow soils with low seed and straw production potential). Although vetch and chickling were not grazed separately, farmers reported that grazing lambs chose chickling before vetch.

Table 5. Performance of lambs grazing forage legumes between 1986/87 and 1992/93.

	Year							
Measurement	86/87	87/88	88/89	89/90	90/91	91/92	92/93	Mean
Rainfall (mm)	262	465	201	207	275	240	214	266
Grazing days	33	48	24	31	40	21	32	33
Number of lambs/ha	30	39	29	36	37	25	36	33
Daily gain (g/lamb)	210	172	139	186	177	217	204	186
Liveweight[1] (kg/ha)	200	324	104	208	209	107	205	194

[1] Note: *Lambs received 300 g barley grain each day.*

Data are averages of five farms, all with shallow soils (<20 cm).

In the El Bab region, grazing lambs on forage legumes fits nicely into the forage calendar because it provides high quality feed after weaning. Lambs averaged a 186 g/day growth rate for an average of 33 days (usually from mid-March to mid-April). This coincides with the period on marginal lands when native legumes need time to flower and set seeds (Osman *et al.* 1991). By weaning lambs early enough to graze forage legumes and leaving ewes on natural pasture (supplemented with modest amounts of straw and barley) the farmer can reduce pressure on natural grazing land and, at the same time, sell more milk products.

Conclusions

Other study area farmers are now sowing forage legumes. Although the yield of barley grain after fallow is greater than under the other rotations, the farmers recognize that the animal feed yield from the whole cycle is greater from the rotations without fallow. This is illustrated in Table 4, which compares the production of animal feed as CP and ME from the four rotations averaged over the years. Forage legume rotations compared favorably with continuous barley rotations. For example, for the BV rotations, total production of CP and ME was 45 percent and eight percent higher, respectively, than for BB.

The barley/legume rotation resulted in higher barley crop yield because of the legume's N contribution to the soil, and a reduced incidence of insects and disease compared to continuous barley. Nevertheless, the El Bab farmers who chose to harvest seed and straw instead of grazing, say that the growing of forage legumes will not become widespread until inexpensive and efficient mechanized harvesting methods are available to avoid the high cost of hand labor. Some promising methods exist. Farmers who wish to save the maximum amount of straw for animal feed can cut with a sicklebar mower at maturity (to avoid leaf drop and pod shattering), after which the crop can be gathered for threshing at a convenient location. However, mechanized harvesting faces problems: in dry years plants are short, resulting in poor straw recovery; in wet years the forage legumes tend to lodge, doubling the cutting time, because cutting can only be against the lodging direction. Farmers still prefer mechanized over hand-harvesting because of high labor costs.

Developing non-shattering varieties of forage legumes is an alternative. Drought and cold tolerance, early maturation and higher harvest index would also increase farmer interest in forage legumes.

Some farmers believe that grazing makes better sense than growing legumes for seed and straw, especially in shallow soil. There are several reasons for this opinion:

1) Grazing eliminates the need for weeding. This is important in the El Bab area where there are no selective herbicides available for broadleaf weeds in forage legumes.
2) Grazing is less expensive because of savings from hand-harvesting.
3) Grazing legumes before normal maturity shortens exposure to climatic risk.

As far as we know, forage legumes were not previously grown in the El Bab area. The trials include several practices that are not traditional in the area. For example, Tully (1984) reported that threshing was often a problem because thresher owners were usually geared for barley harvesting, and forage legumes require a different threshing calibration and speed. Legumes are now more commonly grown because operators' skill and experience have increased, and locally available machines have improved in design and efficiency.

Recommending a 120 kg/ha barley seeding rate and a soil test based fertilizer application has resulted in much less seed and fertilizer being used. It is encouraging that most farmers in the trial, who formerly sowed 220 kg/ha barley and applied 60 kg/ha N, have now adopted lower rates on their farms (based on trial results). In the El Bab area, phosphate fertilizer is not normally used, but attitudes are changing with the introduction of legumes.

Although economic analysis of the rotations is not part of this report, we will assess whole farm profitability (Nordblom *et al.* 1992, 1994) for the different rotations in the future. We will also examine the profitability of using forage legumes for seed and straw or as a grazed crop for lamb fattening.

We are currently performing a detailed economic analysis of the different rotations for profitability based on changes such as mechanical harvesting (Erskine *et al.* 1991) and promotion of improved varieties of vetch (Abd El Moneim *et al.* 1988; 1990a; 1990b; Abd El Moneim 1993a) such as: non-shattering vetch (Abd El Moneim 1993b), new lathyrus varieties (Abd El Moneim and Cocks 1993) and other potentially valuable legume species (Abd El Moneim 1992).

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Preliminary Results on the Development of Integrated Crop/Livestock Production in Algeria

Introduction

In Algeria, integration of crop and livestock production is a traditional system based on subsistence farming practices. Poorly fed animals are associated with poorly managed crops without understanding exactly how to improve the reciprocity and profitability.

To achieve a more harmonious integration of cropping and animal production, a project was initiated in the main cereal and sheep production zone of eastern Algeria. The experiment is at the Institute Technique des Grandes Cultures (ITGC) El Khroub Station (near Constantine). As a long-term rotation trial comparing current to recommended practices, it shows the benefits of improved integrated system management to farmers, extension staff and policy makers.

Materials and Methods

The monthly rainfall for the first three seasons of the experiment is shown in Table 1. The treatments being studied are two types of pasture resources in a biennial rotation with wheat: improved pasture sown with locally adapted annual *Medicago* species versus the traditional weedy fallow.

Table 1. Rainfall at ITGC El Khroub Experimental Station.

Month	1991/92	1992/93	1993/94
September	43.7	22.1	0.0
October	88.3	22.9	11.9
November	22.5	116.1	22.0
December	21.3	192.8	127.0
January	52.8	49.0	66.0
February	33.2	58.0	88.0
March	49.5	26.0	36.0
April	135.0	12.3	79.0
May	60.1	55.0	6.0
June	10.7	15.0	0.0
July	17.3	2.9	0.0
August	10.3	4.8	0.0
Total	544.7	576.9	435.9

The medic pasture is a mix of five local species. At the beginning of the experiment (1992), identical seed lots of 30 kg (composed of equal parts of medic species) were prepared for each medic establishment phase. Sowing rate was 30 kg/ha with the following proportions from each species by weight: *M. truncatula* (54 percent), *M. orbicularis* (23 percent), *M. polymorpha* (11 percent), *M. ciliaris* (nine percent) and *M. aculeata* (three percent).

The experimental design is a randomized complete block with three replications, laid out as a strip-split plot with weedy fallow or medic as main plots; the sub-plots are composed of nitrogen fertilizer stripped across one half of the wheat plots in the cereal phase. The main plots were one ha in size.

In the pasture phase, weedy fallow and medic pastures are grazed with 12 ewes/ha.

Observations and measurements are made of dry matter production and botanical composition in both types of pasture. Seed production is measured for medic species. Sheep performance and grazing days are monitored.

For dry matter production and botanical composition estimations, samples are taken at the start of grazing, with a second sample taken during medic flowering. A total of 12 samples (0.25 m^2) are taken in each pasture for each sampling. Plants are identified, dried and weighed.

Each year in June, new legume seed yields are evaluated by sampling 20 quadrats (0.25 m^2) in the weedy fallow and medic plots. Pods are separated by species and threshed, then the seeds are weighed.

In plots planted to wheat in 1993/94, medic seed banks were quantified by taking 40 soil cores (12.6 cm diameter) to a depth of 10 cm in each replication.

Results and Discussion

Botanical composition and pasture yield

Sowing locally adapted medics increased the legume percentage and dry matter contribution in the pastures, making them much more productive than weedy fallow. At the start of grazing, legumes represented approximately 50 and 15 percent of the dry matter for medic and weedy fallow pastures, respectively (Table 2). At flowering, the legume biomass in the medic pasture represented two thirds of the total dry matter, compared to one third in the weedy fallow.

The total plant number was generally larger in the first sampling than in the second (Table 2). This may be explained by the disappearance of short-lived plants such as *Lamium* spp. and *Veronica* spp. The number and composition of grasses did not vary greatly between sampling periods in either treatment. The grass found most frequently was *Bromus* spp., which can compete with newly established medic and become a serious problem if grazing is not managed specifically to reduce the annual brome in the pasture.

Table 2. Botanical composition and dry matter yields of grass, legume and weed components of the medic and weedy fallow pastures for the two medic establishment seasons.

			1992/93			
	At beginning of grazing			At flowering stage		
TRT	No/m^2	(%)	g/m^2	No/m^2	(%)	g/m^2
FAL						
G	52	(13)	-	44	(24)	164
L	64	(16)	-	44	(24)	28
O	316	(71)	-	92	(52)	164
Tot	432	(100)	-	180	(100)	336
MED						
G	40	(9)	-	44	(9)	160
L	276	(61)	-	388	(84)	308
O	140	(30)	-	32	(7)	28
Tot	456	(100)	-	464	(100)	496
			1993/94			
FAL						
G	80	(20)	80	56	(30)	154
L	60	(14)	14	80	(42)	66
O	268	(66)	40	52	(28)	34
Tot	408	(100)	134	188	(100)	254
MED						
G	60	(11)	60	56	(15)	136
L	268	(47)	74	232	(65)	180
O	236	(42)	48	72	(20)	159
Tot	564	(100)	182	360	(100)	475

Treatment (TRT), Medic (MED), Fallow (FAL), Grass (G), Legume (L), Others (O), Total (Tot)

Medic seed production

The two medic pasture establishment seasons favored certain medic species, and, due to climatic conditions, gave different yields each year. Even though the same seed lots were used to establish each phase, *M. orbicularis* produced the most new seed in the 1992/93 season, while *M. truncatula* was most productive in 1993/94. The second season had less rainfall, started later and finished earlier.

The mixture stabilized pasture production from year to year. *M. orbicularis* produced high seed yields in the more favorable first season while *M. polymorpha* (and to a lesser extent *M. ciliaris*) produced significant seed yields in both years. The sowing rate was less than five kg/ha for each species (Table 3). The evolution of the seed bank will be interesting.

Table 3. Species contribution to the composition of seed yield for medics established in 1992/93 and 1993/94.

	Original seed		1992/93		1993/94	
Species in mixture	kg/ha	%	kg/ha	%	kg/ha	%
M. truncatula	16.2	54	309	39	228	49
M. orbicularis	6.9	23	394	50	132	28
M. polymorpha	3.3	11	50	7	88	19
M. ciliaris	2.7	9	24	3	12	3
M. aculeata	0.9	3	11	1	5	1
Total	30.0	100	788	100	465	100

All species contributed more new seed than was sown, and species behavior can be partially explained by the differences between seed-to-pod weight percentage and number of seeds per pod (Table 4).

Table 4. Seed characteristics of medics harvested in 1993/94.

Species in mixture	Seed wt/Pod wt %	Number of seeds/pod
M. truncatula	26.6	4
M. orbicularis	48.1	14
M. polymorpha	44.8	4
M. ciliaris	33.3	5
M. aculeata	23.8	5
Average	33.6	6.4

Medic seed bank in the soil

One of the original experimental hypotheses was that phosphate treatment of experimental weedy fallow plots would stimulate the production of naturally present leguminous species. Approximately 20 kg/ha were measured in the seed bank of the weedy fallow, composed primarily of *M. orbicularis* and *M. ciliaris* (Table 5).

Table 5. Seed bank measurements taken in 1994 in cereal plots that followed 1992/93 medic pastures.

	Weedy fallow		Medic	
Species in mixture	kg/ha	%	kg/ha	%
M. truncatula	3.2	16	200.6	57
M. orbicularis	8.0	40	96.3	28
M. polymorpha	1.6	8	32.1	9
M. ciliaris	7.2	36	4.0	1
M. aculeata	0.0	0	16.0	5
Total	20.0	100	349.0	100

Only about half the medic seed produced in the 1992/93 pastures (Table 3) was produced the following season under the wheat crop (Table 5). Soil cores were taken at a depth of 10 cm and probably some seed was plowed deeper than 10 cm during land preparation for wheat.

The most abundant species was *M. truncatula*, representing 57 percent of the total recovered seed (Table 5). Reasonable quantities of *M. orbicularis* and *M. polymorpha* were also recovered.

Lamb performance

Sheep performance was clearly superior on medic compared to weedy fallow in the first two years. In the first year, grazing started later because of heavy rain. Lambs grazed weedy fallow and medic pasture for seven weeks in the 1992/93 season and for 11 weeks in 1993/94. Grazing ended (both years) when animals were moved to stubble at cereal harvest time.

Table 6. Lamb performance on medic or weedy fallow pasture for the establishment years of the experiment.

	Medic		Weedy fallow	
Measurement	*1992/93*	*1993/94*	*1992/93*	*1993/94*
Weeks grazing (12 sheep/ha)	7	11	11	7
Average daily gain (g)	176	111	130	84.9

Clearly, medic provides better nutrition for lambs—resulting in better average daily gain and off-take. Lack of herbage in the weedy fallow plots necessitated supplementary barley hay and grain for the animals (before moving to cereal stubble). Sheep on medic pasture were not fed supplement.

Conclusion

Medic pastures have shown their superiority to weedy fallow pastures in the first two years of the El Khroub experiment in eastern Algeria. These were establishment years (receiving 576 and 435 mm rainfall, respectively) for medic. With seed banks established, the future performance of the pastures in meeting the needs of sheep will be interesting to watch. Likewise, the evolution of botanical composition and seed banks in both weedy fallow and medic pastures will be important.

Farmers are now expressing interest in the medic system, and placing new priorities on seed production. This effort must be given the highest priority. Efforts must be made across a larger geographical area in Algeria to further promote the improved weedy fallow and cereal/pasture rotation system. With this in mind, we suggest that the ICARDA pasture seed sweeper and Maktabi/ICARDA thresher be made available in greater numbers to increase opportunities for farmers or farmer cooperatives to produce locally adapted medics.

—A. Zeghida, S. Hamrit, M.L. Korichi, G. Gintzburger and S. Christiansen

Medic Pasture Establishment Using Pods Sown into Barley in the Year Prior to the Pasture Phase

Summary

The trial objective was to determine a sowing rate, using medic pods broadcast into barley, that, in the following year, will produce a dense plant stand from softened seed inside the pods.

In autumn 1992, before planting barley, we broadcast pods of *Medicago rotata* and *M. rigidula* in a 50:50 mixture (by weight) at sowing rates of 0, 100, 200 and 300 kg/ha. The barley crop was then sown, harvested in May 1993, and the barley stubble was not grazed in the summer of 1993. In the autumn and winter of 1993/94, we counted seedlings on three occasions. We also determined the quantity of pods and seeds left in the soil after all germination, and later measured the contribution of medic and volunteer barley to pasture dry matter yield. Finally, we quantified the medic seed, produced in spring 1994, in the seed bank.

Seedling plant densities averaged about 50–500 plants per m^2, depending on the sowing treatment and date of counting, with higher densities at higher sowing rates. We recovered 62 percent of the *M. rigidula* and 38 percent of the *M. rotata* originally sown. About 10, 20 and 26 kg/ha of ungerminated seed were recovered from the 100, 200 and 300 kg/ha pod sowing rates, respectively.

Volunteer barley was managed as part of the medic pasture system. It was heavily grazed by a large flock (150–250 sheep) for one or two days in January and in March (1994) to eliminate competition from barley. By season's end, the barley had recovered enough to contribute approximately half of the pasture biomass. As part of the medic/barley system, barley provided green grazing in spring and straw at the end of the season (contributing a feed resource along with the medic residue and new pods on the soil).

By mid-March 1994, *M. rigidula* (although it produced fewer seedlings due to a lower seed/pod ratio) produced a dry matter yield double that of *M. rotata*. We believe this was because *M. rotata* was less effectively inoculated than *M. rigidula*.

Total new seed averaged 167, 289 and 182 kg/ha for the 100, 200 and 300 kg/ha pod sowing treatments; *M. rigidula* contributed about 70 percent by weight. Our results suggest that a sowing rate of 150 kg pods/ha is enough to produce a pasture establishment density of about 250 seedlings/m^2. Under the 373 mm rainfall received in 1993/94, a successful seed bank was obtained containing, on average, more than 200 kg/ha new seed.

Introduction

In Syria, small ruminants traditionally graze natural pastures (hillsides, fallow land and steppe). Due to rapid population growth and tractor availability, large areas have been cultivated (Jones 1988) and have extended onto land previously used only for grazing (Lewis 1987). Farmers use high stocking rates on common grazing areas and must provide supplementary feed (usually barley) for their animals. Few crops other than barley can be cultivated in areas receiving 250–300 mm rainfall. To meet the growing demand for feed, the traditional cereal/fallow rotation has been replaced by continuous cereal cropping.

Intensive mono-cropping has led to loss of soil fertility and organic matter content, increase of disease and insect pests, build-up of weed populations and loss of water holding capacity (Krause *et al.* 1988). Pasture sown with medics research aims to:

- Incorporate a pasture legume into fallow or continuous cereal production (Abd El Moneim and Cocks 1986; Cocks 1988).
- Oversow native annual legumes on degraded marginal lands that should not be cultivated (Osman and Cocks 1992).
- Rehabilitate marginal plowed land.

Although most sheep producers are familiar with *Medicago* spp., they do not cultivate medics because seed is not locally available and seed production is still too time consuming and difficult. Farmers need a simple way to harvest seed with which they can improve pastures.

Medic seed is formed in pods in a variety of sizes and shapes; in general they are ovoid and can, therefore, be easily swept off the ground. This led ICARDA scientists to develop a medic pod sweeper (with no engine) to harvest pasture seed (Christiansen 1993).

Medic seeds in pods will germinate over the course of several years because the plant produces a very high percentage (up to 99 percent) of seeds that are impermeable to water in the first season after seed set. Hard seed production is an ecological adaptation for persistence under variable climatic environments where seed might not be produced every year. Hard seed breakdown depends on the species, genotype and yearly environmental factors. Sowing naked seed is fundamentally different from sowing pods because the physical force needed to thresh medic pods will scratch the seed surface and make most seeds permeable to water when they are sown.

Establishing a seed bank is central to the use of self-regenerating pastures. The seed bank is the dynamic fluctuation of stored seeds in the soil, accumulating or depleting over the course of each season. In many Mediterranean ecosystems, the chance of survival for an annual plant depends upon a persistent seed bank, since it provides a buffer against drought and overgrazing, and allows the annual legume to survive in a field during a period of cropping (Cocks 1992a,b; Cocks 1993).

The creation and maintenance of a sufficiently large seed bank can be manipulated by pasture management. Abd El Moneim and Cocks (1986) showed that pasture dry matter yield is directly related to seedling number. Since the number of seedlings is mostly dependent on the number of germinating seeds, it is necessary to know how many seeds will germinate from medic pods over a series of years. A seed bank of 150 kg/ha is recommended, given that the pods contain about 20–40 percent seeds by weight and (as previously explained) the hard seed impermeability degrades slowly from a starting point of over 95 percent. The recommendation is based on a compromise between immediate summer feed requirements for sheep (pods are quite nutritious) and the long-term persistence of medics in the pasture.

Previous experimental evidence from Morocco (Boulanouar and Christiansen 1991), shows that in the first year of pasture establishment a seedling density of 250 plants per m^2 is sufficient for production of over 3.5 t DM/ha of medic, as well as the seed to regenerate the pasture.

Objectives of the current project are to:

1) Determine amounts of pods (in a medic mixture of 50 percent *Medicago rigidula* and 50 percent *M. rotata* by weight) needed for success-

ful pasture establishment when sown into barley in the year before the pasture phase. (Establishment was characterized as successful if seedling density was >250 plants per m^2 in the pasture year following barley.)

2) Determine amounts of hard but potentially germinable seeds left in the soil after establishment of the pasture phase.
3) Quantify contributions of the two medics and volunteer barley to dry matter yield in the pasture.
4) Assess new medic seed additions into the soil seed bank.

Materials and Methods

The trial was in north Syria at the ICARDA headquarters experimental site at Tel Hadya, about 30 km southwest of Aleppo (35055' N, 36° 55' E, elevation 362 m). The mean annual precipitation is 330 mm (rainfall between October and April). Soils are deep, well-structured and classified as *Vertic Luvisols* with a pH of 8.0–8.5.

Plant materials used in this experiment were: *M. rigidula* (L.) All. accession (Acc) 2713, selection (Sel) 1919, collected from Terbol, Lebanon; and *M. rotata* Boiss., Acc 2600, Sel 2123, collected near Azaz, Syria.

Seed increase fields were established in the autumn of 1991, and seed pods produced in the spring of 1992 were collected from the soil surface with a medic pod sweeper. Hard seed percentages of each species were determined in the laboratory by placing disinfected pods on moist filter paper in a Petri dish (Delavet 1989), counting and removing germinated seedlings over a period of ten days, then drying the pods and threshing out remaining impermeable seeds. *M. rotata* had a germination rate of 1.1 percent and *M. rigidula* of 1.0 percent.

Field plots were established in autumn 1992 in a randomized complete block design with three replications. Medic pods were hand sown on November 1, 1992, with 0, 100, 200 or 300 kg/ha using a 50:50 mixture of medic pods divided into equal proportions (by weight) of *M. rigidula* and *M. rotata*. The field was drilled on November 4, 1992, with SLB 39/10 barley at a sowing rate of 100 kg/ha. On March 31, 1993, any medics germinating in the barley phase were killed using herbicide. The barley was harvested in mid-June 1993 and the straw was removed from the field. No grazing took place.

In winter 1993/94, medic seedlings germinating from pods sown the previous year were counted on December 13 and 28, 1993 and on January 26, 1994 using 20 samples of 0.10 m^2 per experimental unit (plots=400 m^2). *M. rigidula* and *M. rotata* were counted separately following their germination patterns throughout the winter period.

On January 10 and 12, 1994 the whole field was grazed by 250 ewes for 4.5 and 1.5 hours, respectively, to eliminate competition from barley for water, soil nutrients and light. In another grazing period, between March 17 and 23 (1994), 150 sheep grazed the plots for a total of 21 hours to consume barley regrowth.

On December 16, 1993, and January 27, 1994, medics were counted in an adjacent field where medic pasture had successfully regenerated each year since 1985/86 in a two-phase cereal/pasture rotation experiment. These data were compared to results obtained in our establishment trial using pods. Twenty counts within 0.10 m^2 quadrats were taken.

During March 3–5, 1994, soil samples were taken using 117 cores of 10.4 cm diameter to a depth of 10 cm. These samples were later washed to recover medic pods. The pods were dried, counted, weighed and threshed by hand.

Botanical composition and herbage yields were assessed on March 16, 1994, with 10 quadrats of 0.20 m^2 per plot. Pasture herbage yields were assessed on May 31, 1994, using five quadrats of 0.20 m^2 per plot. Medics and barley were separated (seeds of each medic species treated separately). Herbage and pods were dried and weighed. Pods were counted, threshed by hand and the recovered seeds were also counted and weighed.

Seedling numbers, pod and seed recovery data, and dry matter yields of the pasture were tested using analysis of variance procedures with SAS. The plot layout was a randomized complete block design with four treatments and three replications. Since we used a mixture of two medic species sown in each experimental unit, the statistical design was that of a split plot (medic species as the sub-plot) with medic pod sowing rates of 0, 100, 200 and 300 kg pods/ha (whole plots). Seedling counts over the three sampling dates were analyzed as a split-plot in time.

Results

Rainfall during the 1993/94 season was above average at 373 mm. The autumn of 1993 was dry until the first rain on October 31, followed by well-distributed rainfall continuing throughout January and February. Winter temperatures were above average, with frost on only 18 nights, and temperatures below -2° C on five nights. In very cold years there can be up to 50 frost nights during winter (Cocks and Ehrman 1987).

Pod sowing treatments resulted in significantly different seedling numbers in each treatment (Table 1). No medics germinated in the treatment of 0 kg pods/ha (control), showing that the land contained few medic seeds before the trial.

Table 1: Species (SPP) counts from *M. rigidula* (MRG) and *M. rotata* (MRO) seedlings counted on three dates.

Treatment Kg/ha pods	SPP	13 Dec 93	28 Dec 93	26 Jan 94
		Seedlings/m²		
0	MRG	0	0	0
	MRO	0	0	0
100	MRG	49	52	68
	MRO	114	112	103
200	MRG	76	93	93
	MRO	217	240	174
300	MRG	168	164	156
	MRO	321	329	256

Treatments were number of pods sown, each treatment composed of equal weights of both medics.

Seedlings were counted three times to study both the rate of germination and competition among plants. There was no time x treatment interaction (P=0.54). Seedling numbers increased from the first to the second count, and then decreased in the third count for both the 200 and 300 kg/ha pod sowing treatments; for the 100 kg/ha treatment, seedling counts continued to increase slightly across the three dates. We counted *twice as many M. rigidula as M. rotata seedlings in each treatment.*

There were interactions between species and treatments, and species and time. While numbers of *M. rotata* decreased after the second count in all treatments, numbers of *M. rigidula* increased for the 100 kg pods/ha treatment, remained stable at the sowing rate of 200 kg pods/ha and fell only slightly at the rate of 300 kg pods/ha (Table 1).

An adjacent pasture, where *M. rigidula* was sown into a two-phase medic/wheat rotation trial in 1985/86, was used for comparison to the pastures sown with pods. Medics in the rotation experiment successfully regenerated each year, and in January 1994 had a density of 344 medic seedlings/m^2.

Pod and seed recoveries showed a significant ($P<0.01$) and proportional relationship to the number of pods and seeds originally sown (Table 2). Fewer *M. rigidula* pods/m^2 were recovered compared to *M. rotata*; however, the higher pod weight for *M. rigidula* counterbalanced its lower number of pods, resulting in a nearly identical seed number/m^2 and similar seed yield compared to *M. rotata* in each treatment.

Table 2: Seed pod recovery statistics from *M. rigidula* (MRG) and *M. rotata* (MRO) sampled March 3, 1994.

TRT	SPP	PNO	PWT	SNO	SWT
100	MRG	31	28.7	91	5.3
	MRO	43	17.0	91	4.4
	Sum	*74*	*45.7*	*182*	*9.7*
200	MRG	60	59.7	187	10.9
	MRO	73	33.0	176	8.9
	Sum	*133*	*92.7*	*363*	*19.8*
300	MRG	85	77.0	237	13.5
	MRO	108	45.7	238	12.1
	Sum	*193*	*122.7*	*475*	*25.6*

Pod number/m^2 (PNO), pod weight in kg/ha (PWT), seed number/m^2 (SNO), seed weight in kg/ha (SWT). Treatments (TRT) were established by sowing equal pod weights from both species within the 100, 200 and 300 kg/ha treatments.

Residual medic seed in the soil amounted to 9.7, 19.8 and 25.6 kg/ha for the 100, 200, and 300 kg/ha pod sowing rates.

An estimation of percentage germination (Table 3) was made by dividing the number of seedlings by the number of seeds sown, which revealed that about 21 percent of the seeds germinated in the 1993/94 season. Adding the maximum number of germinated seedlings per treatment (Table 1) to the number of seeds recovered (Table 2) and then dividing by the number of seeds sown, gives the quantity of seeds recovered. A statistically significant effect due to species ($P<0.01$) was detected, and the 23 percent lower recovery of *M. rotata* compared to *M. rigidula* suggests that the former is more readily degraded (probably due to its less compact physical structure).

Table 3. Calculated percentage germination of originally sown seed and recovery data estimated for the pods of *M. rigidula* (MRG) and *M. rotata* (MRO) sampled on March 3, 1994.

Pods	SPP	GERMINATION (%)	ACCOUNTABILITY (%)
Excavated Mar 3, 1994	MRG	22.9	61.7
	MRO	21.1	38.3
Originally sown pods	MRG	1.0	100.0
	MRO	1.1	100.0

Accountability=germinated seedlings+recovered seed÷originally sown seed

By mid-March 1994, the *M. rigidula* seedlings had accumulated about twice as much dry matter as *M. rotata*. Barley dry matter yield was higher than for medics at the 100 and 200 kg pods/ha sowing rates (Table 4). The pasture had been heavily grazed by 250 sheep in January to remove most of the barley; however, we did not measure the amount of dry matter present. These data show the amount of barley regrowth.

Table 4. Dry matter (DM) yields March 16 and May 31, 1994.

Treatment	MRO	MRG	MEDIC	BAR	TOTAL
Kg/ha pods			kg DM/ha		
16 Mar 1994					
0	0	0	0	923	923
100	77	149	226	613	839
200	130	289	419	579	998
300	206	395	601	584	1185
31 May 1994					
0	0	0	0	1286	1286
100	248	610	858	1046	1904
200	188	481	669	1010	1679
300	211	597	808	948	1756

M. rigidula (MRG), *M. rotata* (MRO) and barley (BAR). The sum of MRO and MRG is MEDIC.

Total dry matter measured on March 16, 1994, was lower than the total for May 31, 1994 by about 60 percent (averaged over all treatments). The effect of pod sowing rate on total dry matter yield was not statistically different, probably because of the ton of barley dry matter that regrew in all plots following grazing. The medic yield increased relative to barley yield at the higher pod sowing rates.

The data show 167, 289 and 182 kg/ha of new seed (Table 5) contributed to the 10, 20 and 26 kg/ha existing residual seed in the soil (Table 2) for the 100, 200 and 300 kg/ha pod sowing rates, respectively. The pod sowing rates and the species sown had statistically significant effects ($P<0.01$) on subsequent seed and pod production. *M. rigidula* produced the most seed in the treatment where 200 kg/ha of pods were sown. *M. rotata* produced less than half of the total new seed.

Table 5: The contribution of new pods and seed produced in 1994 from *M. rigidula* (MRG) and *M. rotata* (MRO) sampled on May 31, 1994.

TRT	SPP	PNO	PWT	SNO	SWT
100	MRG	313	395	1795	113
	MRO	205	125	813	54
	Sum	*518*	*520*	*2608*	*167*
200	MRG	530	695	3210	209
	MRO	306	178	1259	80
	Sum	*836*	*873*	*4469*	*289*
300	MRG	355	457	2066	127
	MRO	239	146	910	55
	Sum	*594*	*603*	*2976*	*182*

Treatments (TRT) were established by sowing equal weights of medic pods from both species within the 100, 200 and 300 kg/ha pod sowing treatments. Pod number/m^2 (PNO), pod weight in kg/ha (PWT), seed number/m^2 (SNO), and seed weight kg/ha (SWT).

Table 6: Characteristics of new pods of *M. rigidula* and *M. rotata* sampled on May 31, 1994, original pods and those excavated in March 1994.

Pods	SPP	PWT100 (g)	SNO/P	SWT/PWT	SWT1000
Originally sown November 1992	MRG	13.7	6.2	30.0	6.73
	MRO	4.4	4.4	48.8	4.83
Core samples 3 March 1994	MRG	9.3	2.9	18.0	5.77
	MRO	4.3	2.3	26.7	5.01
New production 31 May 1994	MRG	12.9	5.8	29.1	6.38
	MRO	6.2	3.9	42.3	6.38

Weight of 100 pods (PWT100); seed number/pod (SNO/P); percentage pod weight that is seed (SWT/PWT) and 1000 seed weight (SWT1000) in grams.

Characteristics of recovered pods were examined. The lower seed/pod number for *M. rotata* compared to *M. rigidula* (2.3 vs. 2.9) was accompanied by a lower (18.0 vs. 26.7) percentage of pod seeds (by weight). The difference in weight and seed numbers between recovered pods and fresh pods is due to seedling germination and pod weathering. The pod weights and numbers of seed/pod for freshly produced pods tend to be similar (Table 6); however, some characteristics vary with the season, probably due to rainfall patterns that affect pod formation and seed filling.

Discussion

Results from previous experiments, where pastures were established by sowing medic seeds (Boulanouar and Christiansen 1991), showed that about 250 seedlings per m^2 produced a pasture with 3.5 t DM/ha in Morocco in 1988/89 (a year with 326 mm rainfall). The pastures eventually produced a seed yield averaging about 250 kg/ha. To achieve a similar seedling density under the experiment's present conditions, it is necessary to broadcast about 150 kg/ha of newly produced medic pods into a barley crop the year before the pasture is established.

At the 300 kg/ha pod sowing rate, seedling numbers were greater than the seedling count from a regenerating medic pasture in an adjacent long-term rotation trial with an average density of 344 plants/m^2. This density was only slightly higher than the measured density for the 200 kg/ha pod sowing treatment. The long-term trial was managed to keep 100–200 kg/ha seed banks; however, seed of different generations are in the soil and the percentage of soft seed available for germination should be higher than for a single generation of seed—as in the present trial.

Without a careful measurement of seed dynamics in the soil, it might have been concluded—from the seedling counts—that hard seed breakdown in *M. rigidula* was slower than in *M. rotata*. In fact, hard seed breakdown in the two species was similar. The 100-pod-weight of the originally sown *M. rotata* was 4.4 g. One pod contained an average of 4.4 seeds with a 1000-seed weight of 4.8 mg. The 100-pod-weight of the originally sown *M. rigidula* was 13.7 g. One pod contained 6.2 seeds with a seed weight of 6.7 mg. Using these data and the results of the seedling counts, we calculated a germination rate of 21 percent for *M. rotata* and of 23 percent for *M. rigidula*. Since the pods of *M. rotata* weigh only about one third of those of *M. rigidula* but contain relatively more seeds (49 vs. 30 percent), we sowed about 2.2 times more seeds of *M. rotata* when sowing equal amount of pods by weight.

Due to the optimal climatic conditions throughout the 1993/94 autumn and winter, with regular rainfall in combination with mild temperatures, there were no seedling losses attributable to drought or frost. The decline in seedlings at the two sowing rates of 200 and 300 kg pods/ha suggests that there was a competitive effect between the seedlings at higher plant densities or between medic seedlings and volunteer barley.

The abundance of volunteer barley (reaching 679 kg DM/ha in mid-March) resulted from the barley management in the 1992/93 season. The crop was lodged and harvested late; thus a high incidence of head shattering occurred. Barley is readily grazed by sheep but overabundant growth competes with the medic seedlings for light, water and nutrients; therefore, barley management is an extremely important component of the pasture system.

M. rigidula seedlings grew better than those of *M. rotata*, a factor that is probably related to the availability of specific rhizobium (Materon 1991; Materon and Danso 1990). At the Tel Hadya site, *M. rigidula* rarely has inadequate inoculation, whereas *M. rotata*, based on its vigor, did not appear to be effectively nodulated. The higher dry matter yield of *M. rigidula* offset its lower seedling numbers in contributing to pasture yield.

The trampling of seedlings by grazing sheep could explain the seedling decreases in the last count. On January 10, 1994, in particular, the sheep entered the field when the soil and plants were still moist. The sheep moved quickly through the field and turned over some of the soil containing seedlings. At that time, the medic seedlings were still very small, and two weeks later, during the third count, some dead seedlings were seen. Rossiter (1966) showed that sheep trampling can account for up to 25 percent of the total pasture loss.

However, during the grazing period sheep did not eat many medic seedlings. At this early stage of plant growth sheep prefer barley to medics. These observations confirm earlier results which show—especially early in the season—that grazing is an important tool for weed control, since at this time sheep selectively eat mostly grassy weeds.

The barley left in the field after March 23, 1994, was not grazed thereafter. A weak stand recovered somewhat due to 19 mm of rainfall between April 24 and May 1, 1994. At the end of the season barley contributed about half of the dry matter in the pasture (Table 4). Although herbage digestibility and protein content were not assessed, the nitrogen-rich legume straw with the remaining barley straw and grain could be considered a good summer feed for breeding ewes. Here again, the legume and barley components and their management are complementary.

Because climatic conditions, the influence of tillage practices and grazing on potential medic germination, and seedling emergence and survival will differ from year to year this trial is being repeated. Our results show that farmers could easily establish self-regenerating medic pastures by sowing pods. This procedure provides the desired seed bank for their pastures, because the pods buried in the soil under the germinating seedlings still contain part of their original seed in an impermeable state. We recovered about 10, 20 and 26 kg/ha of seed (Table 2) that did not germinate in the 100, 200 and 300 kg/ha pod sowing treatments, and we calculated that a hard seed breakdown of more than 20 percent could be expected in a subsequent year. Seeds, secure in the pods, are better protected until conditions favor germination. If a drought occurs and no seed is produced in a given year, pod planting will show its greatest benefit, since seed will be left in the ground to germinate under more favorable conditions.

In our experiment, seed losses could be due to pod decomposition, particularly for *M. rotata*. Only 38 percent of originally sown seeds of *M. rotata* and 62 percent of *M. rigidula* seeds could be recovered (Table 3). With our method for pod recovery, free seeds in the soil would not have been detected. Data suggest that the amount of recovered seed might have been at least twice as high under optimal conditions. There might have been pods buried to depths greater than 10 cm that were not recovered because of excessively deep cultivation in the autumn of 1993.

Total recovered and newly produced seed yields (Tables 2 and 5) show that a seed bank of 176, 309 and 208 kg/ha is now on or in the soil (representing the 100, 200 and 300 kg/ha pod sowing treatments). Considering plant density, competition with barley and seed production potential, we recommend a 150 kg/ha pod sowing rate for use on farms.

The practical advantage of sowing pods in late summer is that the sowing will not coincide with the planting of other crops in the autumn. Broadcasting the pods is easy and can be done by hand.

The vastness of areas in need of revegetation justifies relaxation of purity controls in pasture seed production. Village-based pod and seed production, outside the formal seed industry, would provide farmers with seeds needed for pasture improvement.

—S. Christiansen, U. Opitz, J. Mitri, W. Bou Moghelbay, G. Gintzburger and D. Marx.

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Core Selection of Farmers for Improvement of Forage Production in the Semi-arid Zones of Morocco

According to recommendations of the ICARDA-sponsored Training Workshop on Analysis of Surveys to Establish On-Farm Trials (Rabat, November 8–12, 1993) a survey was conducted in Settat and Safi provinces (spring 1994). The objectives were to identify farmers' needs for better research targeting and to select farmers for on-farm trials in 1994/95.

Farmers were selected for the survey using typologies defined in previous surveys. Discussions with local extension people ensured inclusion of a representative cross-section of farm types in the semi-arid zone. Twenty four farmers from two provinces and seven extension centers were surveyed.

The questionnaire focused on:

1) The evolution of farm characteristics during the frequent droughts of the 1990s.
2) Forage and pasture production constraints.
3) Farm research needs.
4) Farmers' willingness to work with research and extension people.

Relevant issues for forage and pasture research and development are summarized below.

- Lack of seed and harvest mechanization are the major constraints facing forage production and development.
- Most surveyed farmers had sown medic pastures at least one year since 1985; however, these farmers had developed their own management practices which were different from the ones suggested by the government. On most farms, medic pastures were seeded every year, grazed and hayed, seeded alone or mixed with barley.
- Several farmers grow other forages: barley for grazing, mixtures of cereals and annual legumes, oats for hay, or weeds cut for hay. All farmers appreciate the value of mixing cereals with vetch or pea but are constrained by lack of seeds.
- Many farmers were enthusiastic about collaborating with INRA and extension people. A list was created for use in future on-farm trials.

All farmers stressed the need for development of forage and pasture plants and, particularly, expressed the need for forage conservation.

—S. Christiansen, M. Bounejmate and G. Gintzburger.
—Institutions involved: INRA Rabat and Settat, DERD, DPV, DE, DPA Safi and Settat.

Pasture Seed Production by Farmers in Morocco

Huge areas of weedy fallow and range in Morocco are degraded and need improvement. These areas traditionally feed much of the nation's 25 million livestock. Forage production is insufficiently developed and dependent on imported seed for many species.

Genetic resources for pasture and forage legumes have been systematically collected in Morocco. Clearly, local pasture genotypes are better adapted than imported varieties. However, a seed production bottleneck prevents promising, locally adapted material from passing from the evaluation stage to on-farm testing or broad-scale reseeding.

Pasture seed production of small-seeded annual legumes and shrubs (*Medicago, Trifolium, Astragalus, Trigonella, Atriplex, Salsola*, etc.) must be produced in greater quantities at the farm or farmer cooperative level. No organization to produce pasture species exists on the local level; therefore, this project's objective is to give farmers a simple means to produce and harvest sufficient pasture and forage seed using small-scale machinery.

The following results were achieved in 1993/94:

- Six local medic ecotypes (*Medicago truncatula* [four], *M. orbicularis* [one] and *M. aculeata* [one]) were selected and sown at two sites to provide nucleus seed for distribution to farmers. ICARDA delivered two sweepers and two threshers (one set for El Koudia—INRA, and a second for Khémis M'touh—CPSP DE).
- Two field days were organized to demonstrate machinery use for technicians and farmers. The first, in El Koudia on July 6, 1994, was attended by 12 technicians and 10 farmers from Settat Province. The second, in Khémis M'Touh on July 13, 1994, was attended by five technicians and seven farmers from Safi Province.

—S. Christiansen, M. Bounejmate and G. Gintzburger.
—Institutions involved: INRA Rabat and Settat, DERD, DPV, DE, DPA Safi and Settat

Forage Research and Production Workshop in Northern Morocco

In Tangiers, March 21–24, 1994, a workshop was held to discuss livestock development constraints in northern Morocco, research undertaken and possible ICARDA involvement. About 60 attended, including the INRA forage and livestock group, Ministry Production and Livestock departments, northern Morocco extension people, and two ICARDA participants. Workshop proceedings were jointly published and distributed.

—Institutions involved: INRA Rabat and Tanger, DERD, DPV, DE, DPA zone nord

Morocco/ICARDA (PFLP) Personnel and Information Exchange

- S. Christiansen and N. Nersoyan participated in the Tangiers Workshop.
- S. Christiansen attended the Aridoculture Conference in Rabat.
- L. Materon visited Morocco to discuss rhizobium work progress on *M. aculeata.*
- M. Bounejmate visited ICARDA for the PFLP Internally Managed External Review.
- W. Bou Moghlebay participated in the field day at El Koudia.
- L. Materon and M. Obaton attended the Moroccan National Coordination meeting in Settat.
- E. Thomson and A. Goodchild established collaborative work in Morocco on sheep management and nutrition.

—S. Christiansen, M. Bounejmate and G. Gintzburger.

Development of Medics and Associated Rhizobia for Highland Environments in Morocco

Medics have considerable potential in west Asia and north Africa (Robson 1990), but lack of cultivars specifically suited to local conditions is the primary impediment to their widespread cultivation. Particularly in areas in the Mediterranean region with cold winters, low temperatures limit medic development. Commercially available cultivars tested in northern Syria (Cocks and Ehrman 1987) and in the *Hauts Plateaux* of Algeria (Rapport IDGC 1980) have been killed by frost.

Works by Cocks and Ehrman (1987) in Syria and Bounejmate (1992) in Morocco provide useful guidelines for selection of ecotypes adapted to highland environments. These studies show a clear relationship between altitude at the collection site and frost tolerance. Ecotypes from high altitudes represent a promising source for breeding for frost tolerance.

The present project selects medic ecotypes adapted to Morocco highland environments from local high altitude germplasm. Because medic growth is largely dependent on associated rhizobia, selection of efficient rhizobium strains is also considered.

Nodule and soil collection

A survey was conducted April 19–21, 1994, in the middle Atlas mountains to collect strains of *Rhizobium meliloti* from *Medicago aculeata*. A total of 19 sites were sampled. The altitude varied between 1000 and 1500 m for 31.6 percent of the sites and between 1500 and 2000 m for the remaining 68.4 percent. Forty eight samples of *Rhizobium meliloti* were collected.

Composite soil samples from 50 sites were collected from high altitude zones in the middle and high Atlas Mountains. Most of the sites contained rhizobia in the soil. The rhizobia collected from the middle Atlas were isolated from the regions of Ras El Ma, Ifrane, Michlifen and Timahdit. Similar analyses will be done for soils from the high Atlas zones.

Response of *Medicago aculeata* to nitrogen

Productivity and biological nitrogen fixation of 10 local *M. aculeata* genotypes collected from high altitude areas were evaluated in Meknès. Two factors were tested: genotype and nitrogen (+N, -N). The experimental design was a randomized complete block with three replicates. Plot size was 2x1 m with a 15 kg/ha seeding rate. For the +N treatment, 30 kg N/ha was added at planting, three weeks after emergence and at flowering. Preliminary results show that the N treatment did not improve the yield compared to plots where no N was applied, suggesting that rhizobia was fixing N from the atmosphere. This trial will be repeated in 1994/95.

—M. Ismaili (Moulay Ismail University, Meknès, Morocco),
—M. Bounejmate, I. Thami-Alami, and R. Kettani
(INRA Forage Program, Morocco),
—L. Materon, S. Christiansen and G. Gintzburger.

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The Role of Rhizobial Biodiversity in Legume Crop Productivity in the West Asian Highlands: 1. Rationale, Methods and Overview

Summary

This paper surveys the native bacteria species of the genus rhizobium that are capable of inducing N_2 fixation in both traditional and potential food, forage and pasture legume crops in the west Asian highlands. It examines the number of bacteria and the N_2 fixing efficiency of isolates of *R. leguminosarum*, *R. ciceri*, and *R. meliloti* with appropriate legume crop species from soils collected in Turkey from a wide range of locations with elevations between 500 and 2,200 m. For vetch and lentil nodulated by *R. leguminosarum*, many native rhizobia are present in most locations, but they often have limited fixation capacity. However, for chickpea nodulated by *R. ciceri*, relatively small numbers of bacteria, and the crop's ineffectiveness of fixation capacity point to a need for artificial seed inoculation of chickpea crops as a future agronomic priority. For annual medics (*Medicago* spp.), the wide range in bacterial numbers, coupled with considerable geographic inconsistency and with generally low effectiveness of the indigenous rhizobia, suggests that inoculation would be, initially, a sensible precaution for all sowings.

Introduction

A large potential exists in west Asia for increased food, forage and pasture legume production and for the introduction of cropping sequences that are less demanding of natural resources than the traditional cereal/fallow or continuous cereal systems (Cocks 1988; Oram and Agcaoili 1994). Nevertheless, in the highlands of west Asia outside Turkey (Durutan *et al.* 1988; Acikgoz 1988), evidence for this assertion is slim and supporting research efforts are limited (Saxena *et al.* 1988). For example, equally little is known about the distribution, number and effectiveness of symbiotic N_2 fixing ability within the native species and strains of rhizobium bacteria. Materon and Cocks (1988) reported that the lack of, or ineffective nodulation of annual medics (*Medicago* spp.) appears to be a major constraint in the establishment of this crop in the Mediterranean region. Similarly, Asghar Ali *et al.* (1988) and Rees *et al.*

(1991) have described positive responses to inoculation in food and forage legumes in the highlands of western Pakistan.

Materon (1991) examined the symbiotic characteristics of *Rhizobium meliloti* with pasture legumes over a wide range of soils from five countries in west Asia. The soils were almost exclusively sampled from lowland sites below 500 m. With six species of annual *Medicago*, this study demonstrated that although most soils contain *R. meliloti* bacteria, considerable variability exists in population density and in effectiveness for inducing N_2 fixation. Similarly, Beck *et al.* (1991) examined the effectiveness of symbiotic N_2 fixation for a range of grain legumes—characteristic of those in the Mediterranean basin—at lowland sites in Syria and France. Results indicate considerable variability in the amounts of plant nitrogen coming from symbiotic fixation, and highlight implications for the long-term sustainability of alternative cropping systems. In Turkey, Cakmakci *et al.* (1988) sampled soils from 40 locations in the traditional chickpea (*Cicer arietinum*) and lentil (*Lens culinaris*) production lowlands of southeastern and western Anatolia. Nodulation was poor in lentil, particularly when autumn-planted and in the presence of substantial populations of the nodule-boring larvae of the *Sitona* weevil. Engin (1988) chronicled the rhizobium inoculant production industry in Turkey, originating from the Soil and Fertilizer Research Institute in Ankara. However, recent private sector expansion has led to the availability of commercial inoculants, often with unproven effectiveness and value.

Inoculation of legume crops involves well-known technologies (Beck *et al.* 1993). Nevertheless, lack of facilities and education often limit its practical applications for farmers in developing countries. The rigorous management and quality control required for inoculant production and inherent problems in distribution and use of bio-products contribute further limitations. Successful nodulation with high-quality inoculants requires knowledge of the number, effectiveness, and competitive performance of indigenous rhizobial populations (May and Bohlool 1983; Moawad *et al.* 1988). Soils are often replete with well-adapted indigenous rhizobia that vary considerably in their symbiotic effectiveness (Gibson *et al.* 1975; Materon 1991). The ideal rhizobia inoculant strain combines high symbiotic efficiency, the durability to survive and persist in soil and the ability to effectively compete with indigenous strains over several cropping cycles.

A typical soil rhizobial population between 10^3–10^4 g^{-1} soil is expected to provide adequate N_2 fixation in most crops. Responses to inoculation are usually evident only where populations are sub-optimal. However, because of the highly specific rhizobial requirements of chickpea and medic cultivars (Gaur and Sen 1979; Materon 1991), incompatibility of naturalized rhizobial populations with newly introduced cultivars may limit genetic expression for crop N_2 fixation. Inoculation may therefore be required in circumstances where introduced cultivars cannot express their full capability for N_2 fixation in symbiosis with native rhizobial populations that have themselves co-evolved with local landraces or ecotypes.

A joint research program between the Soil and Fertilizer Research Institute, Ankara and the International Center for Agricultural Research in the Dry Areas was designed to examine the symbiotic characteristics and distribution of native species of rhizobium in the Turkish highlands. It was important to discover whether any climatic or soil chemical variables are correlated with the presence, absence or effectiveness of rhizobia, and to determine future inoculant production needs in Turkey as well as in Iran, Iraq, Pakistan, Afghanistan and other countries in west and central Asia. This series of four papers reports the findings of that program.

Materials and Methods

Site selection

One hundred and five sites were selected from as wide a geographic area in highland Turkey (>500m) as possible, given the following criteria: each site had to be within five km, and at the same elevation, as a meteorological recording station of known latitude, longitude and altitude with a long-term record of annual rainfall, maximum monthly air temperature in July and minimum monthly air temperature in January. Sites were selected with the aid of the most recent agro-ecological zonation scheme coupled with long-term meteorological records (Guler *et al.* 1990; Devlet Meteoroloji Isleri Genel Mudurlugu 1974). A degree of sampling stratification was imposed to ensure that the full range of elevations experienced in the agricultural production zones of central and eastern Anatolia were adequately represented. Similarly, efforts were made to exclude very dry (<200 mm) or very wet sites (>650 mm *per annum*) as these areas are not be suitable for the production of the target food, forage and pasture legume species. In addition and for consistency, only those fields that had been under wheat or barley in the previous year were selected for soil sampling.

Soil sampling

Soils were sampled from several randomly selected locations in each field and from depths of between 0 and 20 cm. Clean spades disinfected with alcohol were used, and samples were taken from September 1991 to June 1992. Subsamples were bulked into pairs, placed in sealed plastic bags and stored in cool boxes until they could be refrigerated at 4–6° C. The first set of samples was used for soil chemical analysis (Soil and Fertilizer Institute in Ankara) and the second set was used for rhizobia characterization at ICARDA, Tel Hadya, Syria. Extreme care was taken to prevent cross-contamination between samples and mortality of bacteria while in transit or storage. Storage times in cool conditions were kept to a minimum and seldom exceeded 31 days. Soil samples for rhizobia characterization were air-dried at room temperature; stones and straw were removed. Each sample was then thoroughly mixed on a clean, disinfected solid surface and 200 g subsamples were selected for rhizobial characterization. These were re-bagged in clean plastic (loosely tied to allow some passage of air) and stored for a short period at 4–6° C in a refrigerator.

Soil chemical analyses

Soils were analyzed using standard techniques for dryland agricultural soils in the Mediterranean region as described by Matar and Ryan (1990) and Tuzuner (1990). Determinations included pH as well as the concentrations of total salts, calcium carbonate, phosphorus, potassium and organic matter.

Host legumes

Pre-selected host legumes were used to determine whether indigenous rhizobia were able to induce nodulation.

a) For *Rhizobium ciceri*: Chickpea cv. ILC 482 was used together with a Turkish local population from Kazan in Ankara Province. Cultivar ILC 482 has been approved for release in highland Turkey; Kazan local is typical of unimproved landraces that are spring-planted in the Turkish highlands.

b) For *Rhizobium leguminosarum*: Lentil cv. ILL 1878, and Woolly pod vetch (*Vicia villosa* ssp. *dasycarpa*) acc. 683 were used. These cultivars are well-adapted to highland conditions and represent the dominant food and forage legume species in this class.

c) For *Rhizobium meliloti*: *Medicago rigidula* (ICARDA sel. 716), *M. noeana* (ICARDA sel. 2351), *M. aculeata* (ICARDA selection IFMA 1466) and *M. minima* (ICARDA sel. IFMA 3279) were used. These species were selected as being either potentially well-adapted to the highlands (*M. rigidula* and *M. noeana*) or as common comparators to the species used by Materon (1991) in his associated survey of the west Asian lowlands.

Preparation of seedlings, inoculation practice and growth conditions for pasture legumes

The methods of Materon (1991) were duplicated as described below, with supplementary technical details provided by Beck *et al.* (1993). Seeds of *Medicago* spp. were mechanically scarified and then surface sterilized by exposure to 95 percent ethanol for one minute followed by immersion in a 5.25 percent sodium hypochlorite (NaOCl) solution for one minute and then repeatedly rinsed in de-ionized sterile water (Vincent 1970). Seeds were then aseptically transferred to Petri dishes containing one percent water agar and spread apart on the surface of the gel. Dishes were kept at room temperature and inverted to provide seedlings with straight roots. Single seedlings were set out in cotton-plugged glass tubes (20x2.4 cm) containing a 1:1 mixture of vermiculite and gravel with Fahraeus N-free nutrient solution (Gibson 1987). From each sample, 10 g of soil was added to a 90 ml sterile water blank. The initial soil dilution was thoroughly mixed in a reciprocating shaker for 20 minutes. Thereafter, 10-fold serial dilutions were prepared up to 10^{-4} to determine rhizobial population levels (Beck *et al.* 1993). One ml of each soil dilution was used to inoculate four replicate seedlings for each of the legume species under test.

Immediately after sowing, the tubes were placed into wooden racks in a room provided with a controlled fluorescent light source giving 325 $Em^{-2}s^{-1}$ PAR at tube level for a 12 h day. The racks were positioned at random and re-arranged at 7-day intervals. Air temperature was adjusted to 25° C (±3°C) during daylight and 12° C (±3° C) at night.

Preparation of seedlings, inoculation practice and growth conditions for food and forage legumes

Soil subsamples were bulked, air-dried at 27° C and sieved to <2 mm. A maximum of 21 days elapsed following collection before the samples were evaluated for rhizobial population size and effectiveness.

A 10 g portion of each soil sample was successively diluted in sterile water using 10-fold dilutions over the range 10^{-1} to 10^{-4}. From each dilution, four replicate one ml aliquots were used to inoculate seedlings grown in aseptic glass house hydroponic culture (Vincent 1970; Beck *et al.* 1993). Seeds were surface sterilized (Vincent 1970) and germinated on water agar plates, prior to aseptic transfer to sterile growth cups containing a 1:4 (v/v) vermiculite-gravel mixture. Plants were grown in the glass house for 42–56 days and watered daily as needed. At harvest, the number of nodulated plants at each dilution was recorded and the population density of rhizobia was placed in one of three semi-quantitative categories: high, medium or low, where high is >1000 rhizobia g $soil^{-1}$, medium is 100-1000 rhizobia g $soil^{-1}$ and low is <100 rhizobia g $soil^{-1}$.

All 105 soil samples were tested for symbiotic effectiveness with chickpea, lentil, and vetch using the aseptic hydroponic gravel culture system in the glass house. Effectiveness tests were replicated four times in sterile disposable one liter plastic cups containing one kg of sterile vermiculite-gravel mixture (1:4, v/v). A sterile N-free nutrient solution, containing 0.5 mM P, 0.92 mM K, 1.56 mM S, 0.76 mM Mg, and 1.0 mM Ca and a standard micronutrient solution (Broughton and Dilworth 1971), was provided to each cup as needed through a drip line manifold attached to a 200 l reservoir. Drainage holes ensured that excess water did not accumulate and the table surface was a wire mesh to avoid cross-contamination. Pots were covered with a plastic lid to prevent surface contamination, through which a 10 mm hole was drilled and plugged with sterile cotton to allow plant stems to grow.

Pots fertilized with combined N and contamination assessment monitoring controls were not inoculated. Nitrogen control treatments received 100 mg NO_3-N pot^{-1} as dilute KNO_3 applied in three equal doses at 15, 29 and 40 days after planting. Plants were randomized in the glass house and received natural daylight supplemented by artificial light to provide 14 hd^{-1}. Temperatures ranged from 12° to 25° C.

Symbiotic assessment of pasture legumes

Shoots were harvested and weighed after 35 days. Plants were graded for their response to nodulation on the basis of dry weight and nodule appearance. The mass of dry shoots was used as a measure of plant response to inoculation and was compared to the mass of N-fed plants that were not inoculated (Vincent 1970). Symbiotic efficiency ratings (0–3) were based on plant mass and type of nodulation: 0, no nodulation; 1, <50 percent of the dry weight of the N control indicating ineffective nodulation—low efficiency; 2, equivalent to 50–75 percent of the dry weight of the N control (0.10 percent KNO_3)—medium efficiency; and 3, 75–100 percent of the dry weight of the N control, indicating maximum plant growth and effective nodulation—high efficiency. The biomass of uninoculated plants was used as a baseline (zero response) with symbiotic effectiveness indicated as a proportion of growth in the N-fed controls. An average effectiveness rating was developed for each population of rhizobia from each sample analyzed, based on the symbiotic response of each of the host species tested.

Symbiotic assessment of food and forage legumes

At harvest, 42–56 days after planting, shoots were removed and dried at 60° C to constant weight. Nodulation was scored using a simple system where 0=no nodulation, 1=nodulation but ineffective in N_2 fixation, and 2=effective nodulation. Differences between 1 and 2 were determined by internal nodule color, the latter being pink/red, the former green/brown.

Symbiotic effectiveness was estimated for each rhizobial population on each cultivar as follows:

SE=(ShD Inoc.-ShD Uninoc.)/(ShD N Cont.-ShD Uninoc.)x100

where SE=symbiotic effectiveness, ShD=shoot dry weight, Inoc.=inoculated with rhizobia, Uninoc.=without inoculation, N Cont.=control treatment with added nitrogen.

From these comparisons with controls given N or not, four classes of effectiveness were defined:

1) High effectiveness, if the isolates produced plant dry weights equal to or greater than 80 percent of the dry weight produced in the 100 mg N pot^{-1} controls.

2) Moderate effectiveness, if dry weights equaled 30–79 percent of N-fed plants.
3) Low effectiveness, where plant dry weights were equal to only 10–29 percent of the controls.
4) Ineffective, where soil populations produced less than 10 percent of the dry matter produced in N-fed controls.

Isolation of strains of rhizobium from nodules

Highly effective strains of rhizobium occupying the nodules of plants showing positive symbiotic responses were selected for isolation. Cultures were authenticated by verifying their nodulation characteristics on corresponding legume hosts (Vincent 1970 1977). To avoid subsequent genetic variation, the bacterial cultures were lyophilized and stored in small glass vials at room temperature.

Results

Survey data are presented to show semi-quantitative estimates (high, medium or low) of the average number of native *Rhizobium meliloti* present in the soil (Fig. 1) and the average values (across four plant species) for their efficiency of N_2 fixation at each location (Fig. 2). For averaging semi-quantitative parameters, an "averaging-down" rule was adopted (for example, medium+medium+low+low=low). This approach will maximize rather than minimize the perceived risk of symbiotic N_2 fixing failure in the surveyed locations. Despite a fairly random distribution of *R. meliloti*, with average numbers in most locations, the picture for N_2 fixing efficiency is somewhat bleaker (Figs. 1, 2). Most sites have low efficiency and no site was given a high efficiency rating.

For *Rhizobium leguminosarum*, bacteria numbers are a good deal higher than for *R. meliloti* (Fig. 3). Most sites have at least medium numbers, but a minority of sites have low bacterial numbers distributed in a seemingly random geographic manner. Efficiency ratings for *R. leguminosarum* again show a different trend (Fig. 4). Nearly 20 percent of sites had high efficiency ratings but showed no geographic clustering.

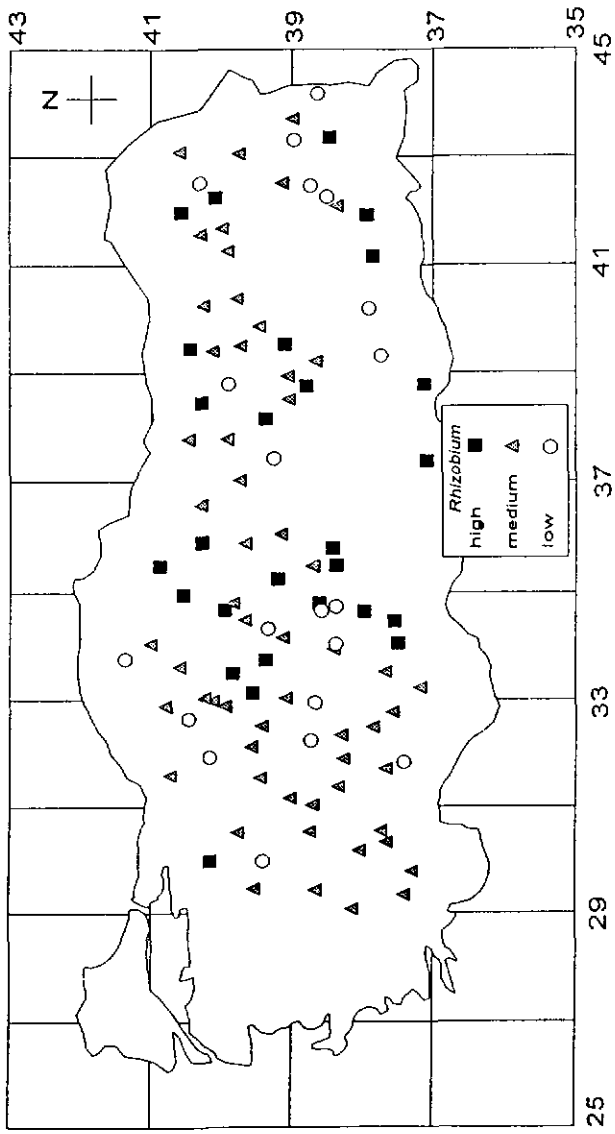

Figure 1. Diversity in relative numbers of native *Rhizobium meliloti* bacteria in the soils of the highlands of Turkey.

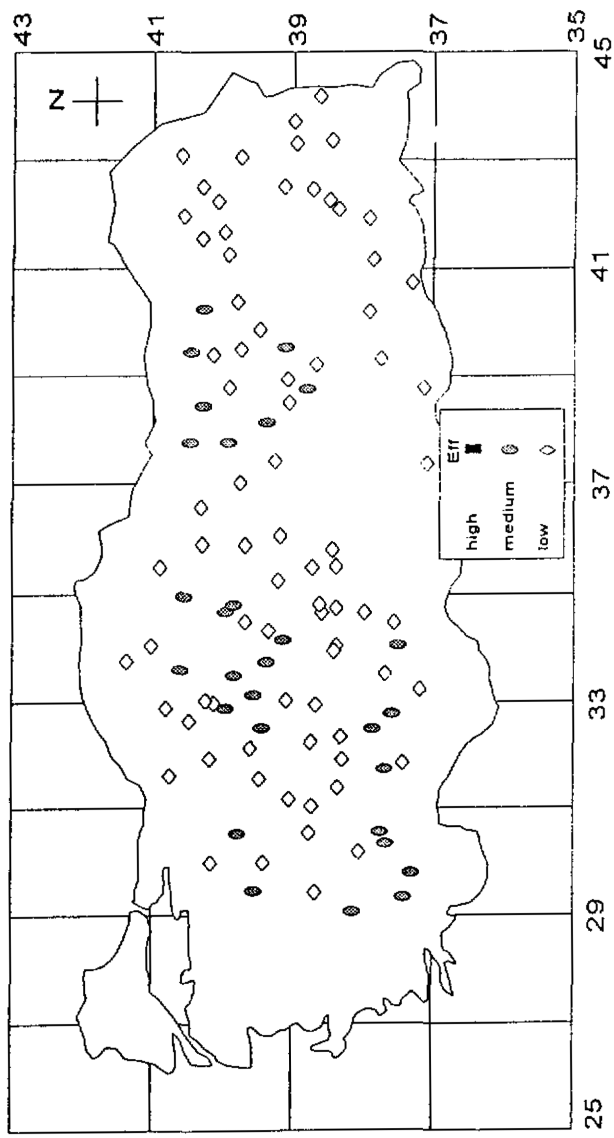

Figure 2. Diversity in N_2 fixing efficiency of native *Rhizobium meliloti* bacteria in the soils of the highlands of Turkey.

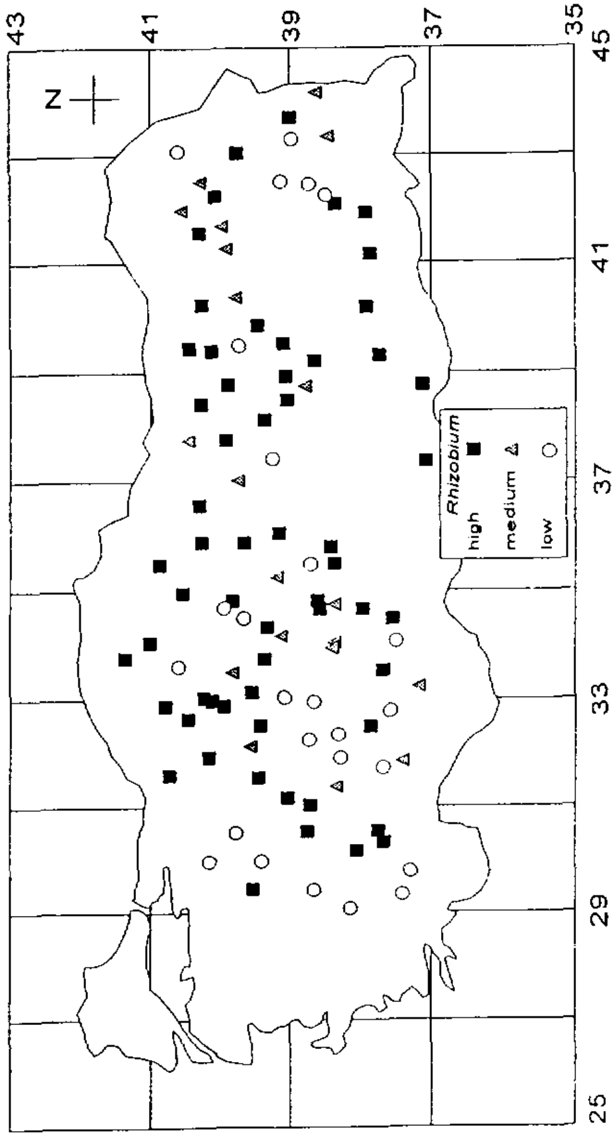

Figure 3. Diversity in relative numbers of *Rhizobium leguminosarum* bacteria in the soils of the highlands of Turkey.

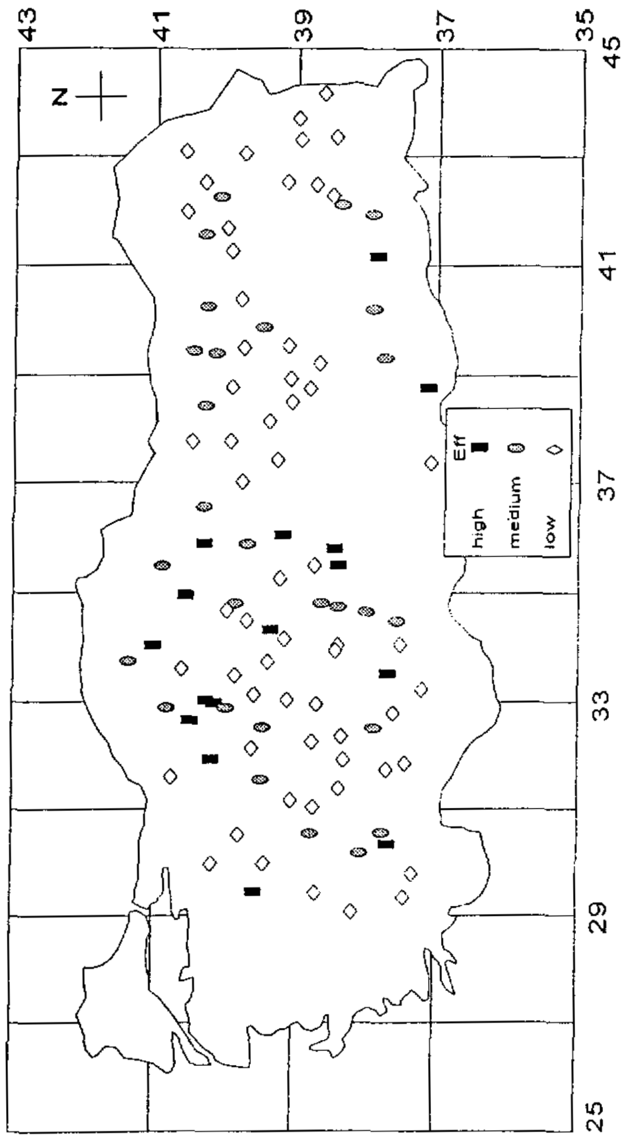

Figure 4. Diversity in N_2 fixing efficiency of native *Rhizobium leguminosarum* bacteria in the soils of the highlands of Turkey.

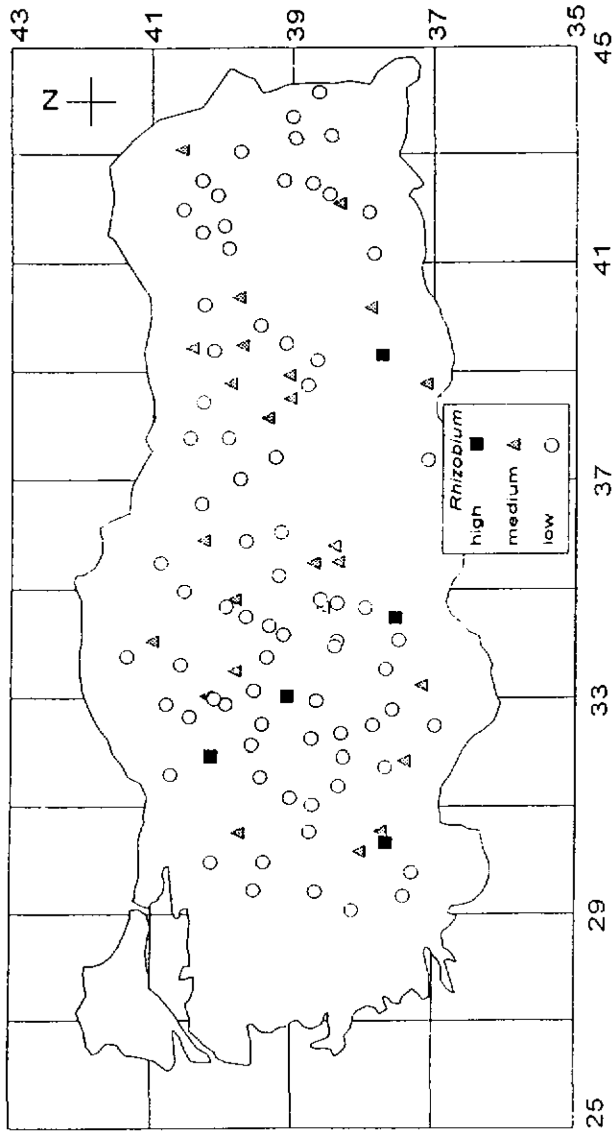

Figure 5. Diversity in relative numbers of *Rhizobium ciceri* bacteria in the soils of the highlands of Turkey.

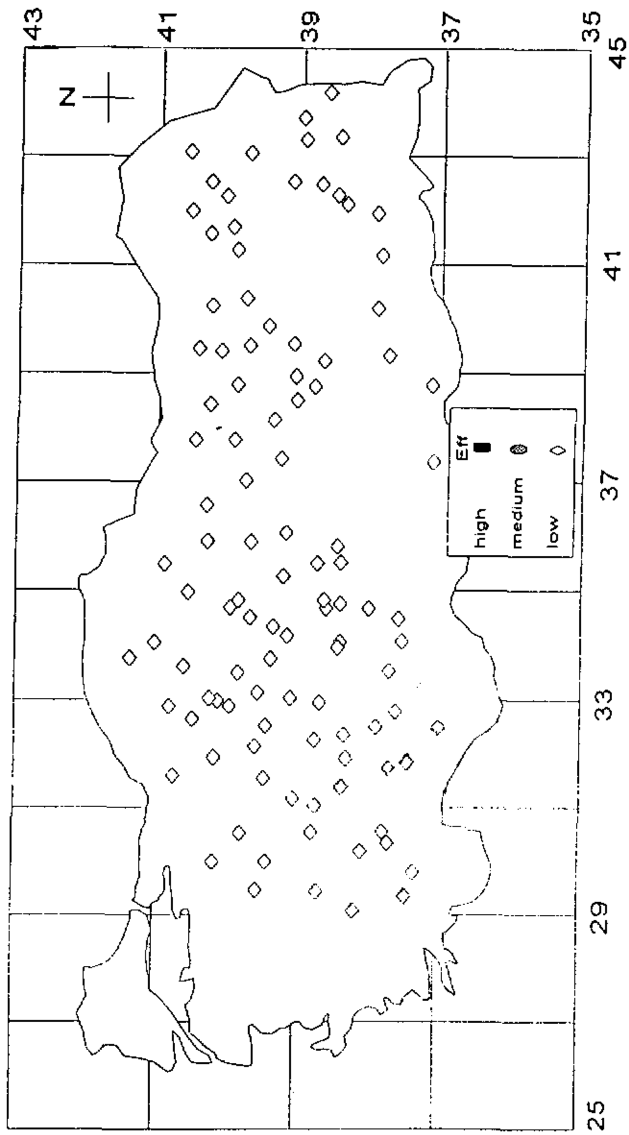

Figure 6. Diversity in N_2 fixing efficiency of native *Rhizobium ciceri* bacteria in the soils of the highlands of Turkey.

In contrast, for *R. ciceri*, numbers of bacteria are low, and for N_2 fixing efficiency the picture is clear—all 105 sites showed low average fixation efficiencies (Figs. 5, 6).

Clearly, irrespective of species of native rhizobia, there are substantial differences between the numbers in the soil, but not in their N_2 fixation efficiencies, which all tend to be low.

Table 1a. Simple statistics for characteristics of rhizobial N_2 fixation efficiency for 105 sites in the Turkish Highlands.

Variable	Mean	Std. Dev.	Min	Max
M. rigidula	31.7	39.1	0	204
M. noeana	25.6	26.2	0	110
M. aculeata	241.5	644.8	0	6568
M. minima	3.7	9.3	0	77
Chickp.ILC482	223.3	33.5	0	161
Chickp. Kazan	30.2	19.8	1.7	88
Lentil	76.9	40.2	0.9	193
Vetch	101.7	51.8	0	266

Extensive statistical analyses were carried out to examine the interactions between N_2 fixing effectiveness of species of rhizobia (Table 1a) with a selected range of climatic and edaphic variables. It was not possible to duplicate the analysis for rhizobial numbers, given the use of a semi-quantitative rather than fully quantitative estimation procedure. Climatic and soil chemical variables were chosen on the grounds of both the availability of long-term average data (air temperature and rainfall) and for their probable influence on bacterial numbers and symbiotic N_2 fixing effectiveness, either individually or in combination (environmental and edaphic parameters). Parameters included annual rainfall, extreme minimum monthly mean air temperature in January, extreme maximum monthly air temperature in August, elevation, and for soil, electrical conductivity, pH, and concentrations of organic matter, phosphate, calcium carbonate and potassium. The range in climatic variables and soil parameters was substantial, particularly in elevation, rainfall, minimum and maximum air temperature, lime, P_2O_5, K_2O and organic matter content (Table 1b). Differences in electrical conductivity and pH were less extreme. No very salty or very acid soils were sampled. Simple correlation coefficients between individual environmental variables against rhizobium N_2 fixing effectiveness were typically very weak but occasionally significant ($P \leq 0.05$) (Tables 2 and 3). Simple correlations do not appear sufficiently adequate to explain the geographic randomness of any of the data illustrated in Figures 2, 4 and 6.

Table 1b. Simple statistics for environmental parameters for 105 sites in the Turkish highlands.

Variable	Mean	Std. Dev.	Min	Max
Elev (m)	1130	339	526	2175
Rain (mm)	462	130	286	1056
MINT (°C)	-4.8	3.5	-17.3	1.4
MAXT (°C)	29.4	3.6	24.4	38.9
EC (ds/m)	0.05	0.03	0.0	0.17
pH	7.7	0.4	5.9	8.7
Lime (ppm)	12.9	10.3	0.4	38.9
P_2O_5 (ppm)	3.6	2.4	0.8	18.2
K_2O (ppm)	132	120	31	865
OM (%)	1.8	1.0	0.1	7.2

Where: MINT = Extreme mean monthly minimum air temperature (in January), MAXT = Extreme mean monthly maximum air temperature (in August), OM = Organic matter content

Table 2. Pearson correlation coefficients and statistical significance ($P \leq 0.05$) between *Rhizobium meliloti* N_2 fixation efficiency characteristics and environmental parameters for 105 sites in the Turkish Highlands.

	M.rigidula	*noeana*	*aculeata*	*minima*
Elev (m)	-0.21	-0.28	0.11	0.02
	0.03	0.004	0.27	0.83
Rain (mm)	0.07	-0.04	0.24	-0.02
	0.50	0.65	0.02	0.80
MINT (°C)	0.22	0.26	-0.11	-0.12
	0.03	0.01	0.27	0.23
MAXT (°C)	0.06	0.08	-0.03	0.05
	0.53	0.41	0.73	0.60
EC (ds/m)	0.12	0.13	0.12	-0.05
	0.23	0.18	0.29	0.64
pH	0.07	0.07	-.05	0.12
	0.47	0.47	0.58	0.21
Lime ppm	-0.03	0.07	-0.08	-0.10
	0.76	0.48	0.44	0.33
P_2O_5 ppm	-0.02	-0.04	0.05	-0.06
	0.82	0.70	0.64	0.53
K_2O ppm	-0.12	-0.14	0.001	-0.11
	0.22	0.16	0.99	0.27
OM (%)	-0.40	-0.39	0.07	-0.05
	0.001	0.001	0.51	0.59

Where: Elev = Elevation, Rain = Annual average precipitation, MINT = Extreme mean monthly minimum air temperature (in January), MAXT = Extreme mean monthly maximum air temperature (in August), OM = Organic matter content

Table 3. Pearson correlation coefficients and statistical significance ($P \leq 0.05$) between *R. leguminosarum* N_2 fixation efficiency characteristics and environmental parameters for 105 sites in the Turkish Highlands.

	CPILC482	CPKAZAN	Lentil	Vetch
Elev (m)	-0.25	-0.12	-0.33	-0.27
	0.01	0.21	0.001	0.01
Rain (mm)	-0.13	0.03	-0.14	-0.10
	0.18	0.73	0.15	0.29
MINT (° C)	0.26	0.20	0.36	0.29
	0.01	0.04	0.001	0.003
MAXT (° C)	0.18	0.17	0.33	0.06
	0.06	0.08	0.001	0.57
EC (ds/m)	0.13	-0.10	0.02	-0.03
	0.19	0.32	0.87	0.73
pH	-0.07	-0.06	-0.01	-0.17
	0.51	0.52	0.89	0.08
Lime ppm	-0.17	-0.13	0.09	-0.07
	0.09	0.18	0.35	0.46
P_2O_5 ppm	0.14	-0.04	-0.03	0.05
	0.17	0.70	0.73	0.63
K_2O ppm	0.03	-0.16	-0.22	-0.07
	0.76	0.88	0.03	0.44
OM (%)	-0.10	-0.27	-0.19	-0.03
	0.33	0.01	0.06	0.76

Where: Elev = Elevation, MINT = Extreme mean monthly minimum air temperature (in January), MAXT = Extreme mean monthly maximum air temperature (in August), OM = Organic matter content

Further attempts were made to determine whether more complex relations were being masked by the simple nature of the initial analysis. This approach involved the use of factor and principal component analysis. The outcome revealed that, as expected, there were two major groupings in the environmental variables, i.e. temperature and soil derived. However, these were not strongly correlated with the rhizobium N_2 fixing efficiency variables and are therefore not presented. Residuals showed no patterns and were randomly distributed. Attempts to use various orthogonal rotations on the data set to identify stronger relations proved fruitless. Similarly, multivariate regression response surface analysis was attempted, but improvements in correlation coefficients and any additional understanding of the underlying causes of geographic distribution of symbiotic parameters were marginal. There is little relation between native rhizobial characteristics from the survey and the range of climatic and soil variables against which they were tested, either singly or in simple association.

Discussion

The production of food, forage and pasture legumes in the west Asian and north African region (WANA) is currently low. Oram and Agcaoili (1994) cite a figure for cool season food legumes in WANA of just four million tons (the bulk of which is produced in Turkey alone) compared to more than 40 million tons of wheat (CIMMYT 1991). Statistics on forage and pasture legumes are poorly compiled nationally and are effectively unavailable at the regional level. However, it is unlikely that their production exceeds even 50 percent of the current total production of cool season food legumes. Nevertheless, the potential and need for increased production of these crops seem large. They are needed to replace fallow areas (Durutan *et al.* 1990), and/or to disrupt continuous cereal crop sequences and so help in developing more sustainable systems (Jones 1990; Acikgoz 1988) and to produce a greater supply of quality animal feed (Acikgoz 1988; Keatinge 1994).

A major reason preventing these legumes from gaining greater acceptability by farmers in WANA is their poor yield. Seed yields of one t ha^{-1} or less are the regional average (Oram and Agcaoili 1994) and even in Turkey average yields rarely exceed 1.3 t ha^{-1}. The reasons for poor yield are complex and include the following: poor seed bed preparation, inadequate weed control, poor disease resistance, inefficient seeding time, terminal drought stress, hand harvesting labor constraints and post-harvest inefficiencies in storage and distribution. These problems could largely be overcome with the extension of known improved agronomic techniques. However, there may be one critical hidden factor in this list of constraints—the poor growth rate and production per plant due to inadequate symbiotic N_2 fixation.

Is there a need for large-scale inoculation in WANA that is currently being neglected? Rigorous surveys (of the type reported here) of the distribution and effectiveness of native rhizobial populations from WANA are extremely rare. The experience gained from inoculation trials with legumes, though more plentiful (for example, see papers in Beck and Materon 1988) is almost exclusively restricted to lowlands, and even then these trials seldom adopt a comprehensive survey approach. Results from trials examining responses to inoculation are erratic depending on crop, geographic location, annual rainfall and season. A conservative summary of the current regional position suggests that the case for inoculation is yet unproven, and that it is a factor that requires considerably more detailed and systematic research, as the potential rewards for ensuring good crop N_2 fixation are substantial.

The situation in Turkey is a microcosm of that in WANA. Little is known about the need for inoculation, particularly in the highlands, but some important preliminary work has been undertaken. Cakmakci *et al.* (1988) surveyed 40 locations in southeastern and western Turkey (traditional lowland chickpea and lentil growing areas). They found that populations of *Rhizobium leguminosarum*, which nodulate lentil crops, were quite high at most of the sites sampled, but the opposite was true for *R. ciceri* and chickpea. They suggested that total numbers of rhizobia were positively correlated to the concentration percentage of soil organic matter. In addition, there was considerable variability in effectiveness for lentil between isolates. Acikgoz (1988) summarized earlier work on vetch. He implied that there is usually little response to inoculation in this forage legume, and that inoculation trials showed inconclusive results over sites and years. The inoculation requirements of annual pasture legumes in the Turkish highlands are largely unknown. However, these species are common weeds in Anatolia, and perennial *Medicago* spp., such as alfalfa, do not appear to be limited by poor N_2 fixation under dryland conditions (S. Elci, personal communication 1993).

Current results from the highlands of Turkey are largely harmonious with the findings of Cakmakci *et al.* in the Turkish lowlands and of Materon (1991) in the WANA lowlands. It was surprising to discover the weakness of the correlation between selected environmental and soil chemical variables and N_2 fixing ability in the survey data. Clearly, our current understanding of the causality of native variation in N_2 fixing ability in these harsh environments is weak. Nevertheless, the results of the survey suggest substantial opportunities to improve crop production through targeted inoculation—providing that effective, competitive and persistent strains of specific rhizobia can be identified. The following three papers discuss these issues in more detail, with specific reference to legume species associated with *R. meliloti* (annual medics), *R. leguminosarum* (vetch and lentil) and *R. ciceri* (chickpea).

—L.A. Materon, J.D.H. Keatinge, D. Beck, S. Altintas and N. Cebel and M. Zaklouta

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The Role of Rhizobial Biodiversity in Legume Crop Productivity in the West Asian Highlands: 2. *Rhizobium leguminosarum*

Summary

This paper reports a survey of native rhizobia capable of symbiosis with most annually sown food and forage legume crops in the Turkish highlands. It examines the numbers of bacteria and the N_2 fixing efficiency of isolates of *Rhizobium leguminosarum* with cultivars of Turkish lentil (*Lens culinaris*) and vetch (*Vicia sativa*). Soils were collected from a wide range of elevations between 500 and 2200 m; native rhizobia were present in medium to high numbers in most samples. However, the N_2 fixation efficiencies of isolates were poor in at least 50 percent of cases. Vetch was somewhat less specific in its rhizobial compatibility than lentil. Data suggest that there is potential for artificial inoculation to impact on productivity and sustainability of cropping in both species. Opportunities may be particularly attractive in new potential production areas in central and eastern Anatolia where legumes are not traditionally grown. Further agronomic trials with symbiotically efficient and ecologically persistent strains are required.

Introduction

In Turkey, the area annually sown to pulse crops increased from 0.7 million ha in 1977 to 2.1 million ha in 1987 (Keatinge 1994). This expansion reflects an intensive research and extension campaign directed at replacing fallow periods in crop sequences with food and forage legume crops in areas where annual rainfall exceeds 410 mm (Guler and Karaca 1988; Durutan *et al.* 1990). Consequently, Turkey has now become the world's largest exporter and second largest producer, after India, of lentil (Oram and Agcaoili 1994). Exports have increased in the decade 1977–1987 from approximately 50,000 t to more than 300,000 t (Guler 1990). For lentil, preferred exports are decorticated and split red-seeded types. Increased output has been based on an expansion of the area of production, with average yield remaining at about one t ha^{-1} (Keatinge 1994). However, Turkey's export market and production share of red lentil may soon be seriously threatened by the new one million hectare GAP

(Guneydogu Anadolu Projesi) irrigation scheme being implemented in southeastern Anatolia, a traditional lentil dryland farming area (Yurdakul *et al.* 1990). Current joint research between the Turkish Ministry of Agriculture and Rural Affairs, Central Research Institute for Field Crops (CRIFC) and The International Center for Agricultural Research in the Dry Areas (ICARDA) is designed to determine whether lentil production can be maintained. There are two scenarios: improvements in productivity and a relocation of lentil cropping to the more extreme dryland environments of central and eastern Anatolia where continuous cereal or cereal/fallow crop sequences are now dominant. This shift would allow newly irrigated areas to produce more profitable industrial and horticultural crops. However, it is unclear whether production in these harsher climates will require inoculation with appropriate rhizobia as a standard agronomic practice. Crops are not traditionally inoculated elsewhere in the country.

The increased production of lentil has not been matched by the vetches (*Vicia* spp.). The sown area does not exceed 300,000 ha a^{-1} although vetches are an important constituent in the large areas of natural permanent pastures and meadows found in eastern Anatolia. Why vetch should have remained an under-exploited crop is unclear. Its potential for greater use as good quality animal feed is substantial (Keatinge 1994). However, seed yields are <800 kg ha^{-1} and the price guarantees and marketing support mechanisms, which are provided nationally for food legumes (Durutan *et al.* 1990), do not apply to vetch. Whether inadequate N_2 fixation is a contributory factor to poor yield remains unproven. Very few scientific studies relevant to this geographic area have been reported (Keatinge *et al.* 1995a).

This research is designed to examine the symbiotic N_2 fixation characteristics and native distribution of *Rhizobium leguminosarum* in the Turkish highlands. The long-term objective is to determine future national inoculant production needs for lentil, vetch and related crops in Turkey and throughout similar highland environments in Iran, Iraq, Pakistan, and Afghanistan.

Materials and Methods

Experimental methods are given in Keatinge *et al.* (1995a) with supporting information in Materon (1991) and Beck *et al.* (1993).

Site selection

One hundred and five sites were selected from as wide a geographic area in highland Turkey (>500m) as possible, given the following criteria: each site had to be within 5 km, and at the same elevation as a meteorological recording station of known latitude, longitude and altitude, with a long-term record of annual rainfall, maximum monthly air temperature in July and minimum monthly air temperature in January.

Soil sampling

Soils were sampled from several randomly selected locations in each field from depths of between 0 and 20 cm from September 1991 to June 1992. Soil samples for rhizobial characterization were air-dried at room temperature, and sieved to <2 mm. They were then thoroughly mixed on a clean, disinfected solid surface and a 200 g subsample was selected for rhizobial characterization.

Soil chemical analysis

Soils were analyzed using standard techniques for dryland agricultural soils in the Mediterranean region (Matar and Ryan 1990; Tuzuner 1990) and included determinations of pH and the concentrations of total salts, calcium carbonate, phosphorus, potassium and organic matter.

Host legumes

Pre-selected host legumes were used to determine whether indigenous rhizobia were able to induce nodulation: lentil cv. ILL 1878 (Kislik Yesil 21) and woolly pod vetch (*Vicia villosa* ssp. *dasycarpa*) acc. 683 were used. These cultivars are known to be well-adapted to highland conditions.

Seedling preparation, inoculation practice and growth conditions

A 10 g portion of each soil sample was successively diluted in sterile water using 10-fold dilutions over the range 10^{-1} to 10^{-4}. From each dilution, four replicate one ml aliquots were used to inoculate seedlings in aseptic glass house hydroponic culture (Vincent 1970; Beck *et al.* 1993). Seeds were surface sterilized (Vincent 1970) and germinated on water agar plates, prior to aseptic transfer to sterile growth cups containing 1:4 (v/v) vermiculite-gravel. Plants were grown in the glass house for 42–56 days and watered daily as needed. At harvest, the number of nodulated plants at each dilution was recorded and the population densities of rhizobia were estimated to be in one of three semi-quantitative categories: high, medium or low, where high ≥ 1000 rhizobia g soil^{-1}, medium equals 100-1000 rhizobia g soil^{-1} and low <100 rhizobia g soil^{-1}.

All 105 soil samples were tested for symbiotic efficiency with vetch and lentil using the aseptic hydroponic gravel culture system in the glass house. Effectiveness tests were replicated four times in sterile disposable one liter plastic cups containing one kg of a sterile 1:4 vermiculite-gravel mixture. Sterile N-free nutrient solution with a composition of 0.5 mM P, 0.92 mM K, 1.56 mM S, 0.76 mM Mg, 1.0 mM Ca and a standard micronutrient solution (Broughton and Dilworth 1971) was provided to each cup as needed through a drip line manifold attached to a 200 liter reservoir. Drainage holes in cup bottoms ensured that excess water did not accumulate. The table surface was composed of a wire mesh to avoid cross-contamination between treatments. Pots were covered with a plastic lid to prevent surface contamination. A 10 mm hole was drilled in the lids and plugged with sterile cotton wool to allow for plant stem growth. Pots fertilized with combined N and contamination assessment monitoring controls were not inoculated. The N control treatments received 100 mg NO_3-N pot^{-1} as dilute KNO_3 applied in three equal doses at 15, 29 and 40 days after planting. Plants were randomized in the glass house under natural daylight and supplementary lighting to provide 14 hd^{-1}. Temperatures ranged from 12–25° C.

Symbiotic assessment

At harvest (42–56 days after planting) shoots were removed and dried to constant weight at 60° C. Nodulation was scored using a simple system where 0=no nodulation, 1=nodulation but ineffective N_2 fixation, and 2=effective nodulation. Differences between 1 and 2 were determined by internal nodule color, the latter being pink/red and the former green/brown.

Symbiotic effectiveness was estimated for each rhizobial population on each cultivar as follows:

$$SE=(ShD\ Inoc.-ShD\ Uninoc.)/(ShD\ N\ Cont.-ShD\ Uninoc.)\times 100$$

where SE=symbiotic effectiveness, ShD=shoot dry weight, Inoc.=inoculated with rhizobia, Uninoc.=without inoculation, N Cont.=control treatment with added N

From these comparisons with controls given N or not, four classes of effectiveness were defined:

1) High, if the isolates produced plant dry weights equal to or greater than 80 percent of the dry weight produced in the 100 mg N pot^{-1} controls.
2) Moderate, if dry weights equaled 30–79 percent of N-fed plants.
3) Low, where plant dry weights were equal to only 10–29 percent of the controls.
4) Ineffective, where soil populations produced less than 10 percent of the dry matter produced in N-fed controls.

Isolation of rhizobia from nodules

Highly effective strains of rhizobia occupying the nodules of plants showing positive symbiotic responses were selected for isolation. Cultures were authenticated by verifying their nodulation characteristics on corresponding legume hosts (Vincent 1970, 1977). To avoid subsequent genetic variation, the bacterial cultures were lyophilized and stored in small glass vials at room temperature.

Results

Survey data are presented to show the relative numbers (high, medium or low) of *Rhizobium leguminosarum* in soil capable of inducing nodulation in lentil (Fig. 1) and the value of their N_2 fixation efficiency at each location (Fig. 2). Numbers of bacteria were high in >60 percent of locations, but a substantial minority of locations (≈20 percent) had only low numbers. There was no striking geographic consistency in the distribution of locations with either high or low numbers. The soils sampled from the traditional lentil production zone in southeastern Anatolia all had high numbers (Fig. 1). In contrast, symbiotic N_2 fixation efficiency values were generally low, with the Erzurum/Erzincan region (between latitudes 37–41° E) being universally poor. Even southeastern Anatolia can be described as only a medium N_2 fixation efficiency region. Overall, less than 20 percent of sites were awarded highly efficient N_2 fixation status (Fig. 2).

For vetch, bacteria numbers are also generally high, with similar proportions of medium and low values again seemingly distributed at random (Fig. 3). Yet Figures 1 and 3 are not identical. Approximately 20 percent of sites show differences in *R. leguminosarum* numbers actively nodulating the two species. This implies a measure of (unexpected) specificity for either the host species or host genotypes employed.

Although N_2 fixation efficiency values are different between hosts, values with vetch (Fig. 4) are somewhat higher than those with lentil (Fig. 2). Approximately 50 percent of sites had medium or better N_2 fixation values with vetch. Geographically, this difference is most evident in the Erzurum/Erzincan region of eastern Anatolia where the chances of vetch being inoculated with inefficient rhizobia is only 50 percent, compared to 100 percent for lentil. *Viçia* spp. are common constituents of the permanent pasture in the region.

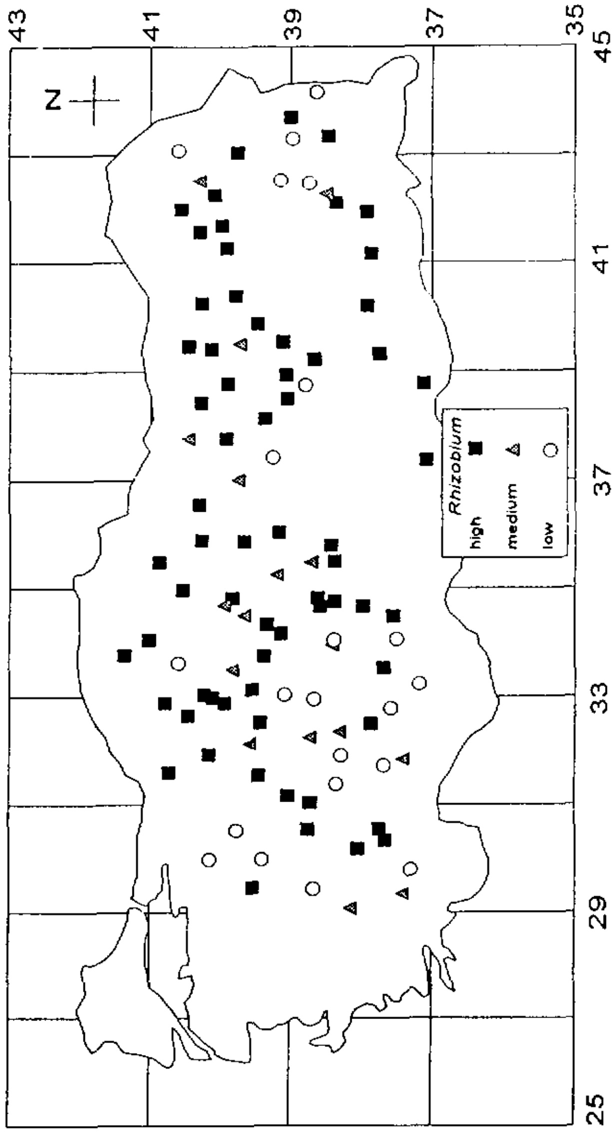

Figure 1. Diversity in relative numbers of native *Rhizobium leguminosarum* bacteria nodulating lentil in the soils of the highlands of Turkey.

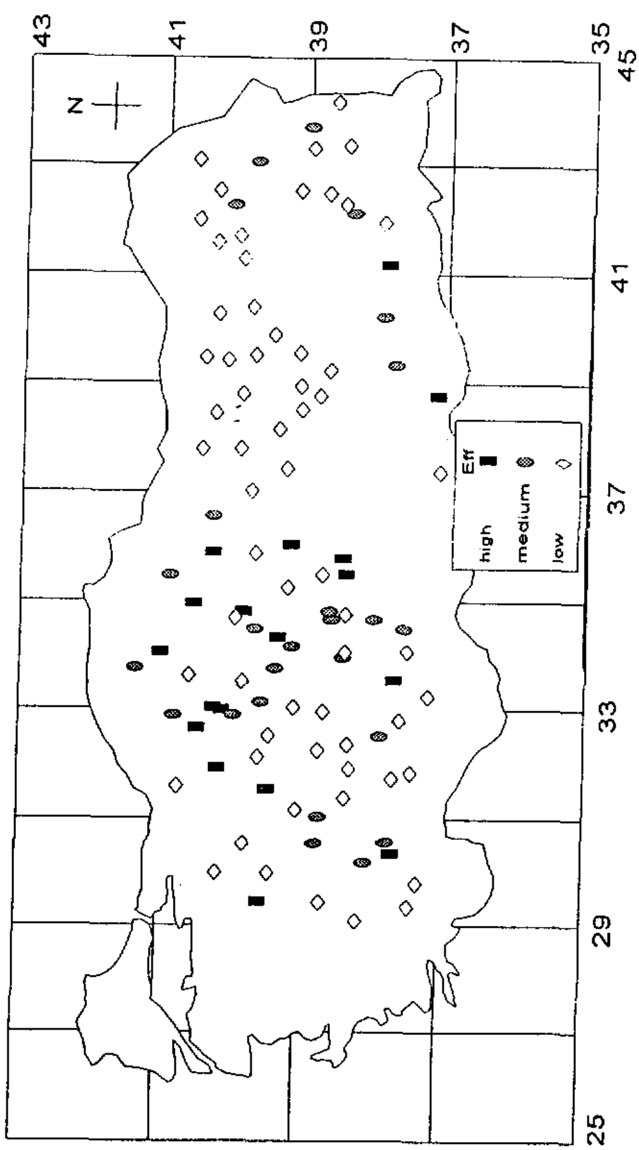

Figure 2. Diversity in N_2 fixing efficiency with lentil of native *Rhizobium leguminosarum* bacteria in the soils of the highlands of Turkey.

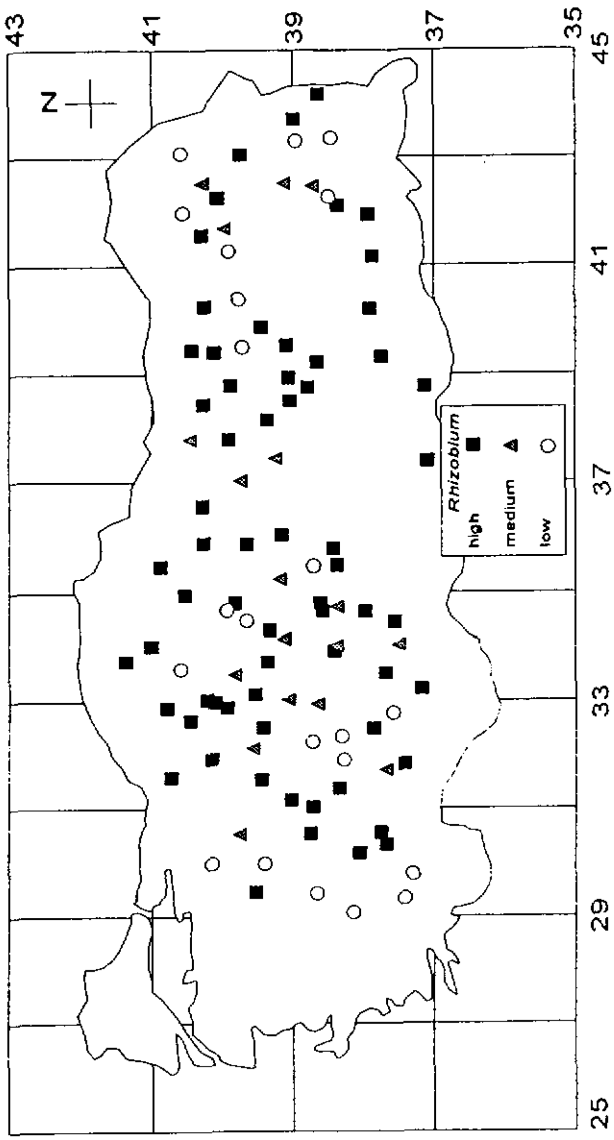

Figure 3. Diversity in relative numbers of *Rhizobium leguminosarum* bacteria nodulating vetch in the soils of the highlands of Turkey.

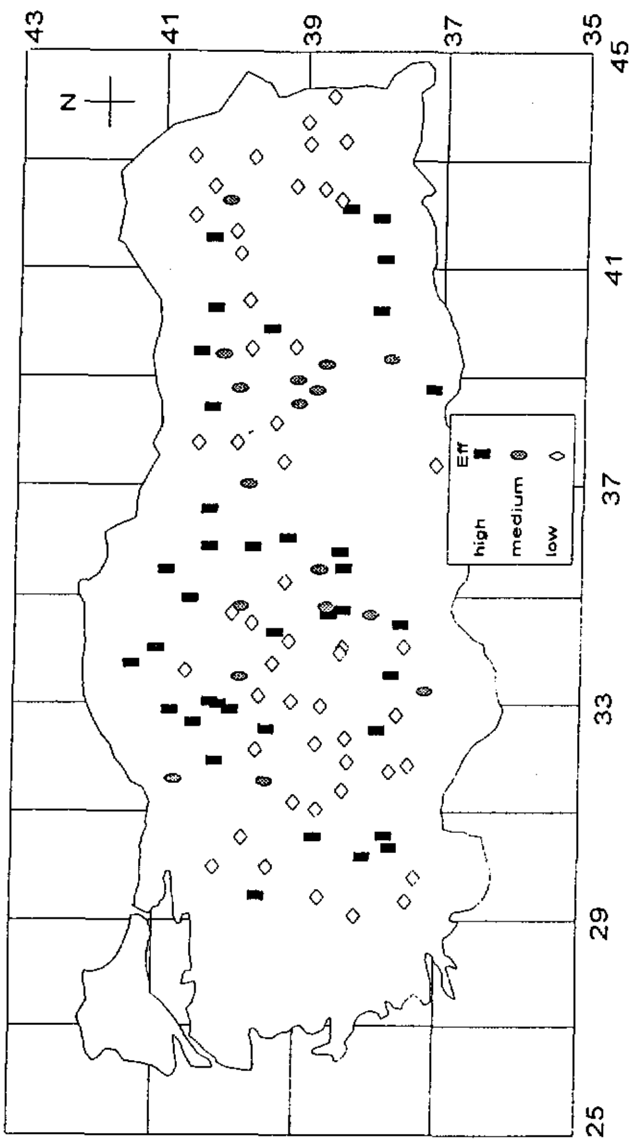

Figure 4. Diversity in N_2 fixing efficiency with vetch of *Rhizobium leguminosarum* in the soils of the highlands of Turkey.

Discussion

Given the propensity of *Rhizobium leguminosarum* for inducing N_2 fixation in a very wide range of legume species found in west Asia and north Africa, it is surprising to discover the variability and geographic inconsistency in bacterial numbers across the Turkish highlands. The slight differences between the numbers of bacteria specifically capable of inducing nodulation in vetch and lentil, together with variability in bacterial numbers, imply that simple, universal statements concerning the adequacy of *R. leguminosarum* numbers at unspecified locations in highland Turkey must now be suspect.

Likewise, it is evident from the N_2 fixation efficiency data for both species (Figs. 2, 4), that adequate N_2 fixation cannot be guaranteed from indigenous bacterial sources unless there has been a history of productive, and apparently non-N limited, legume cropping.

However, conventional wisdom in Turkey (S. Elci, M. Munzur, K. Meyveci, I. Kusmenoglu; personal communication 1993, 1994) provides no agronomic evidence to suggest that major responses to inoculation for vetch and lentil in traditional legume growing areas would be likely. Gurbuzer (1980) reported substantial yield increases of lentil following inoculation with selected indigenous and exotic strains of *R. leguminosarum* in Ankara province (which is not a traditional legume growing area) but Cakmakci *et al.* (1988) reported that responses to inoculation with lentil in Ankara province were not statistically significant. Results of the current survey are supported by the findings of Ulgen (1978) and Gurbuzer (1980).

Evidently lentil and vetch crops grow satisfactorily at many locations, and yet average yields of lentil have been stagnant at one t ha^{-1} for 40 years. It seems likely that symbiotic N_2 fixation rates could be markedly increased, given a highly efficient, competitive and persistent inoculant strain. Where inoculation trials have been undertaken in traditional legume growing areas in Turkey (e.g. Ersin 1978), the lack of a substantial, clear-cut response to inoculation may have been due to the poor competitive ability of the introduced strains in the presence of large bacterial numbers from a comparatively inefficient indigenous population. This hypothesis merits evaluation over a wider regional scale, as field inoculation trials in west Asia often report no substantial response to "improved" rhizobial inoculants (Keatinge *et al.* 1988; Keatinge and Chapanian 1991).

Traditional experience aside, it is likely that if, as national policy dictates, the major red lentil production cropping zone is transferred from SE Anatolia to central and eastern Anatolia as a result of the GAP irrigation scheme (Yurdakul *et al.* 1990; Keatinge *et al.* 1995b), lentil will then be grown in non-traditional areas and suitable inoculation with rhizobia would be a sensible initial precaution. The case for vetch is less clear, but a cautious farmer in central or eastern Anatolia would be minimizing risk of poor yields by using inoculation initially when sowing fields of unproven N_2 fixation status. Farmers may also consider inoculation if normal yield expectations fail to exceed the average for vetch hay of 1.5–2.5 t ha^{-1} (Acikgoz 1988).

The survey data may also help in pinpointing suitable strains of *R. leguminosarum* that are superior to commercially imported inocula. For example, those strains indicating high N_2 fixation efficiency for vetch from the Erzurum/Erzincan area appear to be more specifically adapted to the species tested. Likewise for lentil, rhizobial strains from the traditional production area of southeast Anatolia should now be tested for persistency in the more extreme highland environments. The case for inoculation seems to be at best recommended and at worst unproven. Considerably more research in this area is urgently required, not only to increase lentil and vetch yields but also to sustain cereal cropping systems in these harsh highland areas.

—L.A. Materon, J.D.H. Keatinge, D. Beck, K. Karuc, S. Altintas and N. Cebel.

Acknowledgments

The authors acknowledge the technical assistance of Mrs. M. Zaklouta, Mr. F. Afandi, Dr. J. Kanopka and Mrs. M.C. Materon.

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The Role of Rhizobial Biodiversity in Legume Crop Productivity in the West Asian Highlands: 3. *Rhizobium meliloti*

Summary

This paper reports a survey of native rhizobia that are capable of symbiosis with potential pasture legume crops for the west Asian highlands. It examines the numbers of bacteria in soil and the N_2 fixing efficiency of isolates of *R. meliloti* with a range of annual Medicago species. Soils were collected from 105 sites at elevations between 500 and 2200 m. Bacteria numbers were generally adequate to permit efficient nodulation. However, for three of four host species, the efficiency of N_2 fixation with the indigenous rhizobia was often low. *M. aculeata* was a marked contrast, being generally highly efficient. In general terms, no overall geographic pattern in either numbers or efficiency of N_2 fixation was evident. Further research is required before annual medic crops can be successfully introduced into highland crop/livestock systems in Turkey and elsewhere in the west Asian highlands.

Introduction

In west Asia the production area of sown pasture legumes under dryland conditions is small. Semi-perennial species such as alfalfa (*Medicago sativa*) and sainfoin (*Onobrychis viciaefolia*) account for the majority of that area. For example, in Turkey in the late 1980s, there were about 200,000 ha of alfalfa, of which less than 50 percent was produced under dryland conditions. In contrast, almost all of about 100,000 ha of sainfoin was produced under dryland conditions (Government of Turkey, State Institute of Statistics 1991). There is no known farm use of sown annual medic species based on the south Australian wheat/medic rotational system in the highlands of west Asia. However, with the urgent need for the introduction of cropping sequences less exploitative of natural resources than the traditional cereal/fallow or continuous cereal cropping system (Cocks 1988; Keatinge 1994), the potential for the introduction of annual medics and other legumes merits consideration. This prospect is being researched by the Turkish Ministry of Agriculture and Rural Affairs in collaboration with ICARDA.

In the highlands of west Asia the potential for increased production of annual medics is apparent from the common occurrence of annual pasture legumes in uncultivated, natural meadow and rangeland, protected from the generally intense grazing pressure (Keatinge 1994). Little is known about the distribution, numbers and effectiveness of the symbiotic N_2 fixing ability of the associated native rhizobium bacteria in these areas. Elsewhere, Materon and Cocks (1988) have reported the lack, or ineffectiveness of nodulation of annual medics to be major constraints to the establishment of this crop in the Mediterranean lowlands.

Materon (1991) later examined the symbiotic characteristics of *Rhizobium meliloti* with pasture legumes over a wide range of soils from five countries in west Asia, including Turkey. These soils were all sampled from sites below 500 m. The study demonstrated that for six species of annual medic (*M. rigidula, M. noeana, M. rotata, M. orbicularis, M. truncatula* and *M. polymorpha*), although most soils contained *R. meliloti*, considerable variability exists in population density and in N_2 fixation potential. Analyzing 40 samples from the intensively farmed and productive Ceyhan plain area of the southern Turkish coast, Materon (1991) reported that *R. meliloti* were present in adequate numbers. He categorized more than 50 percent of the samples as average to highly N_2 fixation efficient for *M. noeana, M. polymorpha* and *M. orbicularis*. In contrast, for *M. rigidula* there was an apparent nodulation failure, with only 20 percent of samples indicating medium N_2 fixation efficiency, and no sample indicating a high efficiency level. This finding is relevant to highland areas, given that *M. rigidula* is preferred in the large areas of calcareous soils in the mid-elevation Syrian hinterlands (Cocks 1988) which are substantially colder than the areas sampled by Materon (1991) on the Turkish southern Mediterranean coast.

Acute specificity among annual medic species is well known (Brockwell et *al.* 1988; Materon and Cocks 1988; and Materon and Danso 1991). It is essential to combine appropriate rhizobia with a closely compatible medic species if annual pasture production is to be successful.

The research described here was undertaken to examine the symbiotic N_2 fixation characteristics and distribution of indigenous *Rhizobium meliloti* in the highland areas of Turkey. The medium-term goal is to ensure that poor symbiotic N nutrition is not a major constraint to experiments designed to investigate the use of annual medic species. Such experiments are usually performed in rotation with cereals or with permanent pastures. They are needed throughout the Turkish highlands and comparable environments in west and central Asia. Regionally, experiments would be valuable, as the annual medics have undoubted potential to provide much-needed additional animal feed (Osman *et al.* 1990). Wider use of these crops would also help to conserve soil through a reduction in the practices of fallow or continuous cereal cropping. They may as well partially relieve the harsh pressure on areas of permanent grazing (Keatinge 1994).

Materials and Methods

Complete details of the experimental methods are given in Keatinge *et al.* (1995a) with supporting information in Materon (1991) and Beck *et al.* (1993).

Site selection

One hundred and five sites were selected from as wide a geographic area in Turkey as possible using the following criteria: the site had to be within 5 km, and at the same elevation, as a meteorological recording station of known latitude, longitude and altitude, with a long-term record of annual rainfall, maximum monthly air temperature in July and minimum monthly air temperature in January. Only fields which in the previous year had been under wheat or barley were selected for soil sampling.

Soil sampling and chemical analysis

Soils were sampled from several randomly selected locations in each field and from depths of between 0–20 cm from September 1991 to June 1992. Soils were analyzed using standard techniques for dryland agricultural soils in the Mediterranean region as described by Matar and Ryan (1990) and Tuzuner (1990) and included determinations of pH and concentration of total salts, calcium carbonate, phosphorus, potassium and organic matter.

Host legumes

Four species were used to determine whether the indigenous *Rhizobium meliloti* were able to induce nodulation: *Medicago rigidula* (ICARDA selection 716); M. noeana (ICARDA Selection 2351); *M. aculeata* (ICARDA selection IFMA 1466); and, *M. minima* (ICARDA selection IFMA 3279). These four species are either potentially adaptable to highland conditions or are common comparators (*M. rigidula* and *M. noeana*) to the six species used by Materon (1991) in his survey of the west Asian lowlands.

Preparation of seedlings, inoculation practice and growth conditions

The methods of Materon (1991) were adopted with supplementary technical details provided by Beck *et al.* (1993). Seeds were mechanically scarified and then surface sterilized in 95 percent ethanol for one minute followed by immersion in a 5.25 percent sodium hypochlorite (NaOCl) solution for one minute and then repeatedly rinsed in deionized sterile water (Vincent 1970). Seeds were then aseptically transferred to Petri dishes containing two percent water agar and spread apart on the surface of the gel. Dishes were kept at room temperature and inverted to provide seedlings with straight roots. Single seedlings were set out in cotton-plugged tubes (20x2.4 cm) containing a 1:1 (v/v) mixture of vermiculite and gravel with Fahraeus N-free nutrient solution (Gibson 1987). From each sample, 10 g of soil was added to a 90 ml sterile water blank. The soil dilution (10^{-1}) was thoroughly mixed in a reciprocating shaker for 20 minutes. One ml of each soil dilution was used to inoculate each of four replicate seedlings for each of the legume species employed.

Immediately after sowing, the tubes were placed in wooden racks in a room with a controlled light source. The racks were positioned at random and rearranged at seven day intervals. The plants were subjected to a 12 hd^{-1} photoperiod with an irradiance of 325 $Em^{-2}s^{-1}$ at plant height. Air temperature was adjusted to 25° C (±3° C) during daylight and 12° C (±3° C) at night.

Symbiotic assessment

Shoots were harvested after 35 days, dried and weighed. At harvest, plants were graded for their response to nodulation on the basis of plant mass and nodule appearance. The mass of dry shoots was compared to the mass of those N-fed plants that were not inoculated (Vincent 1970). Effectiveness ratings (0–3) were based on plant mass and type of nodulation: 0, no nodulation (NN); 1, <50 percent of N control indicating ineffective nodulation (I); 2, equivalent to 50–75 percent of N control (0.10 percent KNO_3) partially effective (PE); and 3, 75–100 percent of maximum plant growth and effective nodulation (E). The biomass of uninoculated plants was used as a baseline for the zero response level with symbiotic effectiveness indicated as a proportion of growth in the N controls. An average effectiveness rating was developed for each population of rhizobia from each sample analyzed, based on the symbiotic response of each of the species tested.

Isolation of strains of rhizobia from nodules

Highly effective strains of rhizobium occupying the nodules of plants showing positive symbiotic responses were selected for isolation. Cultures were authenticated by verifying their nodulation characteristics on corresponding legume hosts (Vincent 1970, 1977). To avoid genetic drift, the bacterial cultures were lyophilized and kept in small glass vials at room temperature.

Results

More than 80 percent of the 105 sites had medium or high numbers of *R. meliloti* without any recognizable geographic clustering of population density (Fig. 1). In contrast—although *Medicago minima* is a component of undisturbed permanent pastures in central Anatolia—the N_2 fixation efficiency of native *R. meliloti* was universally very poor on cultivated land (Fig. 2). A single location, Konya, was exceptional. For *M. noeana*, approximately 20 percent of locations had medium or high N_2 fixation efficiency values (Fig. 3). This finding contrasts with that of Materon (1991), who reported around 80 percent medium or higher N_2 fixation efficiency values for *M. noeana* in the southern Turkish lowlands. *M. noeana* is probably not well-adapted to highland environments.

The symbiotic specificity of *Medicago rigidula* was poorly served by the indigenous rhizobia of the southern Turkish lowlands, with <10 percent medium N_2 fixation efficiency values (Materon 1991). However, when grown in the highlands, 25 percent of all locations showed at least medium N_2 fixation efficiency values (Fig. 4). This species is a component of highland native permanent pastures. Given the findings of Keatinge *et al.* (1995b) and Materon *et al.* (1995) there is a possible suggestion of a clustering of higher values in the Erzincan/Erzurum area of northeastern Anatolia (37–41° E) (Fig. 4). Figure 5 illustrates that *Medicago aculeata* has the most promiscuous rhizobial requirements; it was highly efficient in around 75 percent of all locations. As yet, this host has no proven tolerance to the cold conditions of the highlands.

Discussion

This extensive survey of biodiversity in *R. meliloti* in the Turkish highlands has revealed substantial variability in N_2 fixation efficiency but, in general, adequate bacterial numbers in soil. These findings reinforce those of Materon and Danso (1991). While the symbiosis between *M. rigidula* and indigenous *R. meliloti* in northern Syria was very effective (Materon and Danso 1991), it was considerably less so in the Turkish highlands.

Even more extreme, the N_2 fixation efficiency in *Medicago minima* was totally suppressed by the indigenous rhizobia (Fig. 2). In contrast, the indigenous rhizobia formed effective symbiotic relations with *M. aculeata* (Fig. 5). The N_2 fixation efficiency values in *M. noeana* (Fig. 3) were closer to those of *M. rigidula* (Fig. 4) than either of the other species. Eardly *et al.* (1990) have suggested that *R. meliloti* comprises at least two distinct chromosomal lineages or evolutionary species. The variation in host/bacterial specificity detected in this survey supports the view that there could well be differences within putative *R. meliloti*.

The survey suggests that if the introduction of annual medics as a rotational or permanent pasture crop in the highlands is to be tested rigorously, more research on the interactions between species of *Medicago* and rhizobium will be required. Inoculation will be necessary in research trials, and more information on N_2 fixation efficiency values for specific strains with individual medic species is urgently needed. There is no guarantee that a N_2 fixation efficient strain that is both persistent and adequately competitive in highland environments will be identified. The survey highlights the need in these harsh environments for:

1) Comprehensive sampling of strains from undisturbed permanent pastures, including annual medic species such as *M. rigidula* and *M. minima*.
2) Additional sampling from the Konya region to identify additional N_2 fixation efficient strains for use with *M. minima*.
3) Further sampling from the vicinity of Erzurum/Erzincan which was tentatively identified as a high N_2 fixation efficient region (Fig. 4), as

well as having special rhizobial characteristics in the surveys for *R. leguminosarum* and *R. ciceri* (Materon *et al.* 1995; Keatinge *et al.* 1995b).

4) Evaluation of the production potential and limits of use of *M. aculeata* in cold environments.
5) Establishment of the geographic limits of the effective symbiosis between *M. rigidula* and *R. meliloti* beyond northern Syria (Materon and Danso 1991), including the determination of whether any Syrian N_2 efficient bacterial strains can be competitive and persist in other highland environments.

Before the annual medic potential as a pasture crop can be assessed adequately in the west Asian highlands, additional research will be required before the "Australian" ley farming system can be fully and fairly tested (Halse 1993). Webber (1993) has detailed several likely constraints to the adoption of this system, but Materon and Cocks (1988) and Cocks (1988) emphasize the lack of inoculation or use of inappropriate rhizobia and unadapted medic species as the primary limitations to success. The medic potential for improving both animal and cereal production is substantial. So much so that the research on these topics should be viewed as a regional priority by national governments in west Asia.

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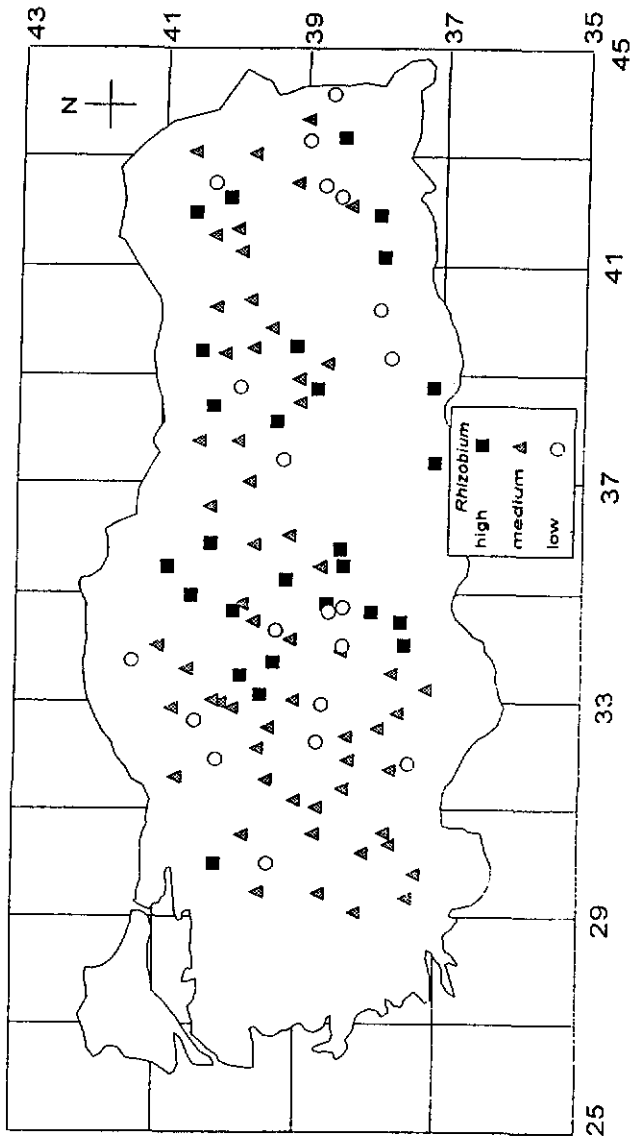

Figure 1. Diversity in relative numbers of native *Rhizobium meliloti* nodulating annual medics in the highlands of Turkey.

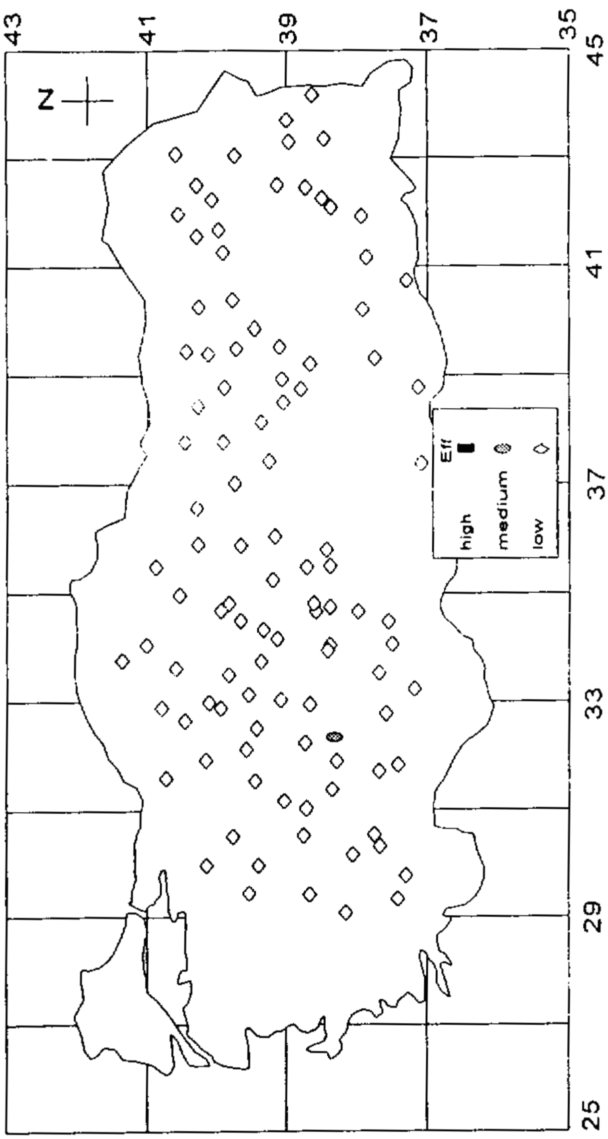

Figure 2. Diversity in N_2 fixing efficiency of native *Rhizobium meliloti* with *Medicago minima* in the highlands of Turkey.

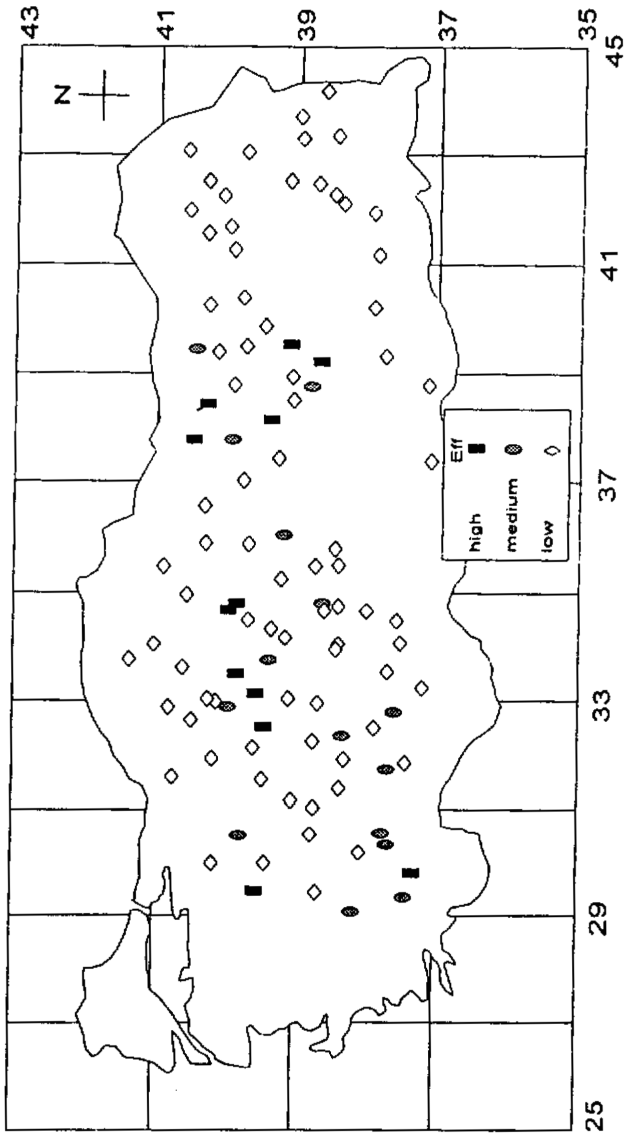

Figure 3. Diversity in N_2 fixing efficiency of native *Rhizobium meliloti* with *Medicago noeana* in the highlands of Turkey.

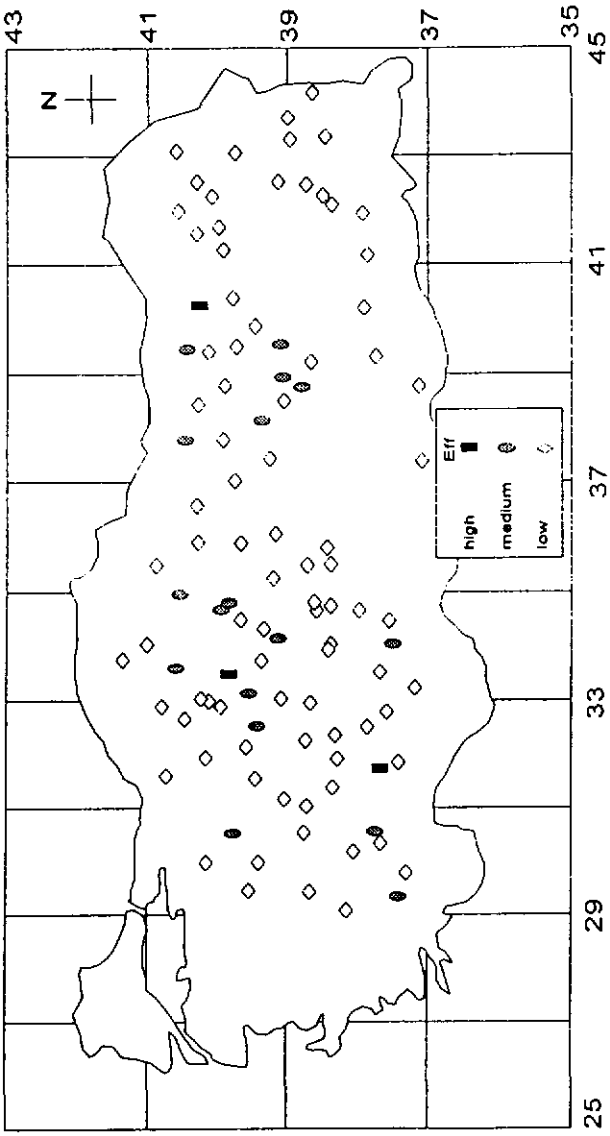

Figure 4. Diversity in N_2 fixing efficiency of native *Rhizobium meliloti* with *Medicago rigidula* in the highlands of Turkey.

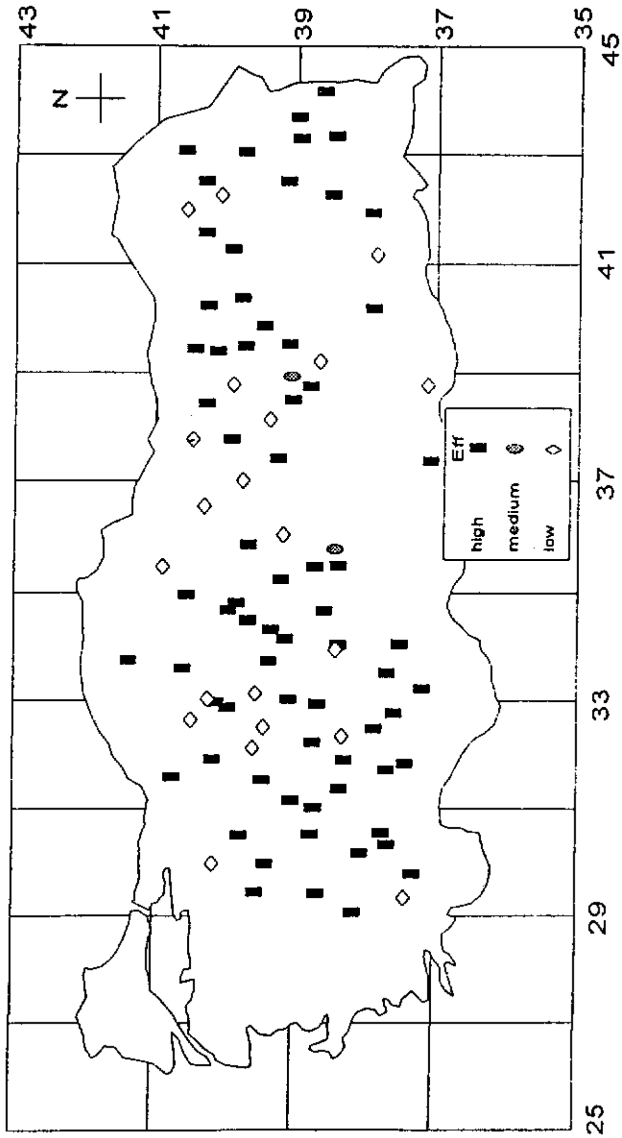

Figure 5. Diversity in N_2 fixing efficiency of native *Rhizobium meliloti* with *Medicago aculeata* in the highlands of Turkey.

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The Role of Rhizobial Biodiversity in Legume Crop Productivity in the West Asian Highlands: 4. *Rhizobium ciceri*

Summary

The native rhizobia capable of symbiosis with chickpea crops in the Turkish highlands were surveyed. The numbers of bacteria and the N_2 fixing efficiency of isolates of *Rhizobium ciceri* in symbiosis with an improved Turkish cultivar and a local landrace were examined. Soils were collected from locations at elevations between 500–2200 m. It became clear that native rhizobia specific to the local landrace were far more abundant than those specific to the improved cultivar. However, N_2 fixation efficiencies of all isolates were universally and consistently poor. Agronomic research priorities must include the identification of strains of rhizobia proven to be symbiotically efficient and ecologically persistent in highland soils. Comprehensive trials with these strains as artificial inoculants on chickpea are now required throughout the region.

Introduction

The origin of the cultivated form of chickpea (*Cicer arietinum* L.) is likely to have been the Anatolian region of Turkey (van der Maesen 1987). The crop has been cultivated for several thousand years in Turkey, and yet average yield remains at or below one t ha^{-1} (Keatinge 1994). Nevertheless, Turkey is now the world's largest exporter and third largest producer, after India and Pakistan, of chickpea (Oram and Agcaoili 1994). This statistic is based largely on an expanded area of production in Anatolia, where hitherto fallowing has been a predominant but essentially unnecessary practice. Exports of the white-seeded Kabuli types increased from around 50,000 t in 1977 to around 350,000 t in 1987, an output that represents approximately 50 percent of total national production (Guler 1990).

Of the legume crops grown in wheat-based rotations of the region, chickpea is often considered inferior in N_2 fixation (Smith *et al.* 1987; Keatinge *et al.* 1988), possibly due in part to the absence of appropriate rhizobial strains. Cakmakci *et al.* (1988) sampled soils from 40 locations in the traditional chickpea production zones in the lowlands of southeastern and western Anatolia and found irregular responses to inoculation. They suggested that total numbers of rhizobia were positively related to the level of soil organic matter. Gurbuzer (1980) tested various *Rhizobium ciceri inoculants with chickpea in four field trials in* Ankara province and recorded large increases in grain yield with three strains. Similar results have been reported by Cebel and Altintas (1989).

In contrast, Karuc *et al.*(1993) indicated that indigenous *R. ciceri* were relatively uncommon in the soils of Kazan district in Ankara province. Beck *et al.* (1991) reported significant, albeit variable, seed yield responses to inoculation of chickpea cultivar ILC 482 at various sites in Syria and France. Pala and Mazid (1992) have also described small and inconsistent responses in extensive inoculation trials over several years with ILC 482 in northwest Syria. The host-specific nature of rhizobia, which are capable of nodulating *Cicer* spp., first indicated by Gaur and Sen (1979) and then Rupela and Saxena (1987), was further extended to include cultivar-strain specificity for N_2 fixation in *C. arietinum* by Beck (1992). In this study with eight cultivars, ILC 482 displayed high rhizobial specificity, with two selected inoculant strains giving significant yield increases under field conditions.

Engin (1988) has described the incipient rhizobium inoculant production industry in Turkey, emanating originally from the Soil and Fertilizer Research Institute in Ankara. However, the recent expansion of the private agricultural supply sector has led to the availability of several commercial inoculants, albeit of unproven effectiveness and untested symbiotic and agronomic value.

This research examines the distribution of *Rhizobium ciceri* and their symbiotic N_2 fixation characteristics in the Turkish highlands. The long-term objective of the Turkish Ministry of Agriculture and Rural Affairs and ICARDA is to determine future national inoculant production needs for chickpea crops in Turkey and throughout similar highland environments in Iran, Iraq, Pakistan, and Afghanistan.

Materials and Methods

Experimental methods are given in detail by Keatinge *et al.* (1995a), with supporting information in Materon (1991) and Beck *et al.* (1993).

Procedures for soil sampling and chemical analyses will not be repeated here. Other details are given in brief.

Site selection

One hundred and five sites were selected from as wide a geographic area in highland Turkey (>500m) as possible given the following criteria: each site had to be within 5 km, and at the same elevation, as a meteorological recording station of known latitude, longitude and altitude, with a long-term record of annual rainfall, maximum monthly air temperature in July and minimum monthly air temperature in January.

Host legumes

Pre-selected host legumes were used to determine whether indigenous rhizobia were able to induce nodulation: chickpea cv. ILC 482 was used together with a Turkish landrace from Kazan in Ankara Province. Cultivar ILC 482 has been approved for release in highland Turkey by the Ministry of Agriculture and Rural Affairs, whereas Kazan local is typical of unimproved landraces that are spring-planted in the highlands.

Preparation of seedlings, inoculation practice and growth conditions

A 10 g portion of each soil sample was successively diluted in sterile water using 10-fold dilutions over a range of 10^{-1} to 10^{-4}. From each dilution, four replicate one ml aliquots were used to inoculate seedlings in aseptic glass house hydroponic culture (Vincent 1970; Beck *et al.* 1993). Seeds were surface sterilized and germinated on water agar plates, prior to aseptic transfer to sterile growth cups containing a 1:4 (v/v) vermiculite-gravel mixture. Plants were grown in the glass house for 42–56 days and watered daily as needed. At harvest, the number of nodulated plants at each dilution was recorded, and the population densities of rhizobia were estimated to be in one of three semi-quantitative categories: high$\geq$1000 rhizobia g soil^{-1}; medium=100–1000 rhizobia g soil^{-1}; and low<100 rhizobia g soil^{-1}. All 105 soil samples were tested for symbiotic efficiency with chickpea host plants using the aseptic hydroponic gravel culture system in the glass house. Effectiveness tests were replicated four times in sterile disposable one liter plastic cups containing one kg of a sterile 1:4 (v/v) vermiculite-gravel mixture. Sterile N-free nutrient solution with a composition of 0.5 mM P, 0.92 mM K, 1.56 mM S, 0.76 mM Mg, 1.0 mM Ca and a standard micronutrient solution (Broughton and

Dilworth 1971), was provided to each cup as needed through a drip line manifold attached to a 200 liter reservoir. Drainage holes in cup bottoms ensured that excess water did not accumulate; the table surface was composed of a wire mesh to avoid cross-contamination between treatments. Pots were covered with a plastic lid to prevent surface contamination. A 10 mm hole was drilled in each lid and plugged with sterile cotton wool to allow for plant stem growth.

Pots fertilized with combined N and contamination assessment monitoring controls were not inoculated. The N control treatments received 100 mg NO_3-N pot^{-1} as dilute KNO_3 applied in three equal doses at 15, 29 and 40 days after planting. Plants were randomized in the glass house under natural daylight and supplementary lighting to provide 14 hd^{-1}. Temperatures ranged from 12–25° C.

Symbiotic assessment

Shoots were harvested at 42–56 days after planting and dried to constant weight at 60° C. Nodulation was scored using a simple system where 0=no nodulation, 1=nodulation but ineffective N_2 fixation, and 2=effective nodulation. Differences between 1 and 2 were determined by internal nodule color, the latter being pink/red and the former green/brown. Symbiotic effectiveness was estimated for each rhizobial population on each cultivar as follows:

SE=(ShD Inoc.-ShD Uninoc.)/(ShD N Cont.-ShD Uninoc.)x100

where SE=symbiotic effectiveness, ShD=shoot dry weight, Inoc.=inoculated with rhizobia, Uninoc.=without inoculation, N Cont.=control treatment with added nitrogen.

From these comparisons with controls given N or not, four classes of symbiotic effectiveness were defined:

1) High, if the isolates produced plant dry weights equal to or greater than 80 percent of the dry weight in the 100 mg N pot^{-1} controls.
2) Moderate, if dry weights equaled 30–79 percent of N-fed plants.
3) Low, where plant dry weights were equal to only 10–29 percent of the controls.
4) Ineffective, where soil populations produced less than 10 percent of the dry matter produced in nitrogen fed controls.

Isolation of rhizobia from nodules

Highly effective strains of rhizobia occupying the nodules of plants showing positive symbiotic responses were selected for isolation. Cultures were authenticated by verifying their nodulation characteristics on corresponding legume hosts (Vincent 1970, 1977; Beck *et al.* 1993). To avoid subsequent genetic variation, the bacterial cultures were lyophilized and stored in small glass vials at room temperature.

Results

Survey data are presented to show the relative numbers (high, medium or low) of *Rhizobium ciceri* in soil capable of inducing nodulation in the landrace (Fig. 1) and the improved cultivar (Fig. 2). For the landrace, about one third of all locations have low numbers and the remainder mostly medium numbers; soils with a high number of rhizobia are rare and are randomly scattered. There is a possible concentration of medium/high numbers in the Erzurum/Erzincan region of northeastern Anatolia (between latitudes 37–41° E). In contrast, numbers are generally low for the improved cultivar with less than one third of all locations ranked medium or (rarely) high numbers. Differences between the two chickpeas are particularly marked in northeastern Anatolia, but there are throughout the region substantial differences in specificity between the landrace and the improved cultivar. The symbiotic N_2 fixation efficiency values for both the landrace (Fig. 3) and the improved cultivar (Fig. 4) are universally poor with just a single exception in each case (the sites at Develi and Tomarza).

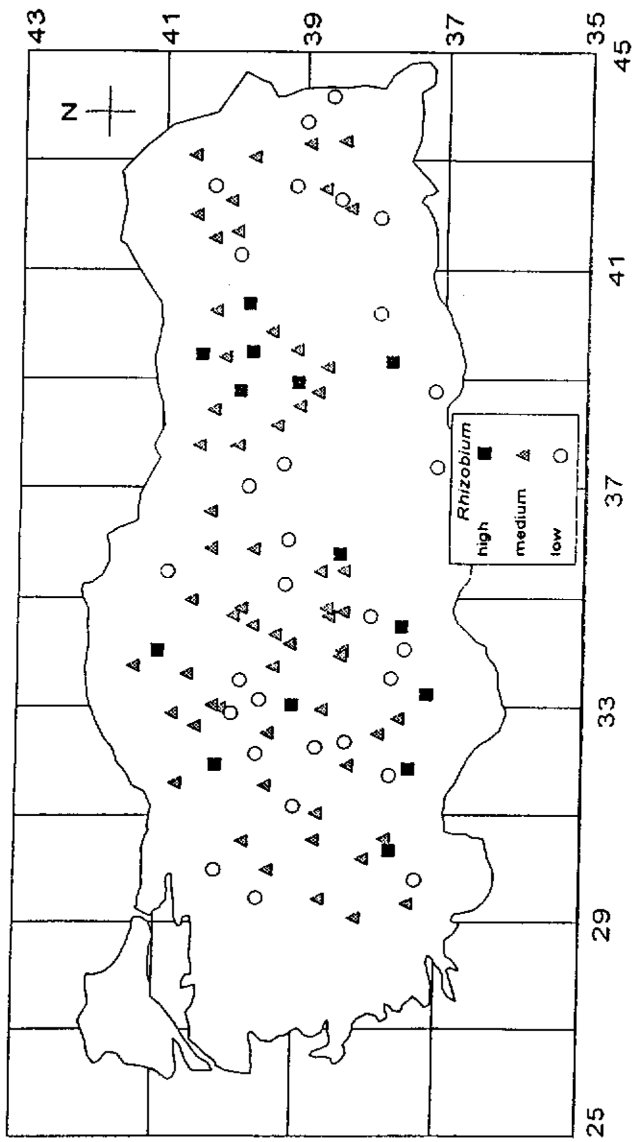

Figure 1. Diversity in relative numbers of native *Rhizobium ciceri* nodulating a chickpea landrace in the soils of the highlands of Turkey.

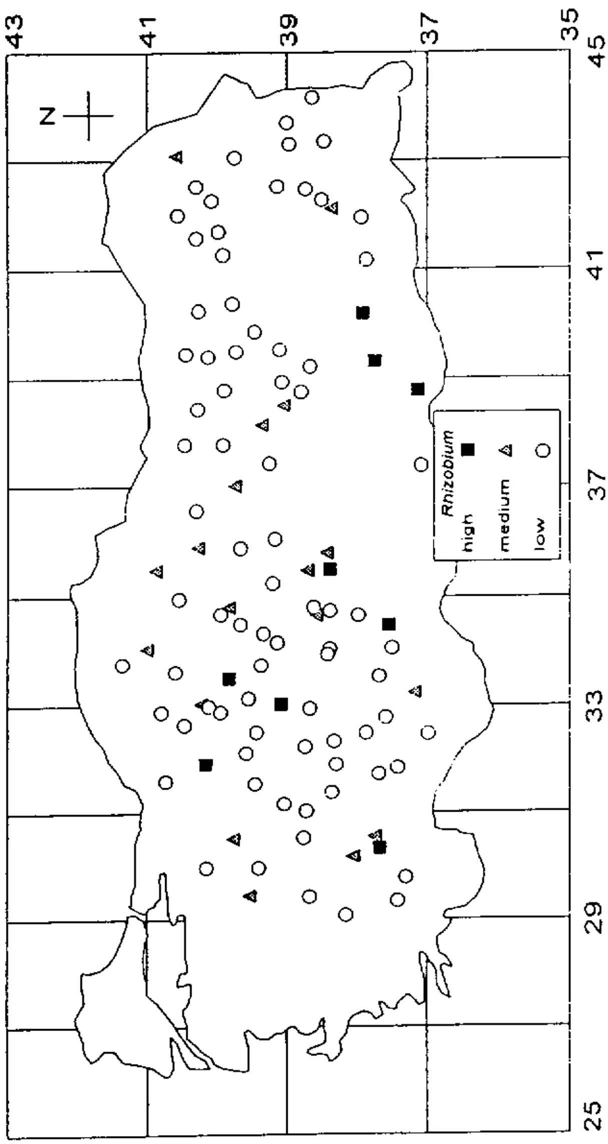

Figure 2. Diversity in relative numbers of native *Rhizobium ciceri* nodulating an improved chickpea cultivar in the soils of the highlands of Turkey.

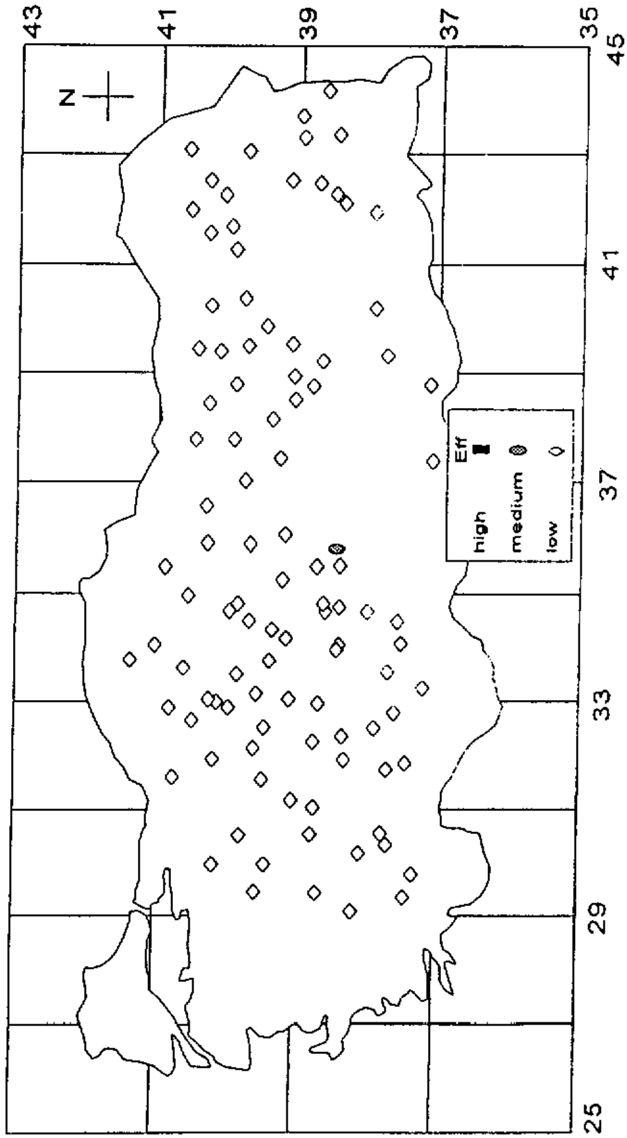

Figure 3. Diversity in N_2 fixing efficiency with a chickpea landrace of native *Rhizobium ciceri* in the soils of the highlands of Turkey.

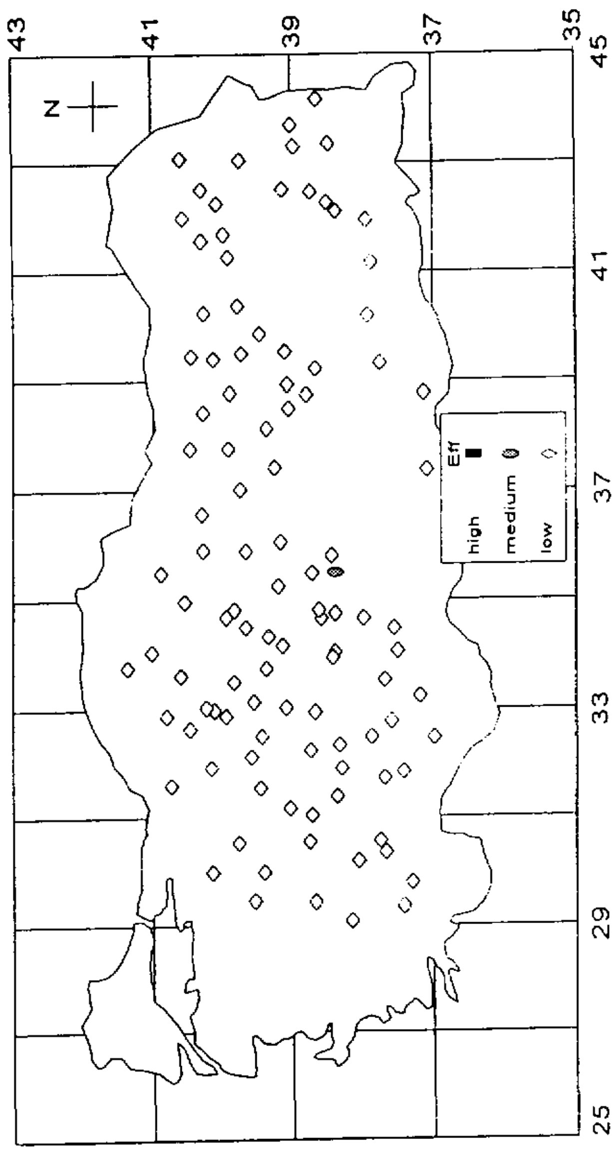

Figure 4. Diversity in N_2 fixing efficiency with an improved chickpea cultivar of native *Rhizobium ciceri* in the soils of the highlands of Turkey.

Discussion

Chickpeas are grown throughout Turkey as a spring-planted crop on an area of less than three quarters of a million hectares with an average yield of around one t ha^{-1} (Keatinge 1994). Keatinge *et al.* (1995a) have conjectured that one reason for these poor yields may be inadequate symbiotic N_2 fixation. Evidence supporting this assertion is now clear from the survey results. Numbers of *R. ciceri* are low throughout the Turkish highlands, as Karuc *et al.* (1993) reported for Ankara province. Numbers of *R. ciceri* contrast markedly with other survey data for *R. leguminosarum* and to a lesser extent with *R. meliloti* (Materon *et al.* 1995a, b). Furthermore, symbiotic N_2 fixation efficiency values of the indigenous rhizobia are consistently poor throughout Anatolia. The combination of low numbers and poor N_2 fixation efficiency values strongly implies that if ecologically persistent and symbiotically efficient strains could be identified for use as inoculants, it is likely that N_2 fixation and possibly chickpea yields would be improved. However, this complex subject includes biological, environmental and other constraints as indicated by Bohlool *et al.* (1992) and Peoples and Craswell (1992). Nevertheless, a basic requirement for growing good legume crops, without which yield improvement is unlikely, is an effective strain of rhizobia in adequate numbers at the correct time to ensure good nodulation. Unfortunately, the work of Gurbuzer (1980) and Cebel and Altintas (1989), which indicated positive responses to inoculation, have received little attention from the Turkish agricultural chickpea research program.

The next necessary step in the research process is to find out where improved inoculant strains should be sought in order to nationally test the potential impact of inoculation. Evidently, earlier concern with the erratic performance of commercial strains expressed by the Soil and Fertilizer Research Institute in Ankara raised questions about the suitability of imported inoculant products. Alternative options include:

1) To more intensively sample soils in the Tomarza/Develi area near Kayseri which were the only locations with medium N_2 fixation efficiency values (Figs. 3, 4) and thus may prove to be a further source of efficient and persistent material.
2) To re-survey fields with low nitrogen status, albeit with a long history of successful chickpea cultivation such as can be found in western and southeastern Anatolia.

3) To investigate the Erzurum/Erzincan area more thoroughly, given that this area was also highlighted for its differences in rhizobial efficiency between vetch and lentil (Materon *et al.* 1995a). Clearly, this region is of special interest with respect to rhizobial populations, although the reasons for the symbiotic superiority of the indigenous rhizobial population is not yet understood.

One further major complicating question in determining future research policy is whether substantially narrower rhizobial strain specificity has been an additional but unforeseen outcome of crop breeding efforts. The major successful breeding thrusts in chickpea have been selection for resistance to *Ascochyta* blight and increased cold tolerance, as required for the newly introduced winter or very early spring sowing technology (Saxena 1988). Could this progress have been achieved at the expense of reduced N_2 fixation ability in association with indigenous rhizobia? The improved variety ILC 482 was originally selected for blight resistance from a northwestern Turkish landrace population (collected from Adapazari; Singh *et al.* 1991) but it is clearly now more narrowly specific than the contrasting Kazan landrace (Figs. 1, 2). This is substantiated by the exceptional strain-specific response of ILC 482 for N_2 fixation shown previously (Beck 1992).

Further coordinated research between agronomists, breeders and microbiologists will be required if chickpea yields in the Turkish highlands are to improve substantially above one t ha^{-1}. In addition, this survey suggests that other countries in west Asia with agricultural highland regions, such as Iran, Pakistan and Afghanistan, would do well to invest in a careful assessment of their indigenous rhizobial resources. The identification of appropriately competitive, persistent and N_2 fixation efficient strains of rhizobia for use as inoculants could result in a major impact on chickpea productivity.

—J.D.H. Keatinge, D.P. Beck, L.A. Materon, K. Karuc and N. Cebel

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Growth of *Rhizobium meliloti* at Cold Temperatures

Strains of *Rhizobium meliloti* may differ in their capacity to nodulate and fix N_2 in annual *Medicago* species according to the temperature to which they are exposed. Early nodulation at low temperature is an important characteristic, desirable for an early supply of nitrogen to the plant. A pasture legume fixing nitrogen early in the winter may increase its availability to animals and increase herbage yields. However, this particular condition is controlled by the bacterium and plant genomes. Therefore, it is necessary to identify those rhizobial strains and plants that are more tolerant to lower temperatures.

The effect of low temperatures on the growth of 71 isolates of *R. meliloti* collected in highland regions of Turkey was investigated at 4° C and 28° C. Recommended inoculant strains ICARDA M53 and Australian WSM 244 were also included in this test. Two drops of a three day old culture suspension corresponding to each rhizobial isolate were deposited on the surface of plates with yeast mannitol agar (YMA) and allowed to absorb into the gel. Each drop contained approximately $5x10^8$ rhizobial cells. Plates were incubated at each temperature for seven days and kept inverted after the second day of incubation to prevent contamination. Observations for mass bacterial growth were done seven days following inoculation. Seven days following inoculation a qualitative scale (- for no growth, +/- for little or moderate growth, and + for growth) was used to record bacterial growth.

Table 1. Growth of *R. meliloti* on yeast mannitol agar (YMA) at 10° C seven days after inoculation.

Growth response	Number of isolates	% of totals
Abundant	17	23.6
Intermediate	18	25.0
None	37	51.4

Results show that temperature affects growth of *R. meliloti* at low temperatures (10° C). About half of the rhizobial isolates tested were not able to grow at 10° C, whereas 17 isolates showed abundant growth response (Table 1). Inoculant strain ICARDA M53 grew abundantly at lower temperatures while WSM 244 was classified as intermediate. As expected, all rhizobial isolates, including strains ICARDA M53 and WSM 244, were able to grow normally at 28° C.

—M. Obaton, L.A. Materon and G. Gintzburger.

Selection of *Rhizobium meliloti* for Annual *Medicago* Species for Optimum N_2 Fixing Ability Under Cold Conditions

The program has discovered that the one limiting factor affecting early growth of annual *Medicago* in the WANA region is low temperature. Little is known about how low temperatures affect N_2 fixation in annual medic species. Previous investigations at ICARDA have revealed that strains of *Rhizobium meliloti* responded differently when grown on yeast mannitol agar (YMA) plates at 10° C. This may have important implications when these strains induce nodulation in their legume hosts at low temperatures. If early nodulation is produced in the root under these conditions, then the plant will have a sufficient nitrogen supply to grow and develop. For instance, in Tel Hadya, the soil temperature taken at a five cm depth during the planting months of November and December ranges from 6.2–18.7° C.

The objectives of this investigation were: (1) to develop an appropriate technique to grow medics *in vitro* so that the shoot and root systems could be exposed simultaneously to two different temperature regimes, and (2) to screen rhizobia for early nodulation on different medic species.

Medic seeds were surface sterilized with a 20 percent Chlorox (5.25 percent sodium hypochlorite, NaOCl) solution for two minutes and rinsed six times in sterile distilled water. They were then placed in Petri dishes containing a 20 percent gel of water agar, kept overnight at 4° C and then placed in an incubator set at 28° C until germination (one or two days). Seedlings were aseptically transferred to a small hole on an aluminum foil sheet covering the top of a test tube (15x1.8 cm). As the root grew it then reached the surface of the N-free medium agar gel. The tubes were placed in a rack inside a water bath so that water surrounding the tubes reached the level of the seed inside the tube. The water bath was inside an environmentally controlled growth chamber. A week later, a one ml aliquot of a suspension containing 10^9 rhizobia per ml was used to inoculate each plant. Five strains of *Rhizobium meliloti* (ICARDA M53, ICARDA M525, ICARDA M538, ICARDA M583 and WSM 244) were selected to inoculate *M. rigidula* sel. 716, *M. polymorpha* sel.

Tah, *M. truncatula* cv. Jemalong, *M. aculeata* acc. 80 (Algeria) and *M. rotata* sel. 2123.

The refrigerated water bath was set at a temperature similar to that of the soil in the field when medics are planted. The temperature of the water surrounding the tubes was assumed to simulate field soil temperatures to which roots are exposed. Similarly, the ambient temperature inside the growth chamber simulated diurnal and nocturnal temperature ranges for the plant shoot. The light intensity corresponded to 170 $\mu E.cm^{-2}.sec^{-1}$ over a 10 hour photoperiod. The relative humidity was set at 80 percent.

The treatments corresponded to root temperatures of 5, 10 and 15° C, with root temperature controls of 17° C (night) and 22° C (day). The ambient temperatures for the shoots for all root treatments were 15°C for the night (14 hours dark) and 22°C for the day (10 hours light). Time of the first nodule appearance and subsequent nodulation were recorded on a daily basis. In addition, the root lengths were measured weekly.

We invested considerable time in solving problems related to the pH of the growing medium, temperature adjustment of the water bath, seed positioning—so that seed tips would not dry—agar concentration in the medium and calibration of the new growth chamber (CONVIRON). We report results for the 5° C root treatment only, since the other root temperature treatments (1° C and 15° C) were not yet completed during this report period.

We found that the five species of *Medicago* inoculated with the five strains of rhizobia did not show any sign of nodulation at 5° C. We concluded that nodulation of medics is drastically affected when root temperature is at 5° C.

All plants from the inoculated control at root temperatures of 17/22° C (day/night) were normally nodulated. Time of the first nodule appearance varied between species and strains. Strain ICARDA M53 nodulated *M. aculeata* after 9.2 (±1.1) days from inoculation, whereas it took 16.0 (±1.7) days to produce the first nodule with *M. rigidula*. We observed that the first nodule in *M. polymorpha* appeared after 9.4 (±1.3) days when inoculated with strain ICARDA M53 and after 12.8 (±1.1) days if inoculated with strain M525.

Root temperature markedly affected root length throughout the period of plant growth (34 days). The average length of roots in the control (17/22° C) was 8.2 cm, and 2.6 cm for plants growing at 5° C.

The investigation of effects of cold temperatures on annual medic N_2 fixation will continue using 1° C and 15° C to cover a wide representative range of soil temperatures when seed is planted.

—M. Obaton, L.A. Materon and G. Gintzburger.

Response to Phosphorus, Zinc and Nitrogen of Annual *Medicago*, *Vicia* spp. and *Lathyrus sativus* Under Field Conditions

Introduction

Traditionally, a fallow rotation in alternate years was used with cereals to obtain adequate yields, largely due to moisture conservation. With increasing land pressure, the proportion of fallow land has decreased, with inevitable concerns about decreasing soil fertility and sustainability. The concept of integrating annual medics (*Medicago* spp.) with cereal cropping (Clarkson *et al.* 1987; Puckridge and French 1983) was initially developed in Australia, and is now being used in the WANA region. This system, i.e., ley farming, is designed to provide forage in the alternate year and benefit the cereal crop through biological N_2 fixation.

Notwithstanding the capacity of medics to fix atmospheric N, the adaptive potential of native ecotypes largely depends on the presence of specific rhizobia (Materon 1988; Eardly *et al.* 1990). As shown by Materon and Danso (1991), medic species differ in their specificity to *Rhizobium meliloti*, e.g., *Medicago rigidula* nodulated well while *M. truncatula* did poorly with indigenous strains in the same soil. In such cases, inoculation is necessary (Brockwell *et al.* 1988). Fortunately, some rhizobial strains can nodulate more than one species, e.g., *M. rigidula* and *M. noeana*, and highly effective strains for medic nodulation are found, though less abundantly, throughout the Mediterranean region (Materon 1991). Nevertheless, the presence of ineffective rhizobia is considered a major constraint to ley farming in WANA (Materon and Cocks 1988; Riveros *et al.* 1993).

Successful annual legume pasture establishment requires more than microbial adaptation. An essential nutrient, phosphorus is widely deficient in most soils of the WANA region (Matar *et al.* 1992); where available P values (Olsens's $NaHCO_3$) are less than about seven mg kg^{-1}, rainfed cereals and legumes are likely to show yield increases due to P fertilization on crop land (Ryan and Matar 1992) and on marginal pasture land in Syria (Osman *et al.* 1991). The few studies of medics in relation to P suggest the importance of P fertilization. Together with sulfur , P increased five-fold the pasture output of *M. truncatula* (cv. Jemalong) on a P-deficient soil (Clarkson *et al.* 1989). Even the P content of medic seeds was related to its subsequent yield (Bolland and Baker 1989); not only was growth of *M. polymorpha* increased with P, but nodulation was also enhanced (Del Pozo *et al.* 1989). Notwithstanding the overall effect of P on medics, differential responses of P were observed for *M. polymorpha*, *M. noeana*, and *M. rotata* depending on the P concentration in a hydroponic medium (Lorenzetti *et al.* 1989). Similarly, wide variation in P response was shown for several ecotypes of *M. rigidula* (Lorenzetti *et al.* 1988).

Research on medic P fertilization in the WANA region is limited. The observations of Derkaoui *et al.* (1990) in Morocco showed substantial field responses for *M. scutellata* (L.) Mill. (Sava) and *M. truncatula* (Gaertn.) (Cyprus) but not for *M. polymorpha* (L.) (Serena), suggesting inadequate inoculation. In another Moroccan field trial, none of the medics tested responded to applied P, while only one vetch, *Vicia villosa* L., and *Lathyrus ochrus* L. responded (Ryan *et al.* 1992). However, despite the evidence of the importance of P for medics, a report from Ethiopia (Nnadi and Haque 1988) suggests that medics such as *M. scutellata* and *M. truncatula* have a low internal requirement and are less sensitive to low P soil than *Vicia* spp.

A potentially important related but less known factor in crop production in calcareous soils—and therefore in the WANA region, where soils are mainly calcareous (Kassam 1981)—is zinc deficiency. The limited research on Zn nutrition for pasture legumes is on alfalfa (*M. sativa* L.), with little research on *Vicia* and *Lathyrus* species. While foliar applications of Zn (and iron) appear to improve seed setting (Manjunathreddy and Kulharni 1986), soil and foliar-applied Zn had an inconclusive effect in another study (Stout *et al.* 1987); evidently, soil-available Zn levels were not low enough to inhibit growth. However, in another study, Zn did increase both yield and Zn content of tropical legumes, which included alfalfa (Andrew *et al.* 1981). The scant evidence we have indicates that, according to criteria of Lindsay and Norvell (1978), available Zn is low to marginal in northwestern Syria, i.e., < 0.6 mg kg^{-1}. As conditions in the soils of the WANA region are conducive to producing forage of low Zn concentration, and as livestock depend almost entirely on grazed fresh forage or cereal stubble, the potential negative implications of low Zn intake for animal health (Blood and Radostits 1989) cannot be overlooked.

In this field study, we evaluated the impact of nodulation, and P and Zn nutrition, on a range of adapted cold-tolerant pasture and forage species with potential for release in the farming systems of the region.

Materials and Methods

Soil

The experiment was conducted at Tel Hadya, Syria, (330 mm yr^{-1} long-term average rainfall, 36° 01' N, 36° 56' E). The soil is classified as a *Calcixerollic Xerochrept* (Ryan *et al.* 1993). This is one of the most common soil types in Syria's rainfed (200–600 mm yr^{-1}) cereal-producing zone, which is characterized by a typical xeric moisture region of the Mediterranean, together with a thermic temperature regime.

Representative air-dry analyses, performed according to standard methods (Page *et al.* 1982) were as follows: pH, 8.0; electrical conductivity, 0.6 mS cm^{-1}; cation exchange capacity, 53 cmol kg^{-1}; organic matter, 9 g kg^{-1}; available P (0.5 M $NaHCO_3$), 3.2 g kg^{-1}; clay 580 g kg^{-1}; and both DTPA-extractable Fe (4.2 mg kg^{-1}) and Zn (0.6 mg kg^{-1}), according to Lindsay and Norvell (1978).

Seed

Pasture legumes

The legumes used for this experiment were annual *Medicago* (medics) ecotypes of species that are omnipresent in the Mediterranean region, and which were selected at ICARDA. These are cold-tolerant (Abd El Moneim and Cocks 1986; Cocks and Ehrman 1987) and are therefore potentially well-adapted to the west Asian region, where frost is common. The seed material was: *M. rigidula* (L) All., selection 716; *M. noeana* (Boiss), selection 15485; *M. rotata* (Boiss), selection 2123; and *M. aculeata* (Gaertn.), selection 80 (Algeria via Morocco). Because of dormancy and the need to ensure germination, the seed was mechanically scarified before planting. The seed was planted by hand.

Forage legumes

Seeds of *Lathyrus sativus* selection 535, *Vicia sativa* selection 715/2556 and *V. dasycarpa* selection 683 were obtained for this experiment. These forage species are common in the region and are cold tolerant. Seed was placed in rows by hand.

Inoculants and mineral nitrogen

Pasture legumes

The four medic species were inoculated with peat inoculum made with an equal mixture of strains of *Rhizobium meliloti* (ICARDA M15 and ICARDA M53), both with various degrees of specificity for each of the medic species. At inoculation, the peat contained 3.5×10^9 rhizobia per gram giving a density of 4.5×10^4 rhizobia per medic seed. At planting, the bulk sample of soil contained 170 rhizobia per gram, as determined by the most probable number technique (MPN) (Beck *et al.* 1993).

Forage legumes

The *Lathyrus* seed was inoculated with *Rhizobium leguminosarum* strain ICARDA L2 and *Vicia* seed with strain ICARDA V6. Both peat inocula contained approximately 10^9 rhizobia per gram. At planting the soil contained 2×10^4 rhizobia per gram.

Uninoculated controls with and without mineral N were included for both trials. The uninoculated mineral N controls consisted of three split applications of urea applied every three weeks. The total mineral N applied was equivalent to 90 kg N ha^{-1}.

Phosphorus and zinc fertilization

The P treatments were 0, 15, 45 and 135 kg ha^{-1} mixed with the soil as solid-phase monocalcium phosphate, $Ca(H_2PO_4)_2$. All P treatments were split into a control without Zn and a Zn treatment at a rate of 48.38 kg Zn ha^{-1} (5 ppm Zn) added as $ZnSO_4.7H_2O$.

Experimental Design

A randomized complete block design (RCB) with four replications was used for each pasture and forage legume trial. The trials were adjacent to each other separated by a five m buffer zone. Plots were 1.05x2.0 (2.1 m^2), with six rows. Rows were 17.5 cm apart. All blocks and plots were separated by a distance of 2.0 m and 1.0 m, respectively.

Procedures

Nodulation
Five plants from each plot were collected at random to observe nodulation vigor and distribution. Plant growth and nodulation scores were based on a scale of one to four, where one is poor and four very good (Beck *et al.* 1993).

Zinc and phosphorus tissue analysis
Samples of five plants from all plots were taken at pre-flowering, flowering, pre-pod filling, pod and physiological maturity stages. The plants were dried at 72° C for 48 hours, finely ground and kept in sealed plastic bags prior to analysis.

Herbage yield
Plants from the inner four rows were harvested at flowering to measure herbage production. Results were expressed as fresh and dry weights.

Statistical analysis
The data for herbage yields were subjected to analysis of variance for main factors with their interactions. Mean separation was performed using the least significant difference method. Regression techniques were applied to determine best models for the P and zinc concentration in plants over time.

Results

Main factors

Pasture legumes
Each of the main factors, i.e., P, Zn, species, inoculation, and N, had a significant effect on dry matter accumulation. Irrespective of treatment, mean yields of the medic species differed widely, in the following order: *M. rigidula*>*M. noeana*>*M. aculeata*>*M. rotata*. Mean responses to applied P were consistent and significant at all P levels, with yield at 45 kg ha^{-1} about 1.36 and 0.86 times that of the control and the 135 kg ha^{-1} rate, respectively. Overall, Zn application significantly increased biomass yield by about 13.4 percent. Inoculation of medic seeds with cultures of *R. meliloti* strains increased growth to a similar extent, like the effect of N fertilization alone (Figs. 1a–1d).

Forage legumes

As with pasture legumes, all the main study factors significantly affected herbage yield. Regardless of fertilization, mean yields of forage legumes were significantly different, ranking as follows: *V. dasycarpa* > *V. sativa* > *L. sativus*. All species, regardless of other factors, responded to all levels of P, and the differences among their means were significant ($P \leq 0.05$). Herbage yield of 135 kg ha^{-1} increased 62.75 percent compared to the control (Fig. 2). Application of zinc to the soil increased herbage production 1.2 times regardless of other factors (Fig. 3). Inoculation of forage legumes with cultures of *R. leguminosarum* strains was responsible for a significant increase in overall herbage yield. As all main factors in both trials showed significant interactions, these are described following.

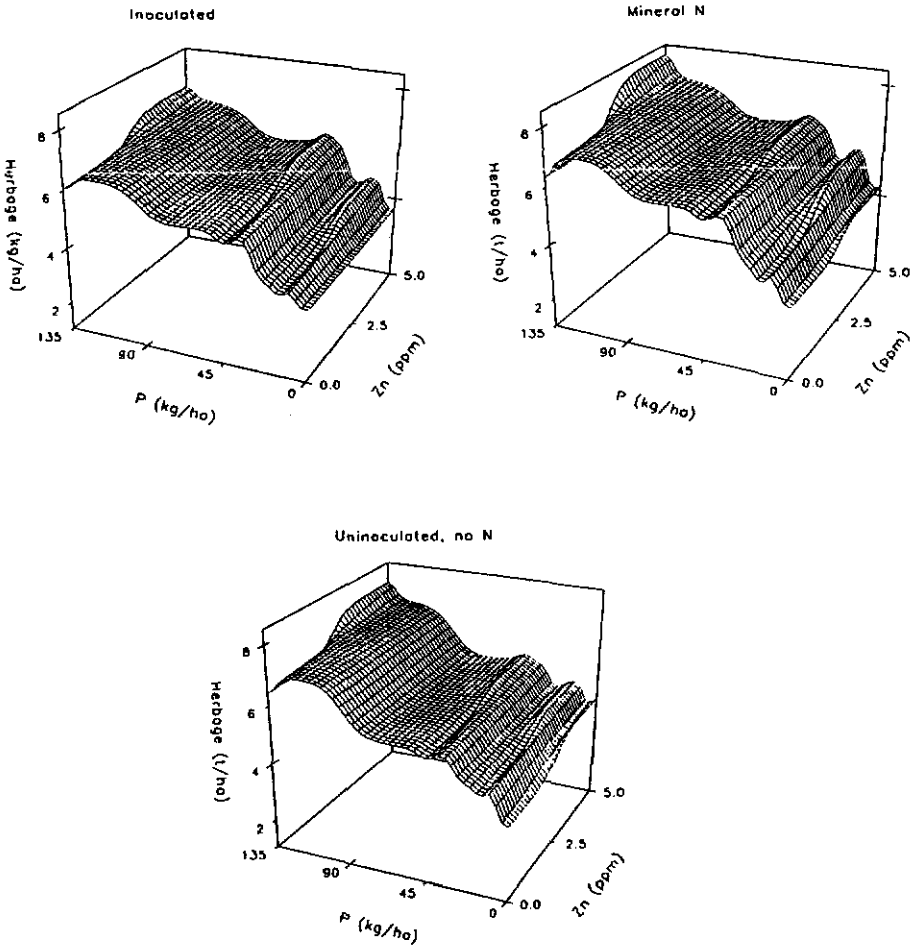

Figure 1a. Herbage response of *M. rigidula* to increasing levels of P and Zn with and without N.

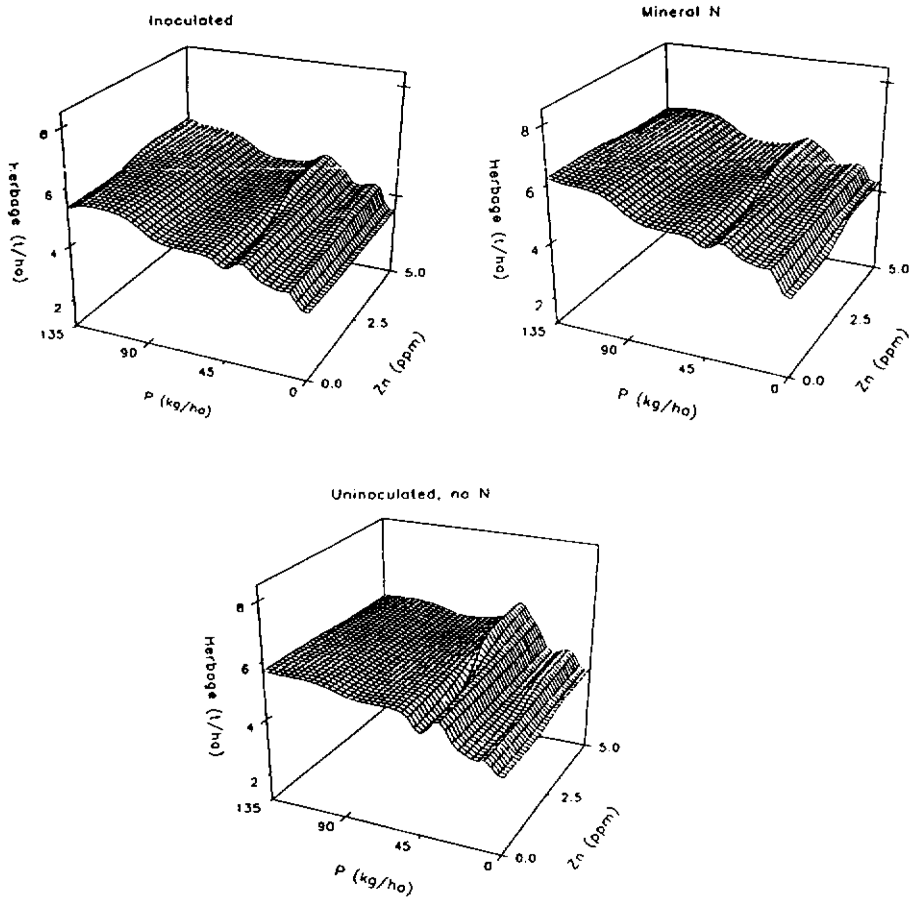

Figure 1b. Herbage response of *M. noeana* to increasing levels of P and Zn with and without N.

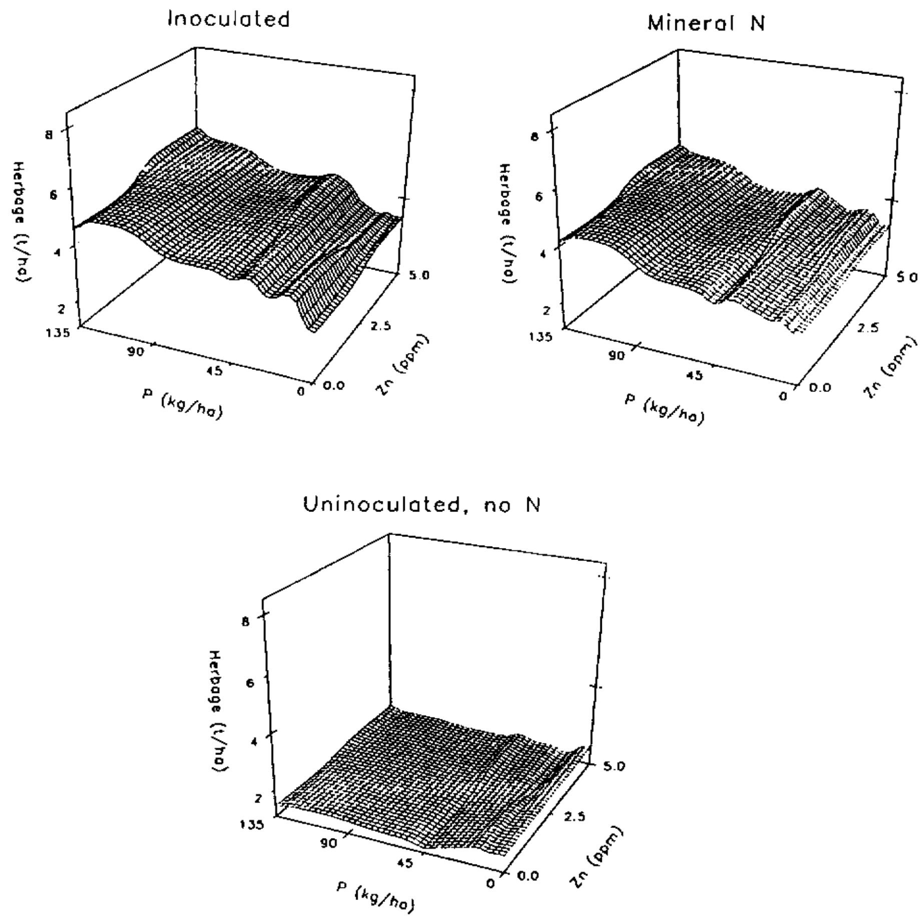

Figure 1c. Herbage response of *M. aculeata* to increasing levels of P and Zn with and without N.

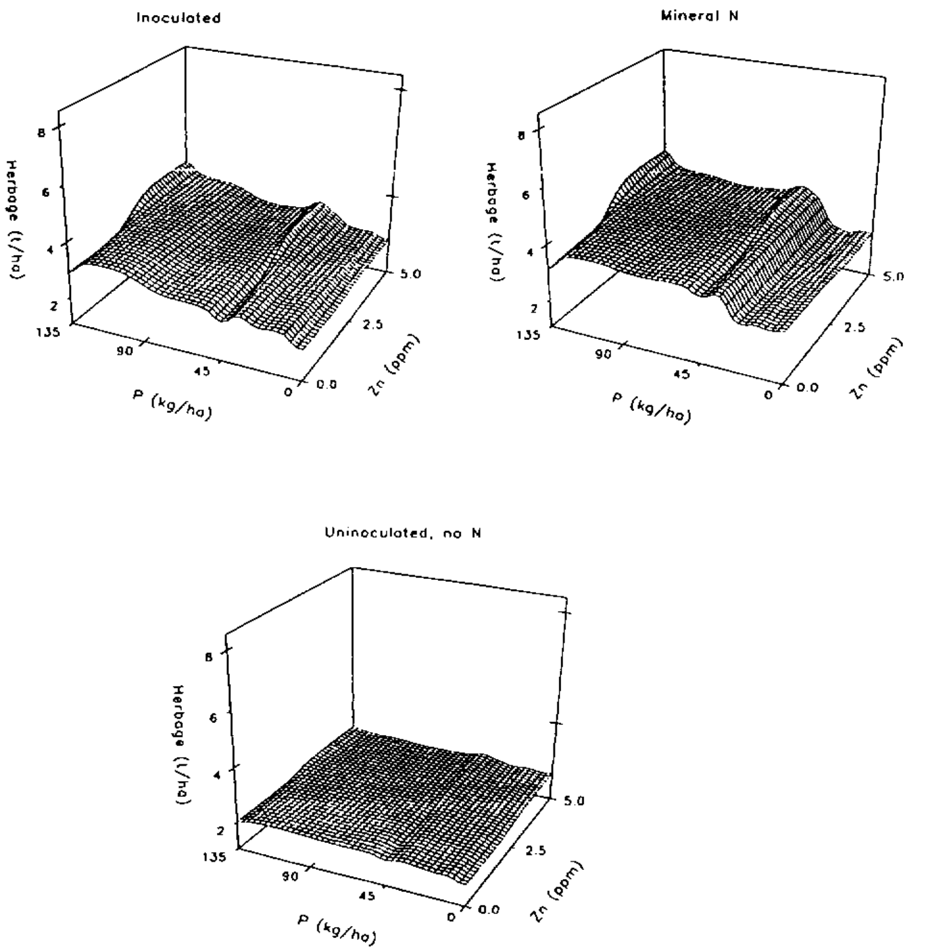

Figure 1d. Herbage response of *M. rotata* to increasing levels of P and Zn with and without N.

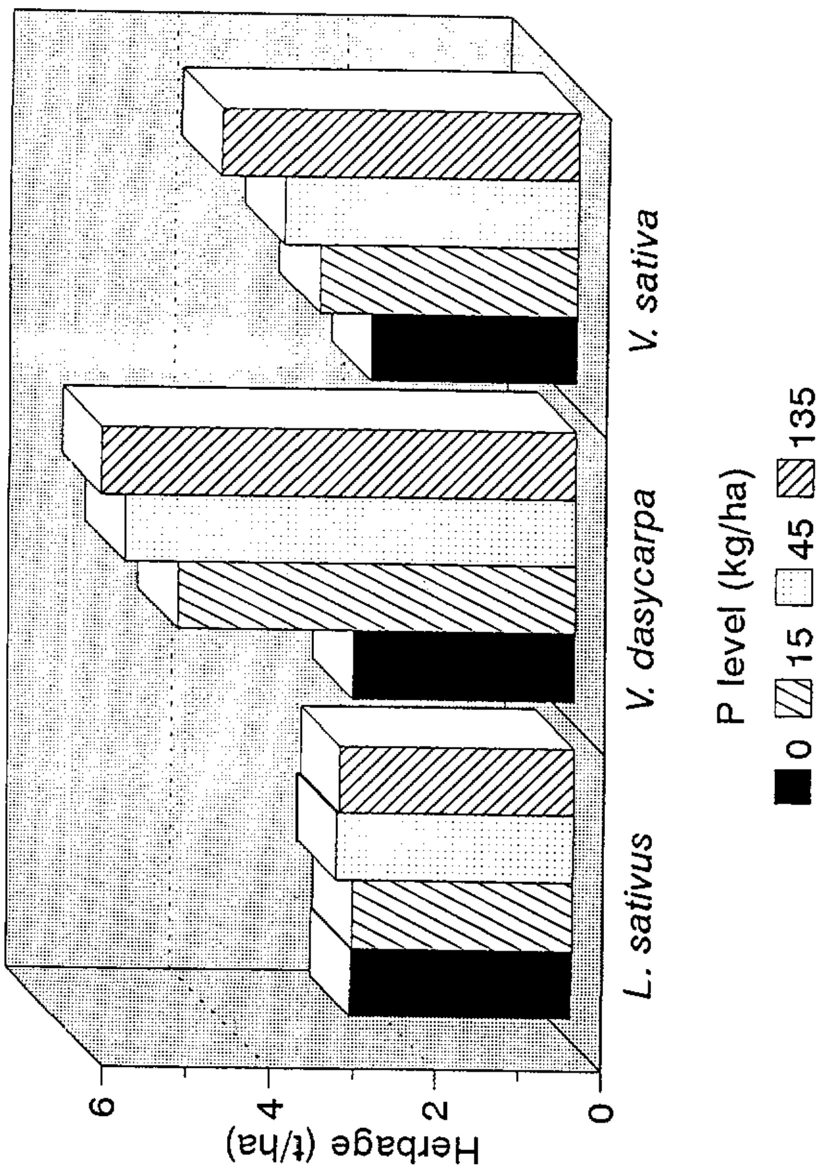

Figure 2. Effect of P in plants of *Vicia* and *Lathyrus*.

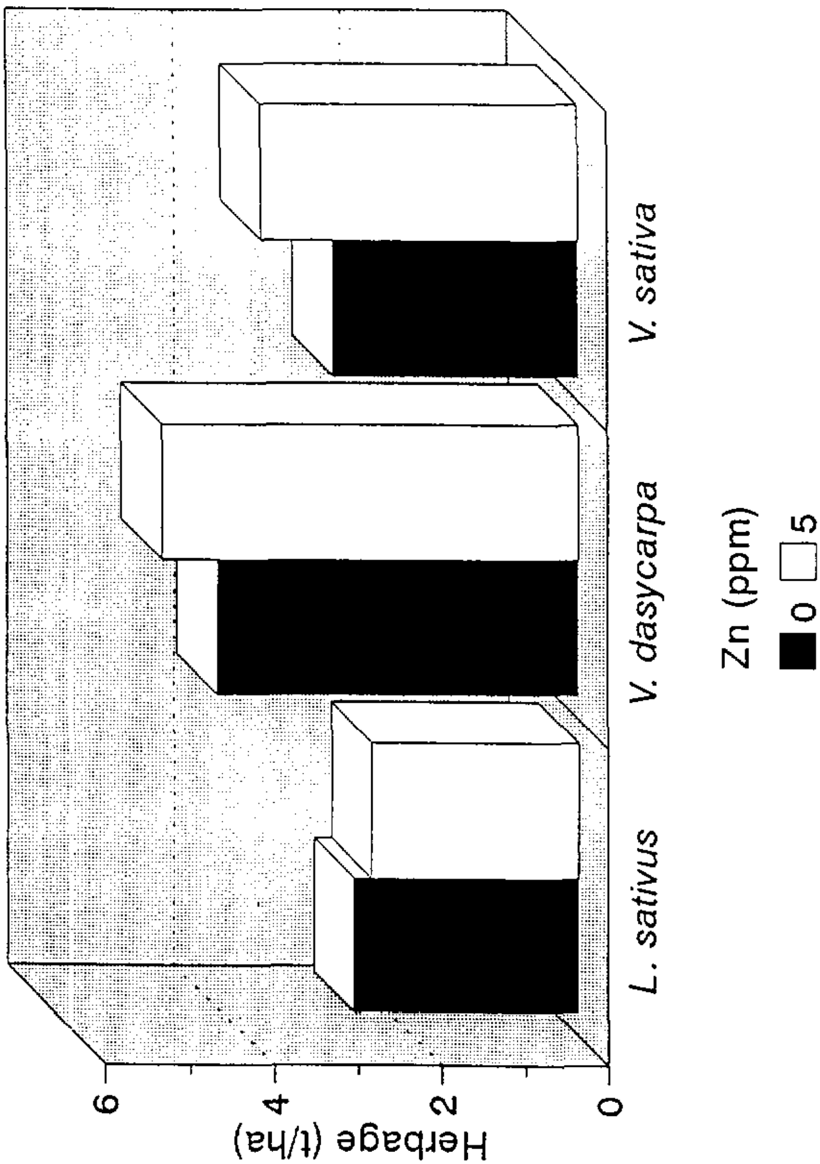

Figure 3. Effect of Zn in plants of *Vicia* and *Lathyrus*.

Species: nodulation/nitrogen

Pasture legumes

Since N addition reflects the potential contribution to growth by inoculation, all species of medics responded to inoculation. Both *M. aculeata* and *M. rotata* responded more markedly than *M. rigidula* and *M. noeana*, producing about 2.4 and 1.6 times more herbage, respectively, when a source of inorganic N was provided (Figs. 1a–1d). Plant scoring for vigor also reflected these differences. Symptoms of N deficiency were observed in those species expressing a need for inoculation. The potential of any management input to increase medic growth is limited by the adaptation of the particular species to indigenous or introduced rhizobial strains.

Forage legumes

Since N addition reflects the potential contribution to growth by inoculation, regardless of P or Zn, neither *L. sativus* nor *V. dasycarpa* responded to inoculation. This suggested that the soils used in this experiment contained specific effective indigenous *R. leguminosarum* for these species to fix adequate amounts of N for growth. In contrast, *V. sativa* responded to inoculation. In addition, this species produced 1.21 times more herbage ($P \leq 0.05$) when a source of inorganic N was provided.

Phosphorus Fertilization

Pasture legumes

The effect of increasing the P application rate was consistent for all *Medicago* species. In addition, N, added in fertilizer form or fixed atmospherically by appropriate rhizobia, was found essential for optimizing the effect of P fertilization. Even under these conditions, responses of the ineffectively nodulated species were still not as pronounced as the effectively nodulated species, *M. rotata* and *M. aculeata* (Figs. 1a–1d).

Forage legumes

Herbage yields increased significantly at all levels of P (Fig. 2). It was also observed that N fertilization, either mineral or atmospheric, was essential to optimize the effect of P. Under such conditions, responses of the ineffectively nodulated *V. sativa* were not as pronounced as the effectively nodulated species, *V. dasycarpa* and *L. sativus*.

Zinc Fertilization

Pasture legumes

*While the effect of adding Zn was not as great as that of P, significant re-*sponses occurred for three of the four species, *M. noeana* being the exception. This verifies findings previously obtained in pot experimentation. As for P, responses were conditioned by both inoculation and N. Thus, without inoculation, all species produced more herbage due to Zn, but differences between means were not significantly different. The medic species showed contrasting behavior; *M. rigidula*, *M. aculeata* and *M. rotata* showed marked responses to Zn regardless of the inoculation status, while *M. noeana* showed essentially no response to Zn (Figs. 1a–1d). This species either has a low Zn requirement or is more efficient in its Zn uptake from soil.

Forage legumes

The addition of Zn did not increase herbage yield as dramatically as that of P; significant responses occurred only for *V. dasycarpa* and *V. sativa* (Fig. 3). In contrast, *L. sativus* showed no response to Zn. As in medics, responses to P were also conditioned by both inoculation and N (Fig. 2). With inoculation, mineral N and P, the forage species significantly responded to applied Zn, except for *L. sativus*. This species either has a low Zn requirement or is more efficient in its Zn uptake from soil.

Zinc and phosphorus interaction

Pasture legumes

Both Zn and P enhanced the growth of pasture legumes (Fig 1a–1d). Application of both elements had a synergistic or additive effect. Zn consistently increased yields, but the effect was significant only at the higher P application rates (45 and 135 kg ha^{-1}) in the presence of N. When P is applied at 45 kg P ha^{-1}, added Zn increased herbage yield by 18.5 percent. These results are in accordance to those previously obtained in a pot experiment.

Forage legumes

The combined action of Zn and P had no relationship to herbage yields ($P \geq 0.65$) of the forage legumes tested (Figs. 2, 3). On the other hand, a marked individual interaction between P and Zn and each of the forage legumes was detected.

Species: nutrient interactions

Pasture legumes

The effect of individual P and Zn treatments for all species with or without inoculation and with N is shown in Figures 1a-1d. For *M. rotata*, *M. aculeata*, *M. noeana* and *M. rigidula* it was clear that Zn accentuated the positive effect of P. Herbage differences between Zn treatments were all significant ($P \leq 0.01$), regardless of added P. The magnitude of the responses to P or Zn also varied with the species.

Forage legumes

No synergistic or additive effect was detected in any of the forage legumes ($P \geq 0.65$) for Zn and P. Similarly, N did not significantly interact with either Zn and P, while forage species varied in their response to both Zn and P.

Discussion and Conclusions

This study showed clearly that each of the factors considered—nodulation, P, and Zn—is vital to maximize the growth potential of annual *Medicago* spp., *Vicia* spp. and *Lathyrus sativus*, potentially important pasture and forage crops in the Mediterranean zone.

Considering the list of constraints to the successful introduction of the Australian concept of ley farming to the WANA region, one might have expected variable responses to inoculation (Riveros *et al.* 1993) depending on the medic species in question. Similarly, with low-P soil, the positive influence of P was not unexpected for the medics (Halse 1993), nor for the forage legumes tested.

The foremost concern for any legume at any one site is whether inoculation is needed. Two of the four pasture species involved in this study (*M. aculeata* and *M. rotata*) needed inoculation to grow adequately and allow for responses to nutrient inputs; therefore, they would need inoculation for successful field establishment in soils such as those used in this study. However, given the range in both distribution and effectiveness of indigenous *R. meliloti* in the soils of west Asia (Materon 1993), one cannot predict such needs without screening the sites for compatible and effective root-nodule bacteria before planting. Nonetheless, Halse (1993) concluded that inoculation was only a problem in the short-term; where strain specificity is an issue, seed could be treated with an appropriate rhizobial strain. Although technical problems with inoculation of small-seeded pasture legumes can be overcome (Materon and Cocks 1988), the challenge is to transfer this technology to the region's farmers. Lack of effective nodulation and N_2 fixation drains relative soil N for the rotated cereal crop, thereby undermining the purpose of the whole system. The problem is less accentuated with forage legumes, since soils in the region generally contain effective populations of *R. leguminosarum*. However, the need to inoculate *Vicia sativa* at this site was clear from this study.

The responses to P were more consistent than to inoculation; although all four medic species responded well, potential maximum increases were greatest for *M. noeana* and *M. rigidula*. Phosphorus fertilization of medics, vetches and *Lathyrus* follows the same trend as observed for cereals (Matar *et al.* 1992). To be most effective, P needs to be applied in the cereal phase; the residual effect of P fertilization thus carries over to the grazed legume phase during which there is no tillage. In farming systems, not only does P greatly enhance the growth of both crops in the rotation but it also promotes medic survival and regeneration by increasing pod or seed numbers. Thus, while the key to sustainable cropping-animal grazing systems is P fertilizer, its economic use can be based on soil testing (Matar *et al.* 1992), a concept that is gaining momentum in the WANA region.

The observed response to Zn suggests that it should be considered in future work with both pasture and forage legumes. Indeed, as Zn deficiency is common in calcareous soils, it is probably a constraint to cereal-growing as well. Though one can fertilize soils with Zn, breeding for tolerance to low Zn levels is a feasible option (Graham *et al.* 1993). As major constraints to production (such as N and P) have been identified and deficiencies remedied, new ceilings to output—such as Zn—must be the focus of future research. Though not calibrated for most crops and soils, the DTPA test (Lindsay and Norvell 1978) is sufficiently general to serve as a basis for indicating in which soils or agro-ecological zones Zn deficiency is likely to be a problem.

In summary, this field study verified previous greenhouse studies and demonstrated the importance for adequate nodulation of *Medicago*, *Vicia* and *Lathyrus* species for expressing maximum potential of growth responses to applied P. As the addition of small amounts of Zn accentuated the P response, future work will focus on Zn in regional soils and cropping systems, and the implications for animal nutrition, i.e., impaired growth and reproduction.

—*L.A. Materon, J. Ryan, M. Zaklouta and S. Masri*

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Network for Research Collaboration in the Dryland West Asia–North Africa Region[1]

Abstract

The goal of the international agricultural research system, under the auspices of the Consultative Group on International Agricultural Research (CGIAR), is to improve agricultural production and alleviate hunger and malnutrition in developing regions of the world. In each of the research centers worldwide, the focus is on strategic applied and adaptive research in conjunction with scientists in the various national programs in their respective mandate zones. A network approach to communication is widely used to facilitate the flow of information and ideas and strengthen the partnership between Centers and national researchers. Networks can be formal or informal, permanent or temporary, and expand or contract in response to the availability and fluctuations of funding. This paper describes primarily the three networks that represent a cross-section of those operated by the International Center for Agricultural Research in the Dry Areas in Aleppo, Syria. Unique features of the Soil Fertility Network (SFN) are on-farm soil test calibration trials, regular workshops and proceedings, while the International Legume Inoculation Network (INONET) provides inoculum of rhizobium and sponsors training courses. The Dryland Pasture and Forage Legume Network (DPFLN) is more management-oriented and publishes a newsletter. Despite current and regrettable shortfalls in funding by donor agencies, networks will continue to be a vital system of communication between collaborating researchers.

Introduction

Despite the complacency about global hunger that has pervaded the world's developed economies in the past few decades, for many countries—notably in Africa and Asia—the wolf of famine and deprivation is

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never far from the doorstep. The recent prognosis of Nordblom and Shomo (1994) regarding the prospect of many Middle Eastern countries to feed themselves is disquieting in the extreme. In the West, concerns about overproduction and the environmental consequences of land use have pushed the images of starving masses to the far corners of our collective consciousness. As a result, the haves of today's world are less inclined to help the have nots, or are unaware of the pressing need to do so. Nevertheless, the past two decades have witnessed various encouraging approaches to improving agricultural research and education and consequently, one would hope, overall rural and national development.

In the past, the primary focus of US technology transfer from developed to developing countries was through degree-level training of host-country nationals, primarily in land-grant institutions. Subsequently, increased attention was paid to the circumstances from which these students came and to which they would return. The need to consider small-scale farming in developing countries was stressed (Rhoades 1984) along with provision of technology compatible with the socio-economics of such farming (Brams 1980) and a framework to prioritize research (Hanson *et al.* 1977). Concomitant with, or perhaps an outcome of, these concerns has been the continued support of Western-style educational institutions in developing countries (Ryan 1982) and, in order to define and tackle realistic problems, an awareness of the advantages of conducting thesis research *in situ* (Mason *et al.* 1987). The International Agricultural Research Centers system, in collaboration with its national partners in research, takes the process of adapting to the research educational and training needs of developing countries a step further.

The perception that agricultural research and education systems in many countries either did not exist, were poorly developed, or did not address national or regional concerns laid the basis for change. The success of the Green Revolution with rice in the 1970s underlined what research can do to improve the lives of many. Thus, in 1971, CGIAR was formed as an international consortium sponsored by the Food and Agriculture Organization (FAO), the United Nations Development Program (UNDP), and the World Bank. Its mission was to increase food production through adaptive research and training of national scientists and technicians through a worldwide network of autonomous international centers.

CGIAR comprises 42 donors, including 19 developed countries, 10 international organizations and development banks, three foundations, and several developing countries which contribute financing and serve as representatives of the major developing regions of the world—Africa, Asia, the Middle East, and Latin America (CGIAR 1994). Of the 17 CGIAR centers now established, some are commodity-oriented with global mandates while others are more regional and multi-disciplinary in their orientation. In fulfilling its mandate, in-service training has been a major thrust (Villareal and del Toro 1993).

The network approach to research in education and training has been used to share the combined experiences of regional scientists with common goals and concerns (van Schoonhoven 1991). The basic concept of the network is communication and training. In much of the world, we take instant communication for granted; the telephone, FAX, and email, in addition to traditional meetings, are the links between scientists. In developing countries, scientists are often isolated and resource-poor; for them the network is essential and fosters personal and institutional relationships that transcend national boundaries. Serving that purpose at agricultural research centers worldwide, networks are formal and informal and take various shapes and constitutions.

The International Center for Agricultural Research in the Dry Areas, which emerged in 1977 as an extension of the Arid Lands Agricultural Development Program (ALAD) of the Ford Foundation, has a spectrum of such networks. Having a global mandate for barley (*Hordeum vulgare* L.) and lentil (*Lens culinaris* Medik.), and a regional one for wheat (*Triticum* sp.) and chickpea (*Cicer arietinum* L.) ICARDA primarily addresses the cereal/legume/livestock-based farming systems of the dryland areas of west Asia and north Africa (WANA); a vast area of 10.5 million km^2 where 350 million people live and farming is largely dependent on low and erratic rainfall. Most ICARDA scientists interact with researchers in many countries of this diverse region through networks; many such networks extend beyond the region's boundaries and involve other international centers. In this paper, we describe in detail three such networks—the Soil Fertility Network (SFN), the International Legume Inoculation Network (INONET) for biological nitrogen fixation and legume inoculation, and the Dryland Pasture and Forage Network (DPFLN)—which illustrate a range of regional and international networks operated from ICARDA.

Soil Fertility Network

After drought, lack of available soil nutrients was the major factor limiting crops in the rain-fed WANA region. However, soil fertility research in most of the region's countries was poorly developed and funded. With little contact between national scientists, there was no common strategy to tackle mutual problems. The establishment of a network of WANA national scientists was seen as a step in the right direction. Given the potential importance of soil testing as a guide to efficient fertilizer use (Matar 1992), the primary concern of the SFN was a standardized approach to calibration of nitrogen and phosphorus soil tests with crop responses, with a strong emphasis on-farm trials (Table 1). Communication was fostered by regular visits of the coordinating scientists from ICARDA to individual countries and occasional traveling workshops of a few scientists to trial sites. Highlights of the SFN were the formal workshops conducted in 1986, 87, 88, and 91, and published proceedings.

Table 1. Characteristics of the three representative networks at the International Center for Agricultural Research in the Dry Areas.

	Soil Fertility Network (SFN)
Objective:	Improve soil test recommendations, fertility management, and laboratory efficiency.
Main activity:	On-farm N and P trials, soil testing.
Communication:	Workshops and published proceedings.
Countries:	Thirteen in west Asia and north Africa (WANA).
	International Legume Inoculation Network (INONET)
Objectives:	Determine needs for inoculation, detect host-rhizobial specificities, train technicians and scientists.
Main activity:	Set up field trials.
Communication:	Information exchange, training courses, publications.
Countries:	Eleven in WANA region and seven outside WANA.
	Dryland Pasture and Forage Legume Network (DPFLN)
Objectives:	Bring international focus on pasture and forage developments in WANA.
Main activity:	Information exchange, pasture seed production, rotation trials, development and distribution of pod harvesters.
Communication:	Pasture and Forage Legume Network News, an informal newsletter published three times per year for regional and international subscribers.
Countries:	Seventeen countries in WANA, 34 countries outside, and 32 international organizations.

The initial SFN meeting in Aleppo, Syria, in 1986 (Soltanpour 1987) was jointly sponsored by ICARDA, the Mid-America International Agricultural Consortium (MIAC) in Morocco, and the International Development Research Center (IDRC). Some general background papers were presented as well as reports dealing with P tests and responses of cereals i.e., bread wheat (*Triticum aestivum* L.) and durum wheat (*T. turgidum* var. *durum*), and legumes in Morocco, Cyprus, Syria, Jordan, Turkey, and Pakistan. Most reports showed consistent crop responses to P fertilizer. Several ongoing studies of soil test methods for N for field crops were also reported, along with a review of N use and crop response in Mediterranean environments in relationship to rainfall. Participating scientists established workplans for conducting N and P fertilizer trials with wheat.

A second meeting in 1987 in Ankara, Turkey (Matar *et al.* 1988) brought an expanded range of participants, and considered issues such as residual P for barley (Cyprus), plant P diagnostic norms (Tunisia), calibration of different P tests for cereals, legumes, and oilseeds (Pakistan), P fertilization of legumes (Syria), and wheat responses in Morocco, Jordan, and Syria. Work plans for on-farm trials were expanded and standardized procedures developed for site selection, soil sampling and analysis, fertilizer treatments and experimental design, and quality control within the region's soil testing laboratories. This was followed by a survey of 50 mainly public (government and university) laboratories including a standard soil sample sent to each laboratory for analysis and a questionnaire (Ryan and Garabet 1994). Inconsistencies in soil test results indicated major weaknesses, and the need for standardization.

Early SFN activities produced considerable progress. Several field studies from northwestern Syria, Jordan and Morocco demonstrated the universal response to applied N when rainfall was adequate. The importance of crop rotation (particularly involving legumes) and of soil type (notably involving depth) was highlighted, as well as the importance of soil nitrate, which gives reliable indications of N fertility in rain-fed soils.

Additional delegations attended the third SFN Network meeting in Amman, Jordan, in 1988 (Ryan and Matar 1990), including representatives from Iraq and Yemen. In addition to P calibration studies with cereals and soil testing procedures, topics included: modeling of residual P responses; P placement (i.e., banding vs. broadcasting); P in rotations; and the adsorption isotherms to evaluate crop P requirements. Work plans were modified to include separate P trials with basal N, rather than more elaborate and expensive factorial trials, since many sites were not consistently responsive to both elements. The importance of N was again stressed by reports from Morocco, Jordan, Pakistan, Cyprus, and Iraq. A more in-depth assessment of the various soil N forms along with residual N was made, and the significance of mineralization potential was introduced in a laboratory-greenhouse study from Morocco. The concept of N in the region's farming systems and the role of organic matter was also introduced.

A fourth SFN meeting, held in Agadir, Morocco, in May 1991 (Ryan and Matar 1992) involved new participants from Iran, Libya, Algeria and Spain. The meeting was the first to have a significant contribution from regional university researchers, notably from the Institut Agronomique et Veterinaire (IAV), Hassan II, Rabat, the University of Jordan and the University of Córdoba (Spain). This introduced a theoretical dimension that had been lacking in previous meetings and helped explain previous observations from a diversity of field trials.

Some presentations dealt with the basic behavior and mineralogy of P in Mediterranean region soils (Spain)—buffering capacity in relation to soil P tests—and distribution of P forms within soil profiles (Morocco). A spin-off from this produced a review of Mediterranean soil P by scientists from ICARDA, Spain and Morocco (Matar *et al.* 1992). A new soil test for P, using dye-impregnated paper strips, was presented (Egypt), while a modification of the standard Olsen bicarbonate method, i.e., NH_4HCO_3-DTPA, was reported as useful (Pakistan). Again, the importance of N for wheat, barley, and triticale (x *Triticosecale* Wittm. ex A. Camus) was clear from field responses with emphasis on rainfall and temperature (Syria, Jordan). The mineralization issue was further developed by considering the various soil N fractions. Reports from Cyprus presented a novel approach to fertility assessment that involves tissue-testing for nitrate. New topics included: potassium and its possible significance in the region (Morocco); and that K is adequate in rain-fed soils, but K fertilizer is needed under irrigated conditions, especially in sandy soils for crops such as sugarbeet (*Beta vulgaris* L.) and potato (*Solanum tuberosum* L.). A new dimension in soil testing involved the idea of spatial variability with important implications for field sampling and subsequent test values. Emphasis was placed on economic considerations such as strategies for fertilizer allocation and N need in relation to crop rotations.

The SNF adopted the Olsen procedure ($NaHCO_3$) as the official soil P test for the region, using a 0–20 cm soil depth; about six mg kg^{-1} was considered the *critical range* below which a response to fertilizer is likely. Fertilizer P rates of 10 to 20 kg ha^{-1} were recommended, depending on the extent of deficiency. While similar criteria have been developed for nitrate, the test is less reliable than that for P, since it is influenced by the cropping system, nitrate mobility with varying soil moisture regime, and with the soil's mineralization potential. Recommendations for cereal fertilization range from little or no N after legumes, 20 to 30 kg ha^{-1} under normal dryland conditions, and up to 90 kg N ha^{-1} in high-rainfall years. The many gray areas of current knowledge were identified and will provide the core of the scientists' concerns in the coming years.

In demonstrating the benefits of soil testing, the SNF can serve as a catalyst for governmental institutions and the private sector to provide such services. In most countries of the region, few farmers test soils. Indeed, facilities for testing are poorly developed and often too expensive for the small-scale farmer. Future SNF efforts will continue to provide a forum for dryland soil scientists and agronomists of the region to share information and enhance their professional development. Without a regional applied soil science/agronomy journal, the SFN proceedings provide an outlet for material that might not otherwise be published.

The initial SFN phase has been funded by UNDP and Institut Mundial du Phosphate (IMPHOS). It is hoped that continued funding will be forthcoming for a second phase to build on the successful foundation and to document its impact. Ultimate success of the SNF will be measured, not in publications or conference proceedings, but in the extent to which farmers use scientific information to manage their soil and fertilizer resources in a sustainable and economic manner.

International Legume Inoculation Network

The WANA region dryland cereal farming system is characterized by rotational cropping. Traditionally, moisture was conserved and fertility restored during the fallow year (Harris *et al.* 1991). Fallowed land is either clean tilled or, as in north Africa, left to grow weeds, which are grazed in the spring. Increasingly, fallow is being replaced by forage legumes such as vetch (*Vicia sativa* L.), pea (*Pisum sativum* L.), and chickling (*Lathyrus sativus* L.), as well as pasture legumes such as medics (*Medicago* spp.)

(Osman *et al.* 1990). The former groups are sown annually, while the latter are self-regenerating. Though fallow replacement with legumes does not conserve moisture, the potential increases in annual output from the system are substantial (Beck and Materon 1988). This potential is what underscores the research program on medics and related N_2 fixing species at ICARDA.

While indigenous *Medicago* species are found throughout the WANA region, they are sparsely distributed due to overgrazing and poor pasture management. The impetus to develop ley farming came from Australia. However, a major stumbling block to introducing biotypes to new areas is the absence of specific rhizobia (Materon and Cocks 1988; Materon 1991). For example, Materon and Danso (1991) showed that in one soil with only indigenous rhizobial strains, *M. rigidula* nodulated well, while *M. truncatula* did not. In such cases, inoculation with the appropriate strains is necessary. Production and handling of suitable inoculants are crucial to the success of any biological nitrogen fixation (BNF) technology transfer program. A suitable medium is essential to ensure rhizobial survival (Wolf *et al.* 1983). In an overview of BNF research in Egypt, Sims *et al.* (1984) concluded that much of the research was unrelated to field situations and stressed the need for BNF technology to be presented as a package of practices to farmers. Recognition of such an outreach approach was the basis for ICARDA's International Inoculation Network (INONET) which focuses on pasture and forage legumes.

In view of the many constraints to introducing pasture legumes (limited seed and inoculum production facilities, and little local expertise [Materon and Cocks 1988]) INONET came into being in 1986 following recommendations of participants in an N_2 fixation workshop (Beck and Materon 1988) urging the establishment of regional need-to-inoculate experiments throughout the WANA region. As with SFN, INONET was established to forge closer links between WANA scientists involved with soil microbiology and N research. It also disseminates information on rhizobial strain selection, host specificity, inoculant production and seed inoculation.

The INONET differed mainly from the SFN in that it provided inoculum and seed for testing in the various environments of the WANA region, from high elevation plateaus in Turkey and Algeria to milder lowland areas in Morocco and Syria. One example of such research is the trial at El

Khroub in northern Algeria, in collaboration with the Algerian Ministry of Agriculture, evaluating ICARDA strains of *Rhizobium meliloti* to fix N in annual medics from Syria (*M. rigidula* selection 716, *M. noeana* selection 2351, *M. rotata* selection 2123) and local *Medicago* ecotypes (*M. aculeata*, *M. ciliaris* selection 80, and *M. scutellata*).

INONET's major focus is training, mostly conducted at ICARDA's headquarters in Tel Hadya, Aleppo. Normally two weeks long with up to 10 participants, the courses range from production of rhizobial inoculants to field techniques to measure BNF (Table 1). Individuals selected for training are usually technicians and are nominated by a cooperator; however, some course participants had MSc and PhD degrees in agricultural microbiology. One course, Techniques in Rhizobiology of Pasture and Forage Legumes, was held outside the ICARDA headquarters in Morocco, and was co-sponsored by FAO, NifTAL (Nitrogen Fixation by Tropical Agricultural Legumes), and the University of Moulay Ismail (Meknes, Morocco). The training material was eventually published as a technical manual (Beck *et al.* 1993) which has been distributed to all regional cooperators.

While INONET is primarily focused on countries of the WANA region, it also involves cooperators in Australia, the USA (California), and Chile, as well as Mediterranean areas of Italy, Spain, France and Greece. Communication with cooperators is mainly by correspondence and occasional personal visits. As coordinator, ICARDA provides rhizobial cultures, experimentation work plans and technical assistance. Normally, at least three rhizobial cultures in pure form are provided to investigators—lyophilized ampoules, instead of peat bags—they then produce their own inoculants (some prefer peat bags when no laboratory facilities are available for inoculant production). These strains are of interest to the individual national programs for adapted pasture or forage species. Uninoculated controls with and without P and N are used to compare biomass yield and nodule number and quality. Work plans also address the impact of pesticides and N on rhizobia and measuring N fixation by the isotopic dilution method. While the main focus of INONET is rhizobium, one collaborative effort with the University of Granada (Spain) involved soil inoculation with *mycorrhizae* in relationship to the common *Medicago* species—*M. rigidula*, *M. rotata*, *M. aculeata*, and *M. polymorpha*. Though core-funded, it does however, stimulate assistance indirectly through FAO, UNESCO (United Nations Educational and Cultural Organization) and IAEA (International Atomic Energy Agency).

Dryland Pasture and Forage Legume Network

Unlike SFN and INONET, both of which are heavily discipline-oriented, the Dryland Pasture and Forage Legume Network (DPFLN) is systems management-oriented and more broadly based. Since most national programs in WANA are organized on a disciplinary basis, ICARDA's Pasture, Forage and Livestock Program attempts to strengthen the link with National Agricultural Research Systems (NARS) by setting up a network. This concept was debated at a workshop held in Perugia (Italy) (Christiansen *et al.* 1993). Subsequently, in 1991, the DPFLN was established at a workshop at ICARDA to improve communication and sharing of resources among scientists to strengthen the efficiency of their research and development work.

While the fertility and inoculation networks are center-oriented, the DPFLN seeks to catalyze links among NARS within the WANA region and between NARS and international institutions. While the DPFLN is primarily dependent on core funds, some activities in north Africa are supported by France; support also comes from UNDP for countries in west Asia. The DPFLN initially involved representatives from Morocco, Algeria, Tunisia, Libya, Cyprus, Jordan, Syria, Turkey and Iran; recently, Pakistan and Lebanon officially joined. The DPFLN is divided into three subregions—north Africa, west Asia, and the highlands (Algeria, Turkey, Iran, Pakistan)—in recognition of the cultural and national diversity and the dominant role of environment on pasture and livestock production.

A unique feature of the DPFLN is its newsletter, The Dryland Pasture and Forage Legume Network News. This informal communication vehicle was created and supported by a grant from the International Board for Plant Genetic Research Institute (IBPGRI) in Rome. To date, nine issues of the News have created interest in, and have given a much needed focus to, the Mediterranean region. In addition, there have been many contributions to the newsletter from Europe, the western hemisphere, New Zealand and Australia.

The DPFLN has catalyzed cooperative activities in Morocco, Algeria, and Syria, where research projects are based on manufacture and use of small machines to harvest and condition pasture seed, and on long-term rotation trials in which pasture and forages can be compared with other crop alternatives. Through the DPFLN, ICARDA emphasizes appropriate machines for on-farm legume seed production. Prototypes of a locally made hand-operated seed (pod) sweeper, which threshes, cleans and scarifies seed, have been sent to Algeria, Morocco, Lebanon, Ethiopia, Jordan and Iraq. The DPFLN also helps in collecting, describing, and evaluating local genetic resources, and provides research support to identify the best use of pasture legumes by animals through grazing or hay production, and in rotation with cereal crops. The latter aspect is currently being investigated at headquarters and in a regional long-term trial in Algeria. Similarly, the DPFLN has assisted three highland countries (Turkey, Pakistan and Iran) in identifying priorities for cooperative research in pasture, forage and livestock (Christiansen and Adham 1993). While there is much interest in involving other highland countries in the DPFLN—Afghanistan and former Soviet republics—little progress has been made. Language barriers and the state of political flux make meaningful contact difficult. As the DPFLN deals with animals, crops and people, and is more broadly based than the other two networks, its institutional obstacles are correspondingly greater.

Other Networks

The wide range of networks at ICARDA reflects the institution's strong regional emphasis (Table 2) and its global connections (Table 3), as well as its subject matter concerning grain legumes and cereals—principally barley, bread wheat, and durum wheat. The Barley Network reflects ICARDA's worldwide mandate for working with and improving this crop, while the Hessian Fly Screening Network underlines the importance of this wheat pest in north Africa. The cereal nursery reflects ICARDA's pivotal role for these crops, and serves as a repository for the region's genetic resources in terms of landraces and developed cultivars. Similarly, the dominance of food legumes is reflected in networks for north Africa (NALRN) and west Asia (WALRN). The recently created Grain Legume Drought Research Network, sponsored jointly by ICARDA and ICRISAT, reflects the strong links and common concerns of these sister international dryland centers. A specific network devoted to more basic research was established for DNA fingerprinting of *Ascochyta*, a major disease of chickpea.

Table 2. Regional and sub-regional networks at the International Center for Agricultural Research in the Dry Areas (ICARDA)

Network Name	Donor	Type
Barley Pathology	USAID	Research, cooperation, information, germplasm exchange
North Africa Grain Legume Research (NALRN)	ICARDA/BMZ/GTZ	Germplasm exchange
West Asian Legume Research (WALRN)	ICARDA/BMZ/GTZ	Germplasm exchange
North Africa Faba Bean Research	BMZ/GTZ	Cooperation
Wheat/Barley Hessian Fly Screening	ICARDA/MIAC	Germplasm exchange
WANA Plant Genetic Resources (WANANET)	IPGRI/ICARDA/ACSAD/FAO	Cooperation, information
Soil Fertility Network (SFN)	ICARDA/UNDP/IMPHOS	Cooperation/information
WANA Seed	ICARDA/GTZ/USAID	Cooperation/information
Agricultural Information for WANA	ICARDA	Information/material
DNA Fingerprinting of Chickpea (*Ascochyta* Blight Fungus)	GTZ/ICARDA	Information/cooperation/material

Abbreviations (see Table 1): USAID, United States Agency for International Development; BMZ, German Federal Ministry for Technical Cooperation; GTZ, German Agency for Technical Cooperation ; MIAC, Mid-America International Agricultural Consortium; IMPHOS, Institut Mundial du Phosphat; FAO, Food and Agriculture Organization of the United Nations; ACSAD, Arab Center for the Studies of Arid Zones and Dry Lands; UNDP, United Nations Development Fund; IPGRI, International Plant Genetic Resources Institute.

As information is one of the pillars of its existence, ICARDA supports regular newsletters in journal format for cereals (*Rachis*) and lentil (*Lens*). While all networks involve information exchange in one form or other, several provide materials, such as germplasm. The majority of networks are funded in part or fully by outside agencies mainly from Canada (IDRC) and Germany (BMZ, GTZ). The activity intensity in any one network depends on the coordinator, the degree of cooperation with NARS, and on funding.

Conclusions

Most of ICARDA's research and outreach activities in the WANA region are based in networks. This mechanism serves as a vital information conduit between coordinating center scientists and collaborators from various national programs. Networks ensure that center research continues to be farmer-driven and based on real not imagined problems, and help identify common problems and promote common solutions. With an education and information platform, some networks are well-established with tangible achievements, while others are less active and may exist in name only. The network system is a flexible one that fluctuates with the ebb and flow of funding; operations can be reduced in lean years or expanded in times of plenty. The network system, however transformed, will continue to catalyze research efficiency, information exchange and technology transfer in this environmentally harsh and increasingly food-deficient part of the world.

Table 3. International networks at the International Center for Agricultural Research in the Dry Areas.

Title	Donor	Type
International legume inoculation Network (INONET)	ICARDA	Cooperation,information, material exchange
Durum Germplasm Evaluation	Italy	Information, germplasm exchange
Cereal International Nursery	ICARDA	Germplasm exchange
International Legume Testing (ILTN)	ICARDA	Germplasm exchange
Dryland Pasture and Forage Legume (DPFLN)	ICARDA/IPGRI	Information, cooperative trials, adapted technology
Faba Bean Information Service	IDRC/ICARDA	Information
Lentil Experimental News Services (LENS)	IDRC/ICARDA	Information
RACHIS (Wheat-Barley Newsletter)	IDRC/ICARDA	Information
Global Grain Legume Drought Research (GGLDRN)	FAO/ICRISAT/ICARDA	Information, cooperation, germplasm exchange

Additional abbreviations (see Table 2 also): IDRC, International Development Research Center; ICRISAT, International Center for Research in the Semi-Arid Tropics.

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Marginal Land and Rangeland Improvement (MTP 94–98/Project 17)

Marginal Land Improvement: From Research to Extension

Introduction

Non-arable land within the cereal zone in Mediterranean areas is often termed marginal land (in Arabic, *hamshia*). This land is normally characterized by steep terrain and stony or shallow soil, and is generally used for grazing flocks of sheep or goats. Degradation of natural range and marginal lands in Mediterranean regions is very common. Martiniello *et al.*, showed that large areas of Mediterranean land have anomalous top soil that causes enlargement of the unproductive maquis. Uncontrolled and heavy grazing is commonly practiced in the low elevation rangelands of Greece (C.N. Tsiouvaras *et al.*). This grazing leads to diminished rangeland productivity by disturbing and degrading the rangeland *ecosystem (Smith 1988; Noitsakis et al. 1992).*

The most widely used agronomic techniques for increasing grass dry matter yield in natural pastures in the Mediterranean area are phosphorus-nitrogen fertilization and reseeding with appropriate species (Arnagino and Brotozu 1978; Crespo and Romano 1978; Corleto *et al.* 1980; Tallamucci and Pazzi 1982; Corleto *et al.* 1984; Olea and paredes 1984; Berg *et al.* 1989; Masson *et al.* 1990; Corleto 1992). Rivoira *et al.* (1989) indicated that many agro-pastoral Mediterranean regions have low quality pastures due to inadequate management, erosion or fire. Some annual self-reseeding legumes can be used to improve low quality pastures (Olea *et al.* 1985; Bullitta *et al.* 1989; Masson and Gintzburger 1989), to reclaim uncultivated land and to reduce the environmental impact of productive systems. The use of self-reseeding annuai legumes for improvement of degraded Mediterranean range lands requires knowledge of the appropriate cultivars that can persist and produce maximum yields(K. Papademetriou *et al.*).

In Syria and the WANA region, marginal land is very important for grazing sheep and goats. This land needs improvement, since high grazing pressure is causing soil and genetic erosion and natural resource degradation. One of the most important strategies for improving Mediterranean marginal land productivity is building up a manageable seed bank in the soil. This is achieved by either direct seeding of suitable species and/or proper management of pasture (fertilization, time of grazing, grazing pressure, etc.).

Farmers in the rainfed cereal zone in northern Syria (200–350 mm annual rainfall) have traditionally maintained flocks of sheep and goats, partly for household consumption and partly as a source of additional income. Flock feed supplies are met by: pasturing in the spring; grazing cereal crop residues in the summer and autumn; and hand feeding during the winter months (E.F. Thomson 1987). Flocks of sheep often migrate southeast into the steppe areas (<200mm annual rainfall) for natural pasture grazing in spring. Since Syria's national flock size has increased and barley cultivation has encroached deeper into the steppe, farmers in the cereal zone have needed to find alternative sources of feed (Leybourne 1993). One possibility is prolonging the period of hand feeding (straw, grain and concentrates), but this is expensive. To cut down on supplement needs, farmers graze their flocks on marginal land near their villages, resulting in overstocking and degradation.

ICARDA research has demonstrated the possibility of improving degraded Mediterranean marginal land through: phosphate fertilizer; seeding with native small legume seeds and pods; and proper grazing management (Osman and Cocks 1992; Osman *et al.* 1994). Under experimental conditions in Syria, results show that application of even small amounts of phosphate, along with stocking rate control, can significantly increase total herbage and animal production (Osman and Bahhady 1993). In Lebanon, this same increase in seed reserves can be achieved by changing grazing management and some protection in spring (Osman *et al.* 1991).

Using medic species—with small seeds and a high recovery rate—can remove the danger of overgrazing in summer (Springborg 1986), which is difficult to avoid in traditional grazing systems in west Asia and north Africa, especially in drought years. The light seeds of clover and their associated high recovery is probably one of the important reasons for their presence in heavily grazed native Syrian pastures (Cocks and Ehrman 1987). One of the major advantages in using small and hard legume seeds in the improvement process is seed dispersal through the sheep (i.e. the sheep seeder). Sheep graze the improved pasture for approximately 10 hours, then are transferred to a target pasture (unimproved) and are kept there for 48 hours, insuring that the maximum quantity of seeds have been passed.

In a proposal for the improvement of Mediterranean grasslands using farmer participatory research, Cocks (1991) outlined constraints to marginal land improvement:

- Poor seed banks, especially legumes.
- Poor grazing management.
- Low commercial availability of phosphate fertilizers.
- Communal land ownership.

In 1993, farmers from Batajek (in the El Bab area, 70 km northeast of Aleppo with 250 mm annual rainfall), who have cooperated in trials to introduce forage legumes into a rotation with barley, requested help with rehabilitation of marginal lands. In November 1993, an experiment began on a 32 ha hill site controlled by three brothers. Plots were marked out as two to three hectare unfenced paddocks in a randomized complete block design with three replications. Treatments included:

1) Fertilizing paddocks with 25 kg/ha P_2O_5 (superphosphate).
2) Oversowing with legume seeds and pods.
3) Oversowing and fertilizing.
4) A control treatment with no seeding or fertilizer.

A rapid survey was conducted in the study area (July 1994) to assess the possibilities of and constraints to improving marginal land, as well as farmer interest. Three villages used this method to improve their marginal lands after seeing the improvements in the first village (Batajek). In November 1994, a total of approximately 60 ha was seeded and fertilized (25 kg/ha P_2O_5). Table 1 shows the location, quantities of seed or pods and seed rate used for reseeding the hill sites.

The first constraint (outlined by Cocks) was dealt with by reseeding with legume species. Grazing did not occur until spring 1995, for two reasons. First, one of the brothers (who has no more than 40 sheep) had feed sources other than the hill and was more influential. He convinced his brother (who has 200 sheep) to protect the hill for one whole season. Second, the brothers hesitated to put their sheep on the experimental hillside because neighbors noticing a single sheep in a pasture will introduce their flocks as well.

Table 1. Legume species and quantities (kg) of seeds (S) or pods (P) and rate per ha in El Bab experimental sites.

Species	Batajek		Tel-Atia		Tarhin		Tel-Jerji	
	S	P	S	P	S	P	S	P
Medicago rigidula.1919		400	60		45		27	
Medicago rigidula.716		400	57		42		26	
Medicago rigidula.2792			60		45		27	
Medicago noeana.15458		400						
Medicago rotata.2119		400						
Medicago rotata.2123			349		261		161	
Seed rate kg/ha		100	20		20		20	
Hippocrepis unisilquosa	2							
Scorpiurus muricatus	3							
Trifolium angustifolium	3		27		20		13	
Trifolium campestre	13		27		20		13	
Trifolium haussknechtii	17		41		31		18	
Trifolium lappaceum	17		41		31		18	
Trifolium pilulare	17		59		44		27	
Trifolium purpureum	17		18		14		8	
Trifolium resupinatum	17		18		14		8	
Trifolium scabrum	1.5							
Trifolium speciosum	27		108		81		50	
Trifolium stellatum	1.5							
Trifolium tomentosum	17		41		31		18	
Seed rate kg/ha	10		15		15		15	

The government would make phosphate fertilizer available to farmers if they were convinced that the investment was worthwhile (Cocks 1991). Seemingly, only one constraint remains—communal land ownership—but, the farmers must be convinced as well. Many surveys show that research projects that fail to account for farmers' opinions are seldom successful (for example, see Leybourne *et al.* 1994).

A survey was conducted in the El Bab area in July 1994, to identify villagers' attitudes towards marginal land improvement projects and to determine the visibility of such projects in each village.

Methods

Twenty different villages were interviewed, selected by using local knowledge of the existence of marginal land. Interviews were made through a short checklist style questionnaire and semi-structured interviewing techniques. In most cases respondents were village heads (*mukhtars*). Visits were made to the marginal land sites of the villages. In most cases, these sites consisted of hill tops where cultivation is not possible.

Results

Most of the villages in the El Bab district have existed for a long time; two villages have apparently existed for over 500 years, and another six village for more than 100 years. Barley is the principal crop sown, with some villages also planting wheat, lentil and chickpea. All the villages have reported an increase in the cultivated area during the past 10 years, either through the reduction of fallow periods or, where possible, encroachment onto marginal land areas.

The average number of families per village was 38 (SD 22), with a minimum of three and a maximum of approximately 100. With such a large difference in the number of families per village it was preferable to detail average land size and sheep numbers on a per family basis, as shown in Table 2.

Table 2. Land area and number of sheep per family (village totals divided by the number of families in each village).

Land	Total land (ha)	Number of sheep	Marginal land (ha)
Average	84	66	8.3
Std. Dev.	169	113	15.7
Minimum	1	10	0.1
Maximum	667	400	50.0

All village flocks graze marginal land in spring; flocks in four villages also graze them in winter, and one grazes them in spring and summer. One village used the marginal land area all year round.

In about half of the villages some cereal stubble is rented out to other farmers or migrant herders (Bedouin from the steppe). Flocks in the remaining villages graze all the cereal stubble available.

A total of 70 percent of the respondents said they experienced problems with people trespassing onto their marginal land areas, either people from neighboring villages or migrant herders. However, over half (55 percent) said they would be able to guard their land if it became necessary.

Most villages (85 percent), having seen or heard of the pilot experiment in Batajek, believed it would be beneficial to improve their marginal land areas, with 11 respondents suggesting the best way would be to simply protect the land. Two suggested reseeding and protection, and one suggested reseeding and fertilization.

When asked if they would participate in an ICARDA experiment (where seeds and fertilizer would be supplied), 13 villages said they would cooperate. Two did not respond, and five said no. The reasons given were that protection and control would be impossible, either because the marginal land was too far from the center of the village, or because there were too many families in the village to successfully manage the land.

In each village the farmers responded to what species would be preferred in a reseeding experiment. The two most common answers were *Poa* spp. and *Medicago* spp., as shown in Table 3. However, given the choice between improving the land and planting barley, all respondents, except one, preferred barley. The farmer who chose improving said the results of the experimental hill (he was not the only respondent to have visited the hill) had convinced him of the usefulness of improved marginal land. In other words, if it is possible to plant barley on a piece of land, most farmers will do so.

Table 3. Preferred species on marginal land areas in El Bab.

Species	No. responses*
Poa spp.	9
Medics	6
Anthemis	2
Erodium	2
Salsola vermiculata	1
Small legumes	1
Wild lentil	1
Adonis	1
Hordeum	1

* Some farmers gave more than one response

Discussion

As expected, the problem of land ownership and control is the principal constraint to improving degraded marginal land areas. While more than half of the villages said they would be able to protect the land from trespassers, one respondent commented that they often had problems with migrant flocks (from the steppe) coming onto their land, but that preventing access to uncultivated areas was not traditionally done. While he agreed that pasture in good condition was better and more economical than barley, cultivation was often the only way to protect the land.

Problems exist from outsiders trespassing onto village marginal land, but problems also occur within villages. There were a number of comments concerning the difficulty convincing people within the village to cooperate. Some reasons given were the high percentage of laborers (with outside interests and little community spirit). In another village, the respondent said that as each family had only 10 to 15 sheep, it would be difficult to stop them from going onto their hill.

In one village, a story was recounted wherein a Bedouin from the steppe had been grazing cereal stubble for free for the past seven years, despite a shortage of available cereal stubble within the village. This caused some families to rent stubble in neighboring villages. Because the villagers were unable to agree among themselves to rent land to each other—there were conflicts concerning ownership and control—the land was used by others with no claim at all, for free. The final comment was that, the village as a whole would not be able to reach an agreement to improve their hill.

In yet another village a five year old dispute over a hill had resulted in the death of the *mukhtar's* nephew and the destruction of some houses. Again, cooperation would not be possible.

In fact, it is amazing how easily disputes occur on a micro-level. Even the pilot experiment land did not escape a dispute, and the experiment almost did not take place. The hill is owned by four brothers, but one of them was not interested in cooperating with ICARDA. Since the other three were keen to cooperate, it was decided to divide the hill into four pieces. The dispute then began over who would have which part, and the argument continued for several weeks. One of our team was called in to diplomatically intervene. The fourth brother claimed a far greater portion than was his right. He attempted to get such a large portion that it would have prevented the experiment from taking place. As a final effort to claim the land and prevent the experiment, he plowed a long line across the whole hill with his tractor. At this point local authorities were called in and the situation was finally resolved.

While 13 villages said they would be interested in participating in an ICARDA experiment, only three or four of the villages were suitable. Some village areas were too small and some villages had too many sheep. We disregarded some responses as unreliable. Some being only trying to please us because the team came from ICARDA, and some because it cost the village nothing to get seeds and fertilizer free. Finally, one respondent commented that the village marginal land would be easier to protect once it became known that it was an experiment. For him, the main benefit in collaborating with ICARDA was to protect the land. He was not necessarily convinced that pasture was better than barley, in fact, he would have sown barley if he could.

One constraint preventing marginal land improvement is the claim that sheep need to graze natural land. One respondent said the hills were like a picnic for the sheep, and another claimed the sheep would die if they did not go onto the hill to graze. Therefore, sheep could not be prevented access to the hills to allow the pasture to regenerate.

Conclusion

From our experiences with farmers it seems that marginal land improvement techniques can be applied if farmers recognize the benefits of improving their land. This can be achieved if the farmers participate in all stages of the demonstration trials.

The two principle problems preventing the successful adoption of techniques to improve degraded marginal lands in the El Bab area are: (1) the ownership and control problem of marginal land areas with traditionally open access, and (2) the lack of conviction that it is a good idea. The first problem was addressed in one village through demonstration plots with farmers. Neighbors think twice before they trespass with their flocks, because they notice the cultivated border around the experiment and, for the farmers, cultivation means clear ownership. They also believed that the work belonged to the government. Adoption of this idea is being addressed by expanding the work to other villages, which stimulates discussion among villagers about improvements taking place at Batajek hill. This has encouraged other villages to ask help from ICARDA to improve their marginal lands.

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The Role of Small-seeded Clovers and Pod Seeding of Medics in the Rehabilitation of Degraded Marginal Lands in the Mediterranean Region

Abstract

Marginal land within the Mediterranean cereal zone is used for livestock grazing. Marginal land is communally owned, intensively grazed by sheep and goats and frequently suffers from soil erosion. One of the previous PFLP activities in the village of Bueda (70 km south of Aleppo) showed that animals grazing marginal land are supplemented at various times of the year by fallow grazing and hand feeding of barley, legume grains and straws. Thus, improving productivity of marginal land should reduce supplementation needs and increase carrying capacity. ICARDA has conducted experiments showing the benefits of applying small amounts of phosphate. The fertilizer stimulates the legume component of grassland, and if grazing is controlled, total production increases significantly.

This study assesses the use of several indigenous legume species for rehabilitation of degraded uncultivated natural marginal land, under farmers' field situations.

Objectives

- Assess, under farm conditions in northern Syria, the use of several indigenous legume species for rehabilitation of degraded native marginal land.
- Measure medic establishment using seeds and pods.
- Study the loss of the seeds and plants during the growing season.
- Study the hard seed breakdown of some legume species.
- Assess the role of sheep in reseeding degraded marginal land.

Experimental sites

El Bab village (80 km north west of Aleppo)

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Date of commencement
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Materials and Methods

In 1993, a farmer who cooperated with PFLP in introducing forage legumes into a rotation with his barley in the El Bab area (Batajek, 70 km northeast of Aleppo; 250 mm annual rainfall) requested help with marginal land rehabilitation. In November 1993, an experiment was started on a 32 ha hill site which was controlled by the farmer and his two brothers. Plots were marked out as two to three hectare unfenced paddocks in a randomized complete block design with three replications. Treatments included:

1) Fertilizing paddocks with 25 kg/ha P_2O_5; (triple superphosphate).
2) Oversowing with legume seeds and pods.
3) Oversowing and fertilizing.
4) A control treatment with no seeding or fertilizer.

In July 1994, a rapid survey was conducted to assess farmers' interest in improving their marginal land in villages neighboring Batajek. Three villages, having seen the effect at Batajek, liked the idea. In November 1994, an area of 65 ha belonging to Tarhin (22 ha), Tel Jerji (13 ha) and Tel Atia were seeded and fertilized (25 kg/ha P_2O_5). Table 1 shows the species and amount of seeds and pods used in each location.

Preliminary results

Distribution of legume plants at Batajek in March 1994, using 20 quadrates (10*100 cm each) indicated that *Trigonella* was the most dominant legume in all treatments (Table 2).

Table 1. Legume species and quantities (kg) of seeds (S) or pods (P) and rate per ha used on marginal lands in four villages at El Bab area

Species	Batajek		Tel-Atia		Tarhin		Tel-Jerji	
	S	P	S	P	S	P	S	P
Medicago rigidula.1919		400	60		45		27	
Medicago rigidula.716		400	57		42		26	
Medicago rigidula.2792			60		45		27	
Medicago noeana.15458		400						
Medicago rotata.2119		400						
Medicago rotata.2123			349		261		161	
Seed rate kg/ha		100	20		20		20	
Hippocrepis unisilquosa	2							
Scorpiurus muricatus	3							
Trifolium angustifolium	3		27		20		13	
Trifolium campestre	13		27		20		13	
Trifolium haussknechtii	17		41		31		18	
Trifolium lappaceum	17		41		31		18	
Trifolium pilulare	17		59		44		27	
Trifolium purpureum	17		18		14		8	
Trifolium resupinatum	17		18		14		8	
Trifolium scabrum	1.5							
Trifolium speciosum	27		108		81		50	
Trifolium stellatum	1.5							
Trifolium tomentosum	17		41		31		18	
Seed rate kg/ha	10		15		15		15	

Table 2. Number of legume plants/m^2 found at hill experiment at El Bab in March 1994.

Treatment*	Trigonella	Medics	Trifolium	Total
S + P	98	3	4	105
S - P	84	6	5	95
N + P	78	-	-	78
N - P	78	-	-	78

Treatment are (S+P seeded and fertilized), (S-P seeded), (N+P natural and fertilized), (N-P natural).

Table 3. Plant numbers and dry matter production in April 1994 from the El Bab marginal land renovation experiment.

Species	(plants/m^2)			
	S+P	S-P	N+P	N-P
Trigonella spp.	216	164	130	115
M. rigidula	12	13	0	1
T. purpureum	21	9	0	0
T. speciosum	3	5	0	0
T. haussknechtii	2	6	0	0
T. pilulare	8	1	0	0
T. tomentosum	2	2	1	2
Dead clovers	16	46	2	1
V. sativa spp. *amphicarpa*	1	3	0	0.48
Other legumes	1	0	0	0.48
Total legumes	*269*	*249*	133	*119*
Total grass	6425	5783	5250	6452
Total weeds	491	343	342	351
Total plants	7197	6374	5725	6922
Dry matter	(kg/ha)			
Legumes	223	219	148	135
Grass	697	558	944	813
Weeds	67	87	111	93
Total herbage	986	864	1202	1040

Treatments are seeded and fertilized with 40 kg/ha phosphate (S+P); seeded without P (S-P); natural and fertilized (N+P); and natural, unfertilized (N-P).

Table 4. Percentage cover of the species at El Bab hill.

Species	% cover from total plant	% from total area
Poa bulbosa	73.54 n.s	56.42 n.s
M. rigidula	.68 n.s	.5 n.s
Trifoliums	1.53 n.s	1.16 n.s
Trigonella monspeliaca	8.04 n.s	5.97 n.s
Astragalus spp.	.12 n.s	.11 n.s
Weeds	7.59 n.s	.11 n.s
Carex	5.70 ***	5.04 ***
Psilurus spp.	2.66 n.s	1.66 n.s
Nardurus spp.	.1 n.s	.08 n.s
Cynodon spp.	.04 n.s	.04 n.s
Barground		11.1 n.s
Stone		12.74 n.s

In April 1994, herbage production was measured using cylindrical samples. Each sample consisted of four cylinders taken from each paddock. The samples were separated into species, plants were counted, oven dried and weighed (Table 3).

In May 1994, vegetation cover was measured using the line transect method (Canfield 1941). Four treatments (paddocks) were covered by this study. The method consists of stretching tape between two points, linear measurements are taken of all plants intercepted by a vertical plane running through the line. The length of the line was five meters, repeated five times in each paddock. Table 4 shows the percentage cover of the species at the hill.

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The Role of Sheep in Reseeding Degraded Marginal Land

This study looked at the role of sheep in distributing seed through feces. Eleven *Trifolium* species, three medics, in addition to *Hippocrepis* and *Scorpiurus*, were fed to sheep as a single meal mixture. Feces were collected at different intervals to monitor passage rate. The feces containing seed were then broadcast in a replicated experiment to monitor the emergence of seedlings in the following season. Results showed that about 60 percent of the small seed, 25 percent of the medium and 35 percent of the large seed escaped digestion, out of which 80 percent passed through the sheep within 40 hours of ingestion. Figure 1 shows the recovery of different legume species.

Feces collected from the sheep after 6, 12, 24, 36, 48, 72, 96, and 120 hours were gently threshed, and seeds were classified according to species, except for *T.Scabrum—T.Purpureum* and *Trifolium Campestre—Trifolium Speciosum*, which are very similar in size and shape. Figures 1, 2, and 3 show the percentages of the species after grouping in three categories (*Medics, Trifolium* and others). Later, a germination test was performed on recovered seeds to assess changes in their hardness and viability after passing through the rumen. Three replications of 100 seeds each, or two replications of 50 seeds each (depending on the availability of the seeds) were tested for germination at 20° C for ten days. Germinated seeds were counted and removed, and the rest were scarified and tested again for germination to assess their viability. Figures 3, 4, and 5 show the germination percentage and viability of three legume species.

Figure 1 shows that recovery of *M. noeana* is greater that 50 percent, while recovery of *M. rotata* and *M. rigidula* is 20–30 percent. Figure 2 shows the different *Trifolium* spp., which can be grouped into at least two categories: small, where the recovery after ingestion ranged between 58–72 percent and large ranging between 10–40 percent recovery. Figure 3 shows the recovery of *Scorpiorus* (39 percent) and *Hippocrepis* (one percent). Figure 4 gives the germination percentage and viability for three Trifolium species (small seeds), showing a slight decrease in hardness after they pass through the rumen. In contrast, Figure 5 shows another group of *Trifolium* that seems to have become harder after ingestion. We now plan to run further tests to confirm this result. The performance of medic is shown in Figure 6 where *M. rigiduala* and *M. noeana* show a slight increase in seed softness after ingestion, while *M. rotata* remains unchanged. Note from the last three figures that viability of legume seeds remains high following ingestion.

—*F. Ghassali*[1]*, A.E. Osman*[1]*, P.S. Cocks*[2].
—[1]*ICARDA* [2]*University of Western Australia.*

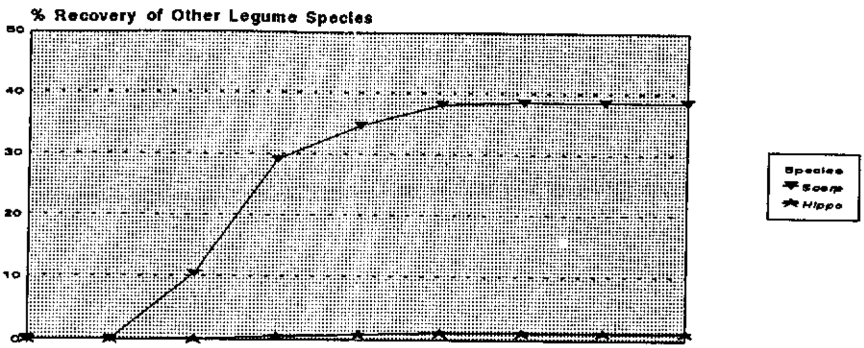


Fig.3

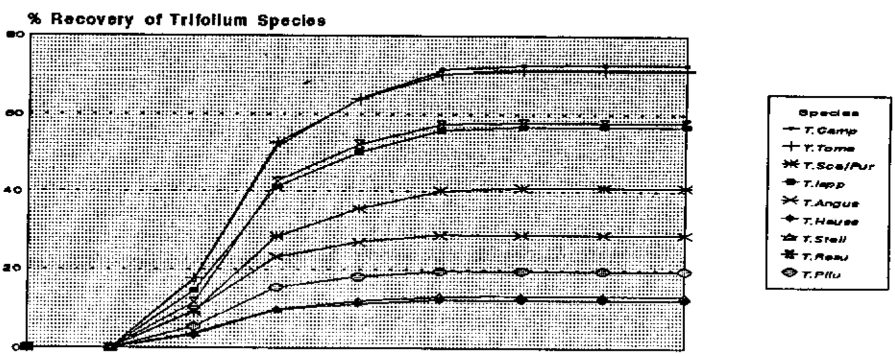
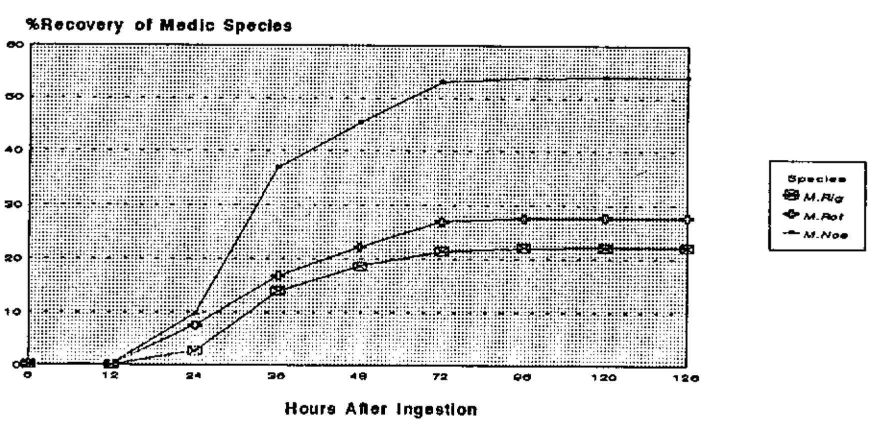


Fig.2



Average of 10 Sheep

Fig.1

Figures 1–3. Percentage Recovery of Legume Species

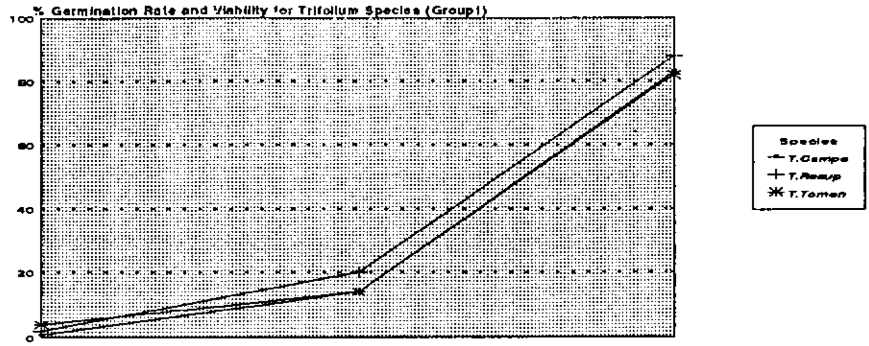


Fig.4

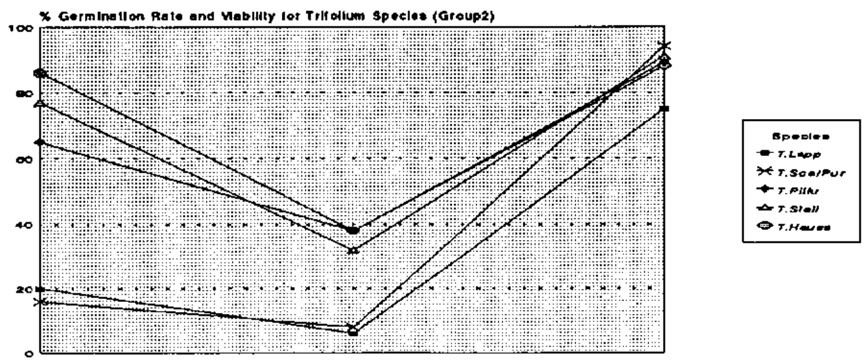


Fig.5

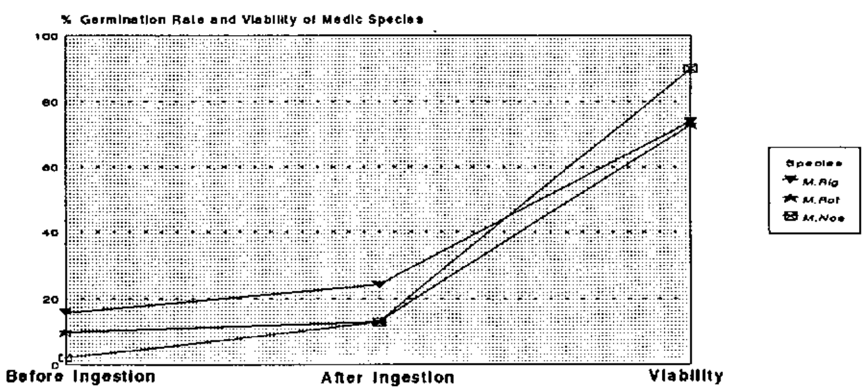


Fig.6

Avg. of Four Intervals (24, 36, 48 and 72 Hours)

Figures 4–6. Germination rate and viability for legume seed ingested by sheep

Residual Phosphate on Marginal Land

An experiment was started in Tel Hadya (1984/85) to test the hypothesis that application of superphosphate to non-arable land (marginal land), which contains annual legumes, stimulates the legumes, eliminates nitrogen deficiency, and so leads to increased herbage production. Phosphate fertilizer (triple superphosphate) was applied in small quantities (11 and 26 kg/ha P) every year for seven years.

Results from this experiment have been previously reported (Bahhady *et al.* 1988; Osman *et al.* 1990; Osman *et al.* 1991; Osman and Cocks 1993 Osman *et al.* 1994). Applications of 11 and 26 kg/ha of P raised Olsen-P values in the soil from approximately 7 mg/kg to about 20 and 40 mg/kg, respectively, by the end of the seventh season (July 1991). No additional fertilizer was applied, and the experimental plots were used to study the effects of residual phosphate on pasture and grazing animals. The present report summarizes the results for 1994.

Available Phosphorus

In May 1994 (44 months following the last phosphate application), plots that received phosphate fertilizer (P_{11} and P_{26}), retained significantly higher phosphorus levels (P<0.01) than the control (P_0). Phosphate levels appear slightly higher under P_0 (29 percent) and P_{11} (19 percent) and slightly lower under P_{60} (13 percent) compared with May 1993 (Table 1).

Table 1. Available phosphorus in the soil (mg/kg) recorded in May in each of four seasons[1] (8, 20, 32 and 44 months after last fertilizer application) at Tel Hadya in northern Syria.

	Phosphate rate[2] (kg/ha P)				
Season	(months following last application)	0	11	26	SEM
1990/91	(8)	6.5	20.8	40.1	1.56
1991/92	(20)	7.3	23.4	38.2	2.07
1992/93	(32)	7.2	12.8	24.8	1.29
1993/94	(44)	9.3	15.2	21.5	1.19

[1]Each value is an average of two stocking rates. There was no significant phosphate x stocking rate interaction.

[2]The last phosphate application was September 1990.

Botanical Composition

Legume pasture components under P_0 comprised between four percent in January and 16 percent in April (dry matter basis), ranging between 14–26 percent under P_{11} and between 8–31 percent under P_{26} (Fig. 1).

Herbage and Seed Yield

The total herbage yield of legumes (Fig. 1) was similar to yields in previous seasons: a higher accumulation of biomass at both P_{11} and P_{26} over the control, with the difference significant ($P<0.01$) throughout the season. There were no significant differences between P_{11} and P_{26}.

The number and mass of legumes, and total seeds are shown for June in Table 2. Seed mass and seed number of legumes harvested in June at P_{11} and P_{26} were four to five times the amount at P_0. Total seed mass of all species, at P_{11} and P_{26}, was 2.6 and 2.3 times the amounts at P_0, respectively. Seed numbers were 2.3 times higher than at P_0.

Table 2. Mass (g/m2) and number of seeds/m^2 of legume and total seeds (grass, legume and weed) in the top one cm of soil as the result of residual phosphate from previous phosphate[1] applications under two stocking rates in June 1994 at Tel Hadya.

Phosphate rate	Legume		Total	
(kg/ha P)	mass	number	mass	number
0	1.1	1437	8.9	6683
11	4.3	5281	23.2	15244
26	5.6	7073	20.9	15165
SEM	0.63	895	3.37	1588
D.F. Error	10	10	10	10

[1]Last phosphate application was September 1990. Each value for phosphate rate is an average of two stocking rates. The stocking rate and phosphate x stocking rate interaction are not significant.

—*A.E. Osman*

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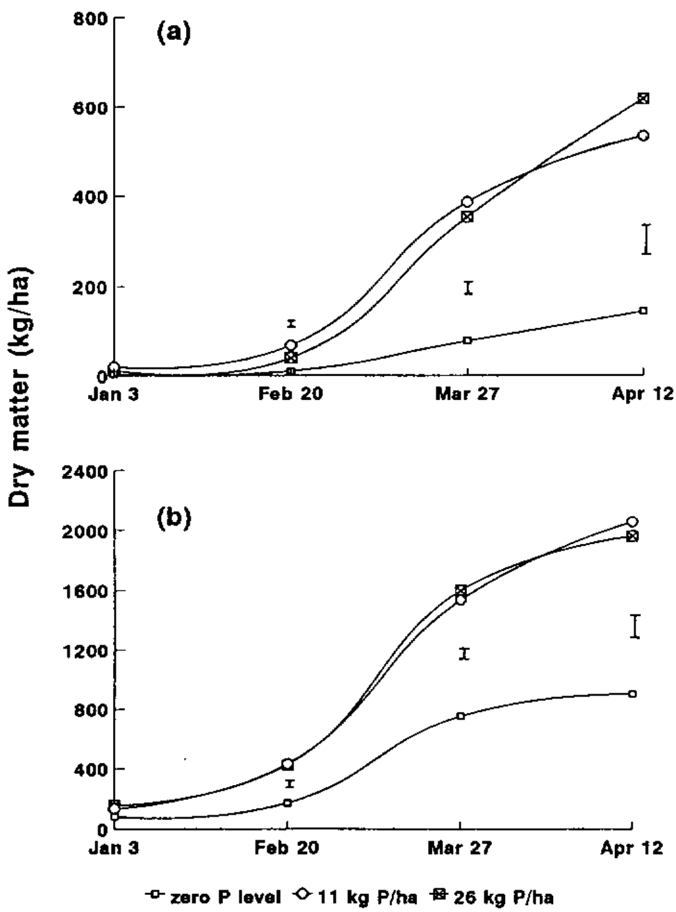

Figure 1. Cumulative legume (a) and total biomass (b) kg/ha as affected by residual phosphate on marginal land at Tel Hadya in 1994. Vertical bars represent S.E.s (D.F. Error 10).

A Simple Pitting Machine for Arid Rangeland Reseeding and Rehabilitation

Syrian steppe rangeland is highly degraded, especially in the Aleppo province. Since the mid-Seventies, the Syrian authorities have made a considerable effort to rehabilitate some areas with fodder shrubs (Osman and Shalla 1994). This requires large nursery operations with seedling transplanting, followed during the summer by two to three irrigations per shrubs for two consecutive years. The alternative of direct seeding fodder shrubs has often been considered but has rarely been successful on a large scale. This is due to a variety of reasons, from poor quality seed to low rainfall after initial establishment (Malcolm and Allen 1981; Malcolm 1994). We have developed the idea of combining direct seeding with micro-water catchments to improve water availability to the newly established shrubs after early germination. This is the pitting technique, not a new idea (Branson *et al.* 1966) but a useful one (Gintzburger and Skinner 1985; Gintzburger 1987; Skinner 1991).

PFLP/ICARDA built a simple pitting machine for use in the revegetation operations of degraded arid rangeland. This low-cost machine consists of a single modified disc plow mounted on a two-wheeled trailer. It makes a string of shallow elongated pits trapping rainwater, organic matter and seeds. This creates a favorable environment for further plant development. The length and depth of the pit can be altered by modifying the disc shape. The machine is meant to operate behind an ordinary car. It is important that the soil disturbance remains minimal and that native vegetation is not destroyed by the towing car and the pitter. It is being tested in rangeland rehabilitation operations at the Maragha station.

This pitting machine is cheap to build and easy to operate, which increases its potential impact. The Syrian Steppe Directorate, the Jordanian Muaquar Rangeland Regeneration Project and range managers from north Africa have all shown interest.

Reseeding operations could be tested on degraded White Artemisia (*Artemisia herba-alba*) range, and commonly degraded *Carex stenophylla-Poa bulbosa* vegetation range from the Aleppo steppe (150–200 mm rainfall zone), either with White Artemisia, *Atriplex halimus* or *Salsola vermiculata* seeds.

—*G. Gintzburger, W. Bou Moughlabay and P. Eichhorn.*

Note from the editor: This machine was manufactured at the ICARDA workshop with locally available agricultural parts. It is the prototype of the one marketed as the KIMSEED Camel Pitter—Western Australian Department of Agriculture from Perth, Western Australia.

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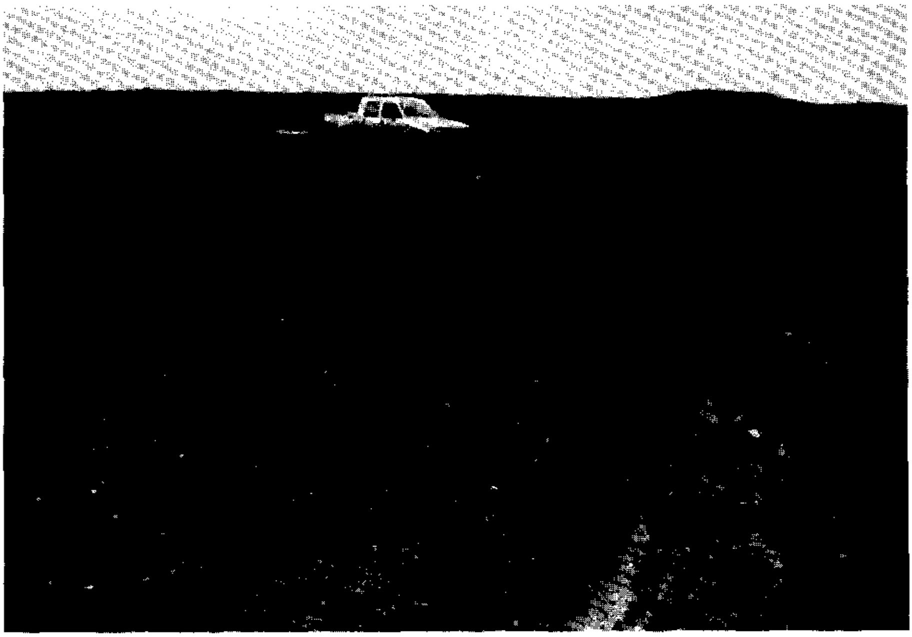

Photo 1: A view of the test site at Maragha (175 mm, degraded steppe of *Carex stenophylla* and *Poa bulbosa*) with the open pits in the forefront.

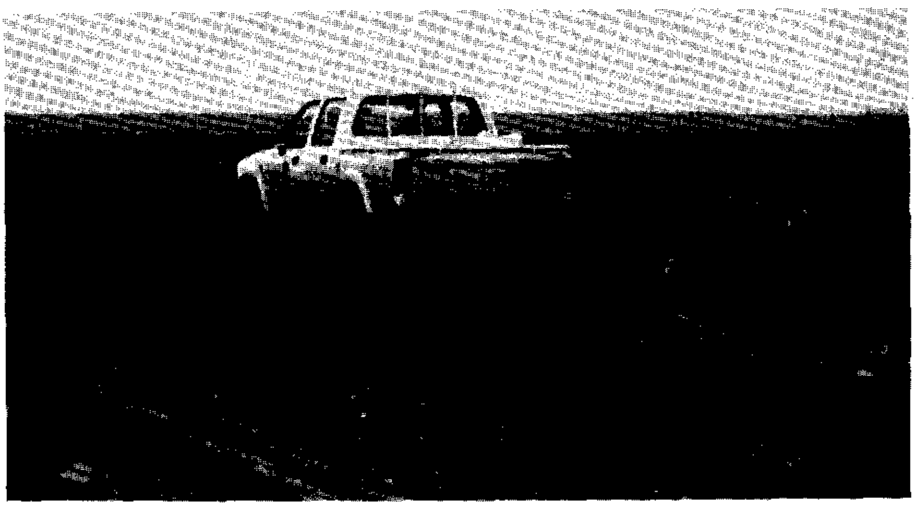

Photo 2 : The pitting machine towed behind a simple utility truck (Maragha—Aleppo province, Syria. Dec 1994).

Natural Resource Conservation and Management in Northeastern Syria (Abdal Aziz Mountain Region–Hassakeh)

Introduction

In marginal west Asian and north African land, with annual rainfall 200–300 mm, land degradation is due to overgrazing, shrub up-rooting and inappropriate cultivation practices. In regions where crop, rangeland, and livestock production are predominant, physical, biological and human system resources should be geographically integrated and interactively evaluated to develop sustainable agriculture systems and land use.

Remote sensing (satellite data and aerial photograph analyses) is one method for capturing and characterizing the physical and biological resources in spatial formats related to local agricultural systems and land use.

GIS (Geographical Information System) is a computer technology that stores, retrieves and analyzes multi-disciplinary thematic maps from remote sensing and other human and biological spatial data from extensive field surveys.

Thanks to geographical referencing (geo-coding), GIS provides powerful capabilities: overlaying one map over another; incorporating human and biological data with GPS (Global Positioning System) coordinates into GIS map data domains; and spatial model referencing of GIS map attributes to external map data created by other spatial models (for example, Neural Network and/or Principle Component Analyses).

GIS applications (particularly with other external models) are useful for identifying current resource degradation and change, for evaluating future resource hazards and for producing sustainable land-use maps.

—*H. Fujita*

Analysis of Vegetation and Mapping of the Test Zone

Aerial Photograph Interpretation and Vegetation Survey

A series of aerial photograph interpretations and vegetation mappings of the Abdal Aziz mountain region was completed in 1994. A total number of 78 aerial photographs, taken in 1981 at a 1:45,000 scale, which cover the test zone (latitude: 36° 15'00"–30'00", longitude: 40° 07'30"–30'00"), were visually interpreted by stereoscope. Spatial distribution of main vegetation types were identified, referenced to a series of vegetation surveys conducted in April, August and October of 1993 at 75 sites.

Classified Vegetation and Mapping

The main vegetation cover forms identified were:

1) Open woodlands.
2) Open dense woodlands.
3) Shrub lands consisting of three sub-types (S1, S2, S3).
4) Dense shrub lands consisting of two sub-types (D1, D2).
5) Annuals.
6) Cultivated lands of rainfed barley and irrigated wheat fields (Fig. 1).

Spatial distribution of the above classified cover forms were presented at a scale of 1:50,000 with a legend of cover forms, type code, plant cover, vegetation types (main species component), and land use.

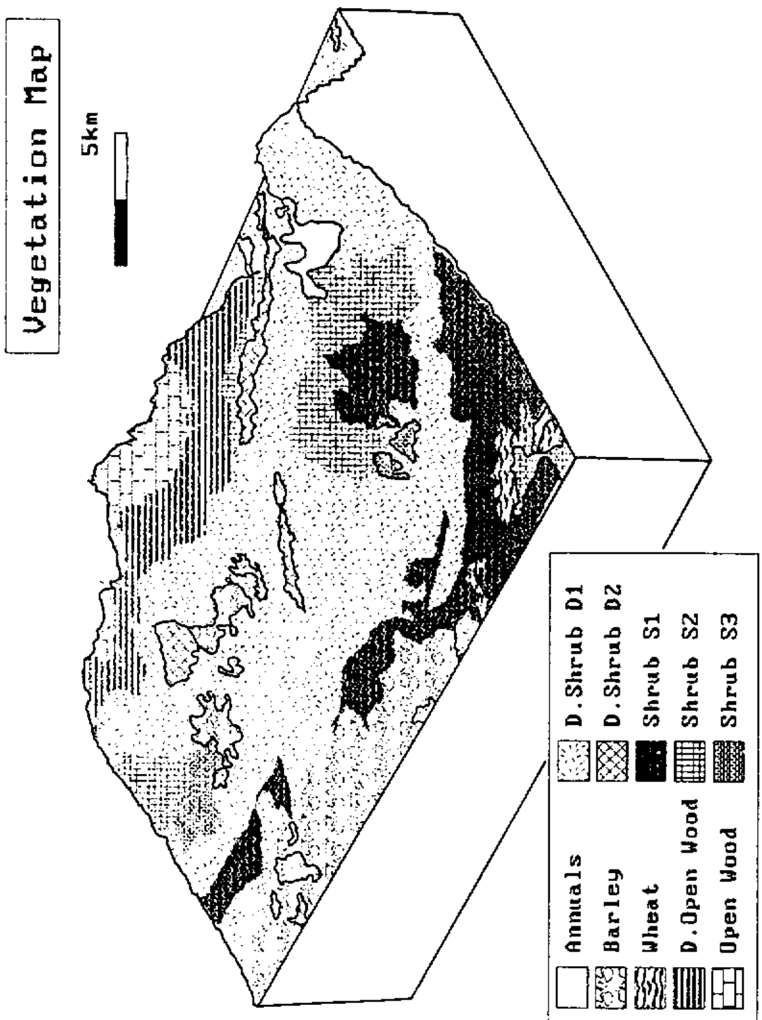

Figure 1. Classified vegetation map of Abdal Aziz mountain test zone, northeast Syria.

The dense shrub communities, consisting mainly of *Artemisia herba-alba* and *Poa bulbosa* (D1), were predominant in many land forms of the test zone, except on the northern slopes (steep slopes and fault escarpment). The open woodlands (W) and the dense open woodlands (O) were only on the northern slopes, fault escarpment and the hogback (folded hilly terrain, where the dense open woodlands were predominant in the central parts of the hilly region). Hence, the plant communities represented by wooden species such as *Pistacia atlantica* and *P. khinjuk* were unique in the northern and adjacent parts of the mountains. Other plant communities, such as S1, S2 and S3 (represented by *Artemisia herba-alba* and *Poa bulbosa, Artemisia herba-alba* and *Salsola vermiculata, Haloxylon articulatum* and *Carex stenophlla,* respectively) are scattered in all locations of the region. It was notable that the relatively higher coverage of annual species was present in all vegetation communities ground truthed in the fields.

Discussion

The classification conducted by the aerial photographs (panchromatic) was made by identifying shadow, tone, roughness, and height of objects. It was, therefore, highly influenced by absolute coverage of vegetation communities. Higher coverage of stones and rocks in the test zone might have affected identification of vegetation communities with minor coverage.

The vegetation map produced presents the distribution of plant communities approximately 12 years ago, along with some changes in vegetation. Conversion to cultivated rainfed barley fields prevails in both northern and southern plains of the region. Updating current vegetation is possible by remote sensing analyses of a new series of aerial photographs, or of satellite data with multiple bands (the latter is readily available).

—N. Battikha and H. Fujita

Map Database Establishment for Resource Management

To solve degradation problems and to plan sustainable land use, a database of land resources is essential. The land resource database in map format using GIS was established to develop many kinds of evaluation, modeling and simulation for resource management and land-use planning.

Coordinate System Verification

The coordinate system used in thematic maps of topography, soil, geomorphology, degradation (Fujita 1993; Loulou and Fujita 1993; Nasri and Fujita 1993) and vegetation (this report) were verified geographically with the GPS coordinate system. Twenty landmark points, easily identifiable both in base maps (used for thematic map delineation) and in the field (such as road crossings or dividing points) were selected. Six 1:25,000 topographical maps, issued by the Syrian General Surveying Organization in 1991, which cover the whole test zone, latitudinally between 36° 15'00"–30'00" N, longitudinally between 40° 07'30"–30'00" E, were used as the base maps. The field verifications on the 20 landmark coordinates in the maps and by the GPS (both projected as UTM—Universal Transverse Mercator) were conducted in November 1994. All coordinate differences between the field and GPS were within the positioning error of GPS (within 100 m), and therefore the coordinate systems of mapping and field were assumed to match.

Creation of GIS maps and Digital Terrain Model

The boundaries of each thematic map were digitized (using a GIS program and a large format digitizer) and filed as a GIS vector map(presented in pairs of X/Y coordinates). The vectorized topographical map of coded contour lines was rasterized (converted to cells with elevation values corresponding to the contour lines). The rasterized map was interpolated linearly to fill in blank cells with estimated elevation values (elevation map). The elevation values of all eight neighboring cells were calculated mathematically to estimate slope degree and slope direction of the center cell (outputting slope and aspect maps—Digital

Terrain Model). The geomorphological map was digitized and filed as land form and land unit maps, respectively, to avoid overlap of boundaries in the original map. Maps with coverage and attributes such as the land form, the land unit, the vegetation, the soil and the degradation were polygonized, assigning each unique map unit to one category of the subject matter.

Table 1. Resources map database files within GIS.

File name Type	File information
TOPOBASE Segment	Contour lines, main roads, village names, power lines
ELEVATION Raster	Interpolated elevation values for all pixcells
SLOPE Raster	Estimated slope angle in degree for all pixcells
ASPECT Raster	Estimated slope directions in degree for all pixcells
VEGETAT Polygon	Polygonized map of 10 vegetation types
SOIL Polygon	Polygonized map of 6 soil types including rockout crops
DEGRADAT Polygon	Polygonized map of 15 degradation combinations in type, degree, extent
LANDFORM Polygon	Polygonized map of landforms such as plain, foothill, slopes
LANDUNIT Polygon	Polygonized map of scattered geomorphological units such as alluvial fans, sink holes, deep valley
GRAZING Polygon	Polygonized map of grazing areas of five flocks with durations

The grazing areas of five chosen flocks were identified by field interview. The estimated boundaries of seasonal grazing areas were digitized and polygonized for each flock. Table 1 shows the resource map database established.

—H. Fujita

Changes in Grazing Areas and Feed Resources

Introduction

Most marginal lands in west Asia are permanent pasture; of 1.16 million km^2, 85 percent are considered in danger of desertification (UNEP). These marginal lands are subjected to human activities and are susceptible to inappropriate land-use practices, such as overgrazing, fuel cutting and inadequate cultivation.

The Abdal Aziz mountain test zone in northeast Syria is located in marginal land with an average annual precipitation of 200–300 mm. The land is predominantly used for rangeland grazing by local flocks, and barley cultivation for small ruminant production(Fujita *et al.* 1992). Evaluation of regional feed resource availability and utilization, and identification of grazing influences on natural resources, are essential to facilitate sustainable land-use development. Grazing areas and changes in feed resources were surveyed on selected flocks in five test zone villages from May to December 1994.

Methods

Grazing areas and feed resources

The locations of the five villages and local grazing land for the selected flocks were measured using GPS. Grazing areas and feed resources were estimated by field survey and information from stock owners.

Measurements on available feed resources

Plant components and coverage at grazing points were measured by line method (25 cm interval in 25 m) in July, September, October and December 1994. Aerial biomass of shrubs and herbaceous plants was measured by clipping at ground level within 5*4 m and 1*1 m, respectively. The plants were oven dried (85° C, 24 hours) to estimate dry matter.

Observation of selected plants

Flock plant selection during rangeland grazing was estimated. Five animals were randomly observed every five minutes for one hour to estimate selected plant frequency for each species.

Results and discussion

Grazing areas

Villages in which the five flocks were based and grazing areas of those flocks were projected in the test zone from May to December 1994 (Fig. 1). There were two patterns of grazing areas and village locations in terms of geomorphology. The two flocks based on the northern foothills grazed barley fields in the northern plain/foothills, where alluvial fans extend to the plain. During autumn and winter, the two flocks grazed rangeland in the northern slope/fault escarpments and the hogback area.

The two flocks, based on very moderate southern slope, grazed barley fields around the villages and rangeland surrounding those barley fields. Since the flock in Al Naasri moved its base from the southern plain to Sufeera on the southern slope, there were two grazing patterns on the southern plain/foothills.

Barley grazing was combined with rangeland grazing in all five flocks between mid-June and mid-October, after which grazing was on rangeland or cotton fields. There was substantial variation in when barley grazing finished completely (September 6 at the earliest and October 26 at the latest), that was associated with when farmers started plowing barley fields for the next season. The grazing area of the Al Jafar flock changed from southwest to southeast of the village in October 1994. This change was associated with several ponds created by a heavy rain and used for local flocks.

Three flocks, based in Al Jafar, Deliyaan and Sabaizlam, left the test zone and entered cotton fields between mid-October and mid-November—where many flocks from the Abdal Aziz mountain region were found along the Khabuur river, 20 km north of the test zone.

The grazing area of the Magaluuja and Al Jafar flocks decreased on October 29 and November 21, respectively.

Feed resources

Fallen barley grain and straw were important feed resources during the harvesting period, as many flocks followed harvesting machines. Barley straw and stubble were the main feed resources in the five flocks after harvest until the end of August.

Barley straw and stubble contributed, along with rangeland plants, to feed resources. Estimated ratios of barley straw/stubble to rangeland plants were two to one for Al Jafar, Deliyaan, and Sabaizlam flocks, and one to one for the Magaluuja, Al Naasuri, and Sufeera flocks (Fig. 2). With the higher aerial biomass of barley straw and grain at the end of September, only barley straw and stubble contributed as feed resources in the Sufeera flock (Table 1).

Table 1 Aerial biomass at grazing points, September/1994.

Flock	Al-Jafar	Magaluuja	Deliyaan	Sabaizlam	Sufeera
Barley straw/stubble	—	—	447	587	940
Rangeland					
Total	279	300	652	1051	288
shrubs/herbs*	234/45	160/140	499/153	303/748	47/241

* = herbaceous plants
unit = D.M.kg/ha

Cotton resources (cotton leaves, cotton bolls, cotton flowers and weeds) were grazed by the flocks based in Al Jafar, Deliyaan and Sabaizlam between the middle of October and the middle of November.

Aerial biomass of new green shoots in rangelands, which started to grow after heavy rainfall in October, varied from 2–45 kg/ha in early December (Table 2). However, the main selected plants changed from dry herbaceous plants (67 percent) at the end of October to new herbaceous plants (86 percent) in early December (Table 3), with a range from 70–95 percent among those flocks. Feed resources changed from dry herbaceous plants to newly grown green shoots during November.

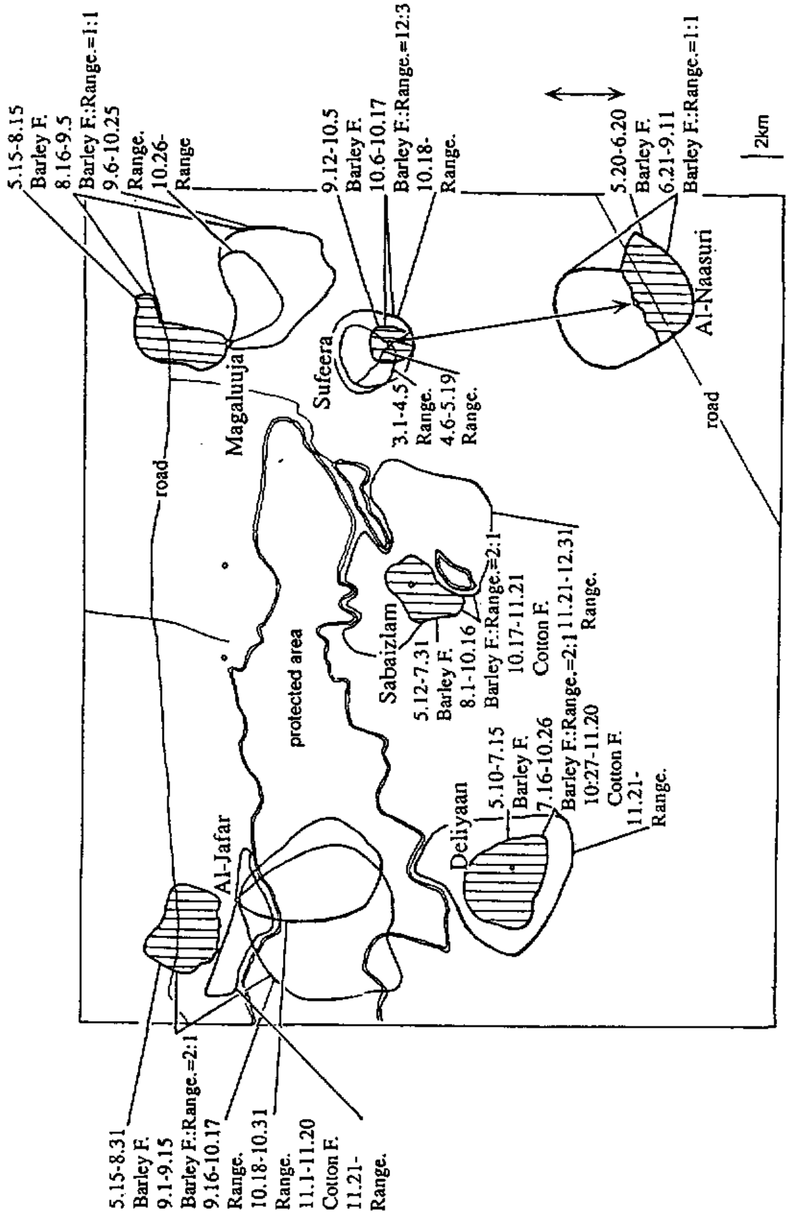

Figure 1. Grazing areas of five flocks from mid-May to the end of December, 1994 in Abdal Aziz mountain, NE Syria.

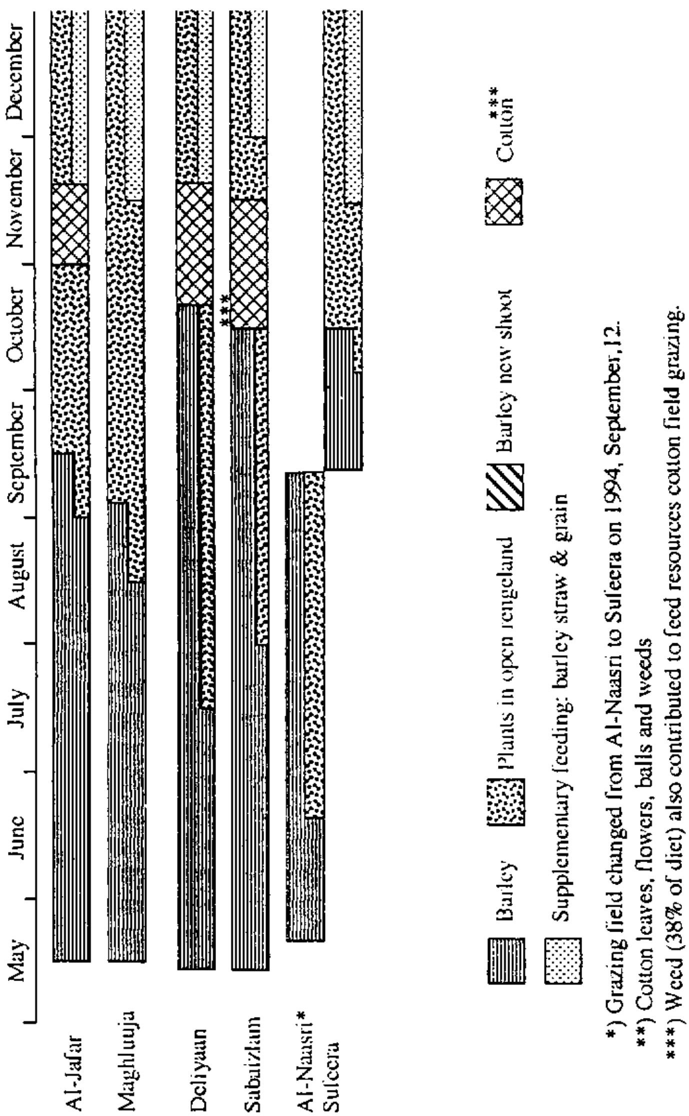

Figure 2. The change of feed resources from mid-May to the end of December 1994, *in* Abdal Aziz mountain area, NE Syria.

Table 2 Aerial biomass at grazing points, December/1994.

Flock	Al Jafar	Magaluuja	Deliyaan	Sabaizlam	Sufeera
Shrubs	130	13	2145	293	n.a.
Herbs*					
Standing dead	19	7	105	27	n.a.
new shoots	21	45	2	2	n.a.
Total	170	65	2252	322	n.a.

* =herbaceous plants
unit=D.M.kg/ha

Table 3 Selected plant frequency(%) of shrubs, standing dead and new shoots of herbaceous plants in October/December,1994 in Abdal Aziz mountains.

	Shrubs	Herbaceous plants		Total
		Standing dead	New shoots	
End October	5	67	28	100
Early December	10	4	86	100

Supplementary feeding of barley grain and straw began in mid-November, 1994—except for one flock in Sabaizlam, which began supplementary feeding in December.

—*M. Hirata and H. Fujita*

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Estimate of Soil Erosion Risks on Abdal Aziz Mountain, Northeast Syria

Introduction

In the Abdal Aziz mountain test zone in northeastern Syria, previous study of land degradation has shown that soil degradation, especially soil erosion, is wide-spread (Loulou and Fujita 1993). This soil erosion may be attributed to natural deformation processes and human activities. The natural deformation processes can be due to climatic, soil, and topographic factors. The human activities center around land use and management.

The previous land degradation study produced a soil degradation status map and indicated that water erosion by the natural deformation processes was predominant on hilly to undulating land areas. The study suggested that water and/or wind erosion might be associated with local cultivation practices. Since the previous study was conducted to identify physical degradation phenomena by remote sensing and ground truth, human activities (such as grazing in the central mountains, and fuel cutting and cultivation in the northern and southern plains) could not be separated from the natural deformation processes. Furthermore, the degradation map shows the results of past soil erosion, not future risk—which is essential for land-use planning.

Methods

Three experimental sites for the water erosion experiment were selected, and measurements started in the 1994/95 rainy season(Fig. 1). Each site consists of two plots comparing soil loss and runoff from different land uses. These two plots in three sites were in adjacent and similar landscapes, as shown in Figure 2. Each plot had an enclosed area of $37.8m^2$ (21m long and 1.8m wide), connected to two collection tanks and linked with a one-seventh divisor (Fig. 3).

As shown in Figure 1, Site 1 (UTM coordinate; X 621957, Y 4029608) is located in the central part of the test zone (mountain area), with one plot in the protected area, and the other in the open-grazed area.

Site 2 (UTM coordinate; X 601722, Y 4029011) is also located in the mountain area (western-central part of the test zone), with the same catchment design as the first site, but with only one collection tank.

Site 3 (UTM coordinate; X 619904, Y 4036366) is located on the plain (northern-central part of the test zone), comparing soil loss and runoff in a barley field and in a reserved shrub land (natural vegetation). The runoff/soil-loss measurement was made after major rainfall, when access was available.

A meteorological station was established in a field located in Maghluuja (northeastern part of the test zone). At this station, temperature, humidity, rainfall, wind direction, and wind speed were recorded.

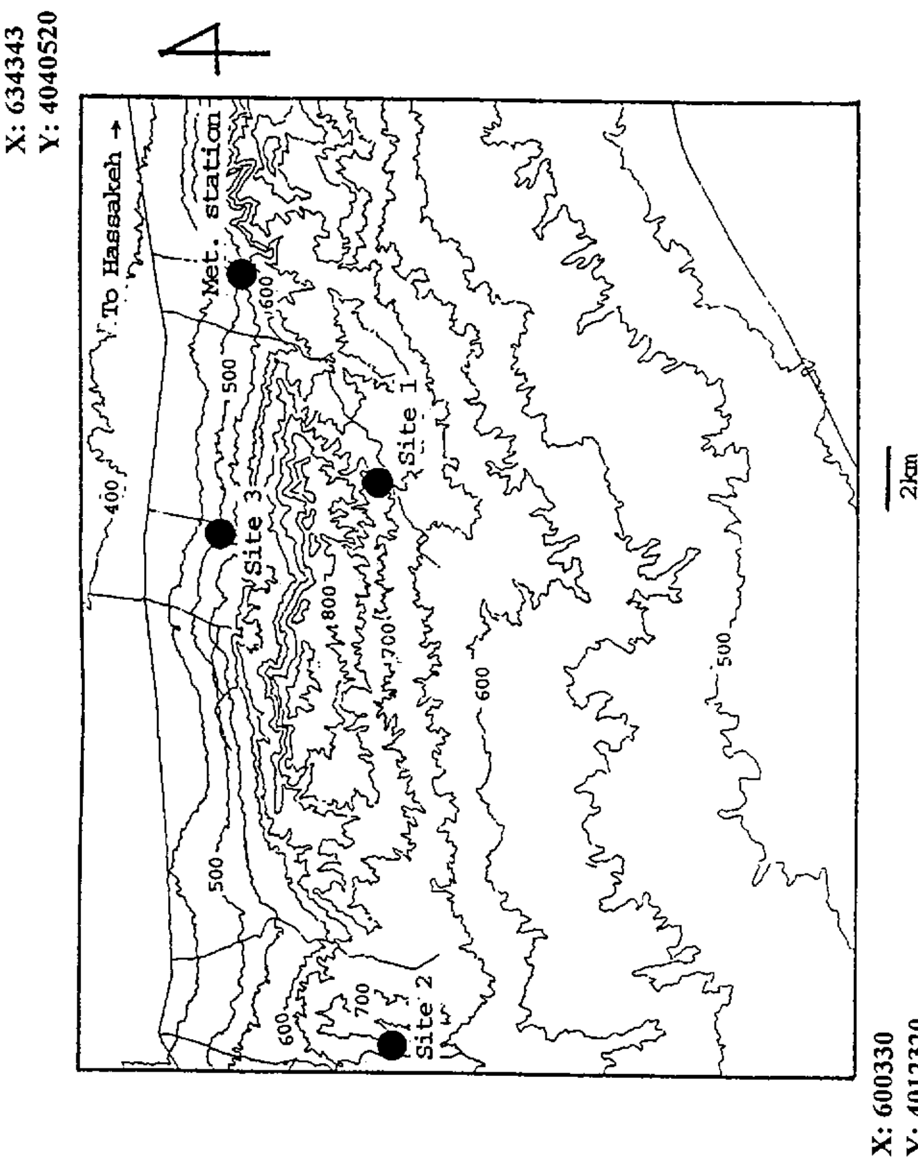


Figure 1. Location of test sites and meteorological station (X,Y coordinates are UTM).

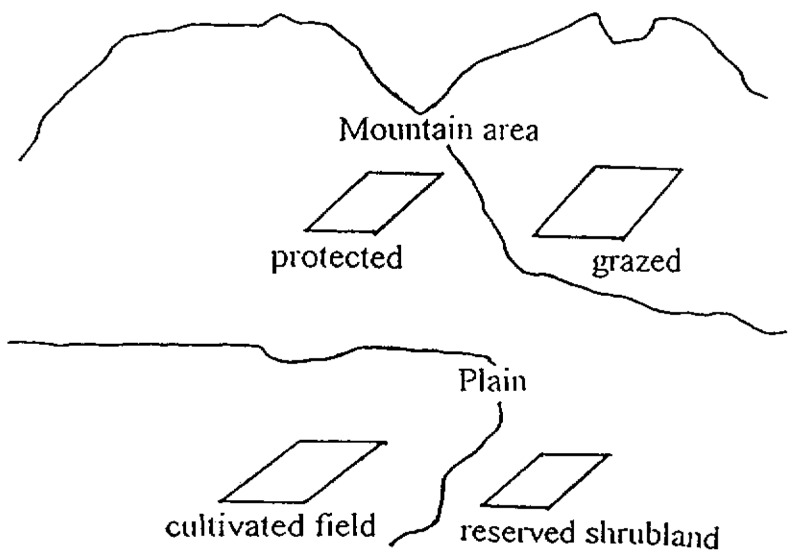


Figure 2. Conceptual plan of test sites.

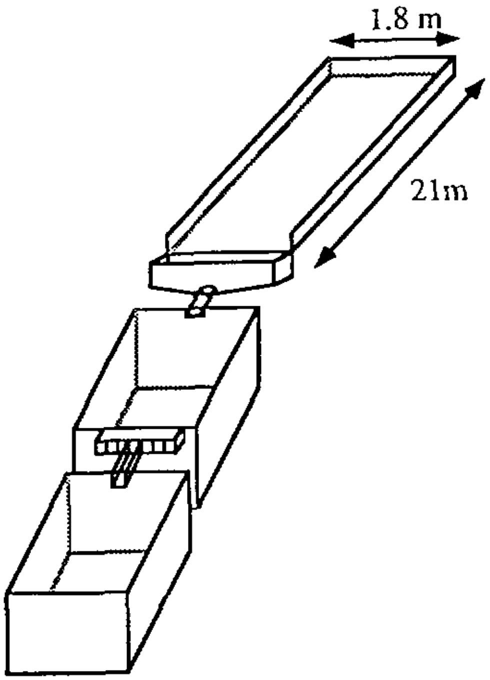


Figure 3. Plot for soil-loss and runoff measurement. (All removed soil and runoff water in a catchement flow into a first tank. A second tank receives overflowing materials from the first tank through a one-seventh divisor.)

Results and Discussion

Results from the first season of the water erosion experiment are shown in Table 1. Although soil-loss data are not available at the moment, runoff volumes in the open-grazed rangeland plot and in the barley field were larger than those in the protected area or in the reserved shrub land in all runoff tests. This might be associated with human activities, such as grazing or cultivation, which may decrease plant biomass and coverage and possibly accelerate water runoff and, eventually, soil erosion. The barley field plot at Site 3 (with a slope gradient of 2°) had much more runoff than the plot in the open-grazed rangeland at Site 1 (with a slope gradient of 10°) although the plant coverage in both sites was similar. This difference might be attributed to the difference in soil properties, e.g., susceptibility to water erosion in each plot. Among those runoff incidences in Site 3, the runoff records in the barley field were not directly reflected by the rainfall amount, and the runoff seemed more associated with rainfall intensity (which is not included in this report).

Table 1 Runoff volume and rainfall (~Jan.13,1995)

Sampling date (Rainfall date)	Runoff volume (mm)*		Rainfall (mm)
Site 1	Protected	Grazed	
Nov. 19(14~16)	0	0.26	20.1
Site 2	Protected	Grazed	
Dec. 19(Nov.16~)	4.96	>10.58(overflow)	127.2
Site 3	Shrubland	Cultivated fallow	
Nov. 14(14)	0	0.79	10.2
Dec. 3 (1,2)	0	1.46	2.8
Dec.31 (29,30)	0	8.86	23.1
Jan.11 (11)	0	4.30	10.6

*Runoff volume was indicated here only when runoff was collected in sites.

To estimate degradation risk, results from the direct soil-loss measurement will be considered, and extensive surveys on soil, vegetation and topography will be conducted, applying parametric ways such as USLE (Universal Soil Loss Equation) or multi-regressional ways such as a link with the Neural Network model. The GIS analysis will enable simulation of future soil erosion with predictive combinations of factors such as rainfall, vegetation, and land use.

— ***H. Shinjo and H. Fujita***

Reference

Loulou, A.R. and Fujita, H. 1993. Natural resource conservation and management in northeastern Syria, In Pasture, Forage and Livestock Program Annual Report for 1993. ICARDA. Aleppo.

Socioeconomics
(MTP 94–98/Project 21)

The Contribution of Women to Labor and Decision Making Processes in Bedouin Farming Systems in Northern Syria

Abstract

Differences in labor constraints, financial incentives and income control can lead to different evaluations of innovations and technologies by women and men, thus influencing interest and adoption. The present study identifies the roles of male and female family members in labor and decision making processes at the family, household and farm levels. The identification of gender roles in small ruminant production and management in three defined Bedouin farming systems can help extension and research institutions to identify the appropriate household members involved in decision making and the carrying out of activities, and to sensitize their work to gender issues.

The three farming systems differ in flock size, cultivated area, off-farm income and the degree of sedentarization. Off-farm occupation by male family members increases the workload and responsibilities of female family members. It also increases women's contact with the market, and thereby allows them some control over household expenditures. In all three farming systems, women are responsible for fodder mixing and supplementary feeding of the flock. This should be considered by research and extension personnel in their efforts to improve flock feeding management.

Introduction

Problem statement

Fifty five percent of Syria's surface area receives less than 200 mm annual rainfall. This area is the base of the Bedouin, who keep some two thirds of Syria's 14 million sheep (FAO 1990). The quality of natural range vegetation has declined in recent decades. One factor contributing to this is the increase of mechanization, which allows the Bedouin to cultivate barley in some parts of the rangeland and improves their mobility. With tractors and trucks they can transport their flocks easily moving them to remote range areas that still provide grazing. The total number of sheep has also increased, leading to overgrazing. The absence of effective control of grazing or barley cultivation in the rangelands and the increased demand for firewood has led to destruction of the vegetation cover and degradation and erosion of the soil.

In 1991, a research project began analyzing Bedouin farming systems in marginal zones (ICARDA/Hohenheim 1989). During the first round of interviews the important contribution of women and children to the farm and household system became obvious (Wachholtz 1995).

Experiences in other developing countries show that different labor constraints, financial incentives and income control lead to a different evaluation of problems by women and men. If research and extension services are sensitized to the existence of gender-specific responsibilities in farm households, they can more effectively target their activities (Berger 1984; Ellis 1988; Evans 1988; Louden 1986). In the context of long-held traditions, it is important to obtain information not only from the male head of household, but also from female family members, to obtain a more complete picture of the situation of farm and household (Feldstein and Poats 1993; Tully 1990).

Data collection and study area

A study area was selected, starting about 40 km southeast of Aleppo and reaching a further 100 km into the rangeland. Precipitation in this area varies from 275 mm in the northeast to 100 mm in the southwest (Wachholtz *et al.* 1993). A random subsample of households was taken a part of a larger survey of Bedouin farming systems by Wachholtz (1993, 1995). For data collection, a standardized questionnaire was used. The data were collected in single interviews with female heads of households, assisted by a female Syrian translator.

Table 1. Characteristics of the three farming systems.

Flock size (head)	Permanent	Transitional	Pastoral
0–20	47%	-	5%
>20–100	38%	45%	40%
>100	15%	55%	55%
Cultivatable land (ha)			
<10	38%	5%	-
>10–50	56%	40%	-
>50	6%	55%	-
Access to off-farm earnings	85%	5%	25%

Characteristics of farming systems

The 74 sampled households were divided into three farming systems according to differences in farming resources and lifestyles (Table 1):

1) Permanent mixed farming system (permanent, n=34) with small flock size, little cultivable land and high dependence on off-farm income.
2) Semi-sedentary transitional Bedouin system (transitional, n=20) with large flock size, extensive cultivable land and little off-farm income.
3) Traditional Bedouin system (pastoral, n=20) with no cultivation of crops, no houses, living in tents all year round, large flock size and little off-farm income.

Labor Division in the Yearly Cycle

To estimate the implications of changes in farming systems on time constraints, incentives and income control among household members, information is needed on labor allocation to main activities in the daily and yearly cycle.

Yearly cycle of activities in the three farming systems

The yearly calendar (Table 2) shows the main activities during the year for the three farming systems. The letters underneath the various systems indicate the months in which an activity takes place as reported by at least two thirds of the households. The letters under the months indicate the gender and age group of persons mainly responsible for carrying out an activity.

PERMANENT SYSTEM

ACTIVITY	O	N	D	J	F	M	A	M	J	J	A	S
Moving time	H	H	.	.	.	.	.	H	H	H	H	H
Off-farm work	H	H	.	.	.	.	.	H	H	H	H	.
SHEEP PRODUCTION												
Hand feeding	.	F	F	F	F	F	F	.	.	.	.	.
Manure Collection	.	F	F	F	F	F	.	.	.	.	.	.
Shepherding	b	b	.	.	.	.	b	b	b	b	b	b
Lambing	.	H	H	H	H	.	.	.	.	.	.	.
Milking	.	.	.	.	F	F	F	F	F	F	.	.
Shearing	.	.	.	.	.	.	M	M	.	.	.	.
CEREAL PRODUCTION												
Sowing	.	m	m	.	.	.	.	.	.	.	.	.
Harvest (machine)	.	.	.	.	.	.	.	m	m	.	.	.
(hand)	.	.	.	.	.	.	.	F	F	.	.	.
Threshing	.	.	.	.	.	.	.	H	H	.	.	.
Straw collection	.	.	.	.	.	.	.	F	F	.	.	.
HOUSEHOLD												
Cooking	F	F	F	F	F	F	F	F	F	F	F	F
Bread baking	.	.	.	.	.	.	.	.	.	.	.	.
Cleaning	F	F	F	F	F	F	F	F	F	F	F	F
Child care	F	F	F	F	F	F	F	F	F	F	F	F
Firewood collection	.	.	.	.	.	.	.	.	.	.	.	.
House/tent repairs	.	.	.	.	.	.	w	w	.	.	.	.

TRANSITIONAL SYSTEM

ACTIVITY	O	N	D	J	F	M	A	M	J	J	A	S
Moving time	H	H	.	.	.	.	.	.	H	H	H	H
Off-farm work	.	.	.	.	.	.	.	.	.	.	.	.
SHEEP PRODUCTION												
Hand feeding	F	F	F	F	F	F	F	F	.	.	.	.
Manure Collection	.	F	F	F	F	F	.	.	.	.	.	.
Shepherding	b	b	.	.	.	b	b	b	b	b	b	b
Lambing	.	H	H	H	H	H	.	.	.	.	.	.
Milking	.	.	.	.	F	F	F	F	F	F	.	.
Shearing	.	.	.	.	.	.	.	M	M	.	.	.
CEREAL PRODUCTION												
Sowing	.	m	m	.	.	.	.	.	.	.	.	.
Harvest (machine)	.	.	.	.	.	.	.	m	m	.	.	.
(hand)	.	.	.	.	.	.	.	.	.	.	.	.
Threshing	.	.	.	.	.	.	.	.	.	.	.	.
Straw collection	.	.	.	.	.	.	.	.	.	.	.	.
HOUSEHOLD												
Cooking	F	F	F	F	F	F	F	F	F	F	F	F
Bread baking	F	F	F	F	F	F	F	F	F	F	F	F
Cleaning	F	F	F	F	F	F	F	F	F	F	F	F
Child care	F	F	F	F	F	F	F	F	F	F	F	F
Firewood collection	.	F	F	F	F	.	.	.	.	.	.	.
House/tent repairs	.	.	.	.	.	.	.	w	w	.	.	.

PASTORAL SYSTEM

ACTIVITY	O	N	D	J	F	M	A	M	J	J	A	S
Moving time	H	H	H	.	.	.	.	H	H	H	H	H
Off-farm work	.	.	.	.	.	.	.	.	.	.	.	.
SHEEP PRODUCTION												
Hand feeding	F	F	F	F	F	F	F	F	F	.	.	.
Manure Collection	.	F	F	.	.	.	.	.	.	.	.	.
Shepherding	b	b	b	b	b	b	b	b	b	b	b	b
Lambing	.	.	H	H	H	H	H	.	.	.	.	.
Milking	.	.	.	.	.	F	F	F	F	F	.	.
Shearing	.	.	.	.	.	.	.	M	M	.	.	.
CEREAL PRODUCTION												
Sowing	.	.	.	.	.	.	.	.	.	.	.	.
Harvest (machine)	.	.	.	.	.	.	.	.	.	.	.	.
(hand)	.	.	.	.	.	.	.	.	.	.	.	.
Threshing	.	.	.	.	.	.	.	.	.	.	.	.
Straw collection	.	.	.	.	.	.	.	.	.	.	.	.
HOUSEHOLD												
Cooking	F	F	F	F	F	F	F	F	F	F	F	F
Bread baking	F	F	F	F	F	F	F	F	F	F	F	F
Cleaning	F	F	F	F	F	F	F	F	F	F	F	F
Child care	F	F	F	F	F	F	F	F	F	F	F	F
Firewood collection	.	F	F	F	F	F	F	F	F	F	.	.
House/tent repairs	.	w	w	.	.	.	.	.	.	.	.	.

LEGEND: H = all males and females in a household M = males (men and boys together)
F = females (women and girls together) m = men only
w = women only b = boys only

(Source: Adapted from PAPE, 1994)

Table 2: Labor allocation among tasks by gender, age-class and month (Oct. 1991 to Sept. 1992), as reported by women of three Bedouin farming systems in NW Syria

During the agricultural year 1991/92, 71 percent of the sampled families in the permanent system and 90 percent in the transitional system moved with their flocks. Among the 29 percent of families in the permanent system that stayed in their villages, 80 percent had small flocks of less than 20 sheep and were able to find enough feed in the areas surrounding the village. In the transitional system, the remaining 10 percent of families hired shepherds to move with their flocks. In the permanent system, most of the off-farm activities were carried out in June, July and October. The main off-farm activity was wage labor for harvesting cotton, maize, vegetables and olives. Families of the transitional system, unlike the permanent system families, move mainly in the rangelands and spend less time in high rainfall areas—this limits opportunities for seasonal off-farm income.

By the end of October, the permanent and transitional system families return to their villages to sow their fields with barley and wheat. Supplementary feeding starts at the end of October, because the range vegetation does not produce enough feed to sustain the flock. Compared to the permanent and the transitional systems, the moving time of the pastoral Bedouin is about one month longer. Since the pastoral Bedouin have no cropping, they extend the grazing period in the cropping areas. In the permanent and transitional systems shepherding and grazing is done only during the moving period, unlike in the pastoral system where the sheep are grazed all year round. For the months of December through March, the Bedouin use the term "taking the sheep out for a walk" for grazing activities, because exercise is considered to be healthy for the animals. Shepherding is generally the work of boys.

Sheep manure in the feeding areas is collected by females to be used as fuel or, in the permanent system, to be sold as fertilizer for irrigated areas.

February is the start of the milking season, which lasts until the end of July in the permanent and transitional systems. In the pastoral system, the milking season begins one month later, since lambs are allowed to take more milk. Milking and milk processing is the work of females. In the permanent system, 55 percent of cereals are hand harvested—by females—and afterwards the threshing is done by the whole household. In the transitional system, most of the cereals are combine-harvested. In the permanent system, straw on fields that are harvested mechanically is collected by females for later use as fodder. In the transitional system, straw is not collected but is grazed on site. After harvest, the permanent and transitional system families again start moving with their flocks.

Household activities for females, such as cooking, cleaning and child care, are daily tasks that are time-consuming due to the lack of electricity and other modern conveniences. In the permanent system, during the moving period in the higher rainfall areas, dry cotton stalks are collected by females for use as winter fuel. In the transitional system, females uproot and collect shrubs in the rangelands from December until the end of February for the same purpose . In the pastoral system, shrub collection continues until June. Unlike the houses of the permanent and transitional households, the tents cannot be heated in winter with diesel stoves, so the amount of shrubs needed for fuel is higher. In contrast to the permanent system, bread is bought in the market by most of the families, while bread is baked daily by the women in the other two systems.

Off-farm activities

In the permanent system, 85 percent of families had additional income from off-farm activities. On average, 2.2 (standard deviation=2) persons per household went off-farm for work during the 1991/92 agricultural year. Off-farm jobs range from two weeks to all year. The average period men spend working off-farm is longer than that of other family members. Men work off-farm 27 weeks on average, boys 19, girls 12 and women 13 weeks. Men and boys receive a higher income per hour than women or girls. Thus, contributions of male members to family cash income are more important than those of the females.

Seasonal labor constraints

May and June are very labor intensive months for farmers in the permanent and transitional systems, because these are the months of barley and wheat harvesting, which overlap the main milking season. Additionally, in the permanent system, some members of most families are involved in off-farm activities during June. Other labor intensive times are March, April and May, when the hand-feeding of sheep, milking and milk processing have to be done in parallel—especially in the transitional and pastoral systems. All these labor-intensive periods are more demanding for female household members than for male members.

Influence of age and gender on the division of labor

Women 50 or older are usually not involved in hand-feeding, milking and milk processing, if there are younger women in the household. Older women are mainly responsible for minding the small children, while the younger women and girls do both the farm and house work. Until the age of seven, girls do little farm or household-related work. Between the ages of seven and 13, they help in the household, and above 13, girls help the women with farm-related work as well. For boys, the age of labor contribution starts later than for girls. When they are about 13, they begin taking responsibility for herding sheep.

Traditional labor division

The division of labor among family members does not depend on seasonal labor constraints or labor shortages. It is more influenced by traditional gender roles. According to these traditional roles, men carry out all mechanized activities on the farm and women do the physical, labor intensive work on the farm and in the household. Even though women and girls are fully occupied during the hand-feeding and milking seasons, with these tasks and the household work, they rarely get support from any of the male family members.

The influence of tradition can also be seen in the exclusion of women from the public market—where men are responsible for buying all household items and for the marketing of farm products (UNIFEM/UNDP 1992; UNU/Wider 1990)—and the restriction of women in traditional rural societies to the compound and the extended family. In this study, evidence was found to support this; women reported they would go to the market about once a year, only to buy clothes and cloth.

A study by UNESCO on women in agriculture in the Middle East describes a similar situation in other countries of the region. According to the study, boys take on labor responsibilities much later than girls, because the girls' help is needed in the household at an early age (UNESCO 1985). Another study on Pastoral Women and Change in the Middle East criticizes the general lack of recognition of women's contribution in the agriculture of the region; the role of young girls (under 15) in farm and off-farm activities is also often underestimated (UNIFEM/UNDP 1992).

Gender division of labor in selected periods

Because hand-feeding, milking and moving are labor-intensive, they were selected for study of the division of labor and daily time allocations more specifically.

Hand-feeding period

The majority of women and girls in all three farming systems report hand-feeding as their main activity during this time of year. In addition, women and girls carry out all household activities. In 10 percent of the farms, men and boys also report hand-feeding as their main activity (Fig. 1-a). The majority of men are not involved in agricultural activities during this period, however, and have extensive leisure time (60–90 percent). They spend their time socializing as well as organizing the food, water and fodder supply for farm and family. The main activity of boys during this period is the herding of flocks.

During the average hand-feeding period of five to seven months per year, women and girls spend two to six hours per day on this activity (Table 3). Households with higher numbers of sheep, in the transitional and pastoral systems, require longer hand-feeding times. The time needed per day is influenced by the number of household members that help with the feeding, amount of grazing, feeding management and amount and mixture of fodder. The hand-feeding frequency per day is higher in systems with smaller flock sizes, though the total time spent in this activity is lower than with larger flocks.

Table 3. Womens' labour data for the hand-feeding period in agricultural year 1991/92 in the three farming systems (means and standard deviations).

Hand-feeding season	Permanent	Transitional	Pastoral
Length of hand-feeding season in months	4.6 (SD=1.8)	5.8 (SD=2)	7.1 (SD=2.3)
Hand-feeding time per day (min.).	124 (SD=58)	165 (SD=60)	252 (SD=100)
Median of hand-feeding time per day (min.).	100	150	240
Minimum/Maximum time per day (min.).	60–240	120–300	120–480
Hand-feeding frequency per day.	3.7 (SD=1.2)	3.5 (SD=0.7)	2.4 (SD=0.6)

Milking period

Women in all three farming systems are responsible for milking and milk processing; in more than 70 percent of the farms, girls help the women with these activities (Fig. 1-b). In the transitional systems, men and boys also help the women with milking the sheep—they divide the flock into groups of about 20 sheep. This parting of the flock is only necessary in larger flocks, and is therefore usually done only in transitional and pastoral systems. The majority of men are not involved in any particular activity except provisioning the farm and household and marketing the products. In about 10 percent of farms in the permanent and the transitional systems, men are mainly occupied with the cereal harvest and off-farm activities during this period. In 20, 35 and 10 percent of farms, in the three farming systems, respectively, the main responsibility of boys is herding sheep. In about 50 percent of all farms however, boys have no responsibilities during this period.

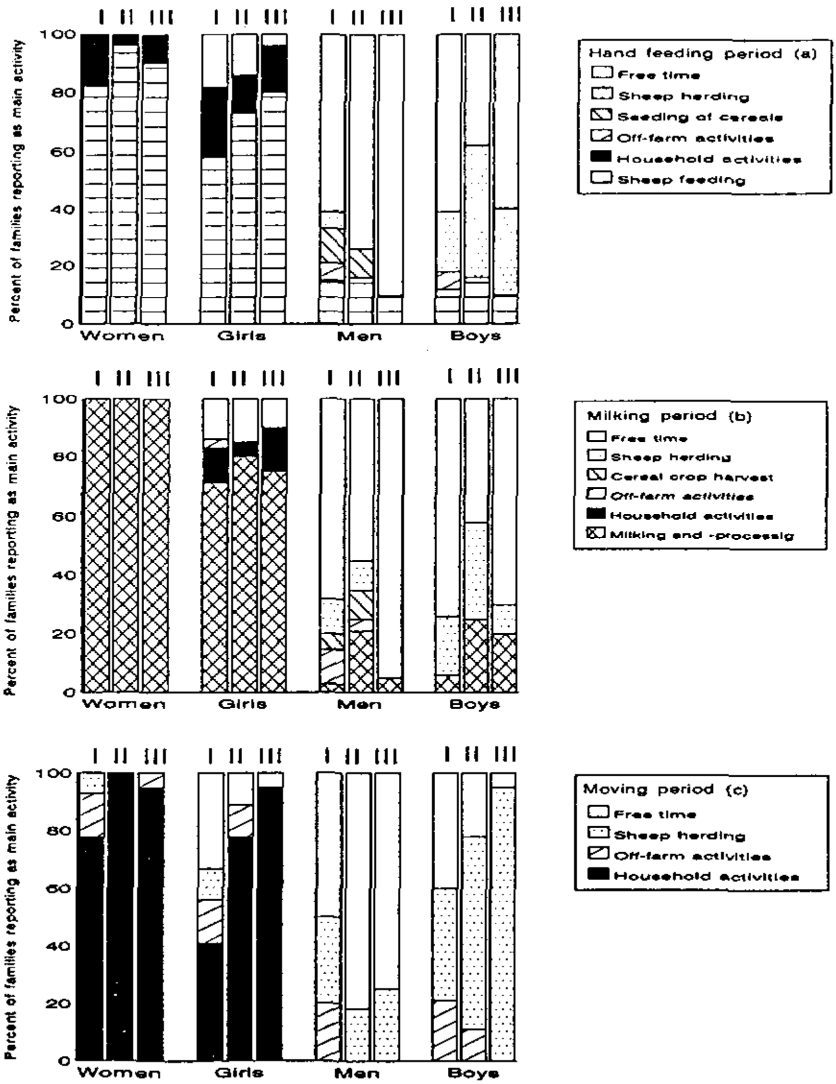
The length of the milking season varies from three to four months. The time needed for milking and milk processing per day is not highly correlated with the number of ewes that are milked (r=0.39). The median of milking time per day in the permanent system, with smaller ewe numbers than in the transitional and the pastoral system, is three hours, compared to four hours in the other two systems (Table 4). The relation between milking and processing time and number of ewes is influenced by the amount of unprocessed milk that is sold, the number of women in the household and the lactation of ewes. In all farms of the three systems, the ewes are milked twice a day. Milking takes about one third of the total time and processing takes two thirds. After milking, the milk is boiled and processed into yogurt, cheese and ghee.

Table 4. Labor data for the milking period in agricultural year 1991/92 in the three farming systems (means and standard deviations).

Milking season	Permanent	Transitional	Pastoral
Milking period in months	3.5 (SD=1.1)	3.7(SD=0.8)	3.8(SD=1)
Milking time per day (min.)	206(SD=60)	270(SD=90)	250(SD=78)
Median milking time per day (min.)	180	240	240
Min/Max time per day (min.)	120/360	120/420	120/420
Milking frequency per day	2	2	2

Moving period

The most important activity during this period is herding the sheep; this is mainly the boys' responsibility. In 20–30 percent of farms, however, this is done by the men (Fig. 1-c). In 12 percent of the permanent system households and in 30 percent of the transitional system households, a shepherd is hired for the duration of the moving period. In the permanent system there are a few households in which women or girls are responsible for herding the sheep; these were households where male members are working off-farm during this period.



Source: PAPE 1994.

Figure 1a–c. Female responses to questions on main farm and household activities carried out by household members in the permanent (I), transitional (II) and pastoral farming system (III), agricultural year 1991/92.

Labor constraints from the women's perspective

According to the women, the only technical innovation which helps ease their burdens is the tractor. Most families own a tractor or have access to one. It is mostly used for transportation. With the help of a man and a tractor, the shrubs that have been uprooted and collected by the women and girls can be transported back to the village or camp and do not have to be carried home on the women's backs or on a donkey. The tractor is also used to carry water to the house or tent, where it is stored in tanks or wells. The women do not have to walk long distances anymore to bring water to their household. Except for three households that own washing machines and stoves, there were few household appliances used in the sample households.

About half of the women think their workload is higher today, or the same, compared to 20 years ago. They said that this is because of larger herd sizes and increased areas of cultivation, both of which add to their work.

Resource and Income Control

The amount of access women have to resources and control over income-use are other important factors for identifying and understanding gender roles (Feldstein 1993).

In none of the three farming systems did women own any farm land or animals. In the pastoral system, women did not have any control over income or access to the market, whereas in the transitional and permanent systems, 59 and 50 percent of women, respectively, had a small income from the sale of sheep manure, eggs and chickens (Table 5).

Table 5. Average direct cash earnings reported by women for the agricultural year 1991/92 in surveyed households of the permanent and transitional systems.

Sold products	Permanent System Returns in SL per year	Transitional System Returns in SL per year
Manure	1366 (n=20)	1025 (n=8)
Eggs and/or chicken	287 (n=6)	585 (n=2)
Average returns of women's sales per farm and year:	1273 (n=20) min:235, max:3500	829 (n=10) min:35, max:3000

SL= Syrian Lira, 1USD=42 SL; n= number of households

Women spend this cash income on clothes and cloth, pots and other kitchen items—and less frequently on hygiene articles or fruits. The purchase of gold was mentioned only once in the sample of 74 households.

Women's views on income control by men

In the pastoral system, 90 percent of the women reported being satisfied with the way the men spend the money. In the permanent system though, 28 percent of the women criticized the men's income control, complaining that men spent the money on themselves and did not contribute enough of it to the household. Women want men to spend more money on kitchen devices, clothes and medical care. Earning money off-farm seems to have enhanced the women's desires to control more of the money they earn.

Farm level decision making

Supplementary feeding

Labor division analysis shows that, in 90 percent of farms, women (with help from girls) mix the fodder and hand-feed the sheep. In 12 percent of farms this is done by male household members. There is obviously a difference between carrying out an activity and having the responsibility and deciding how it is carried out. In 30–40 percent of cases, women carry out these activities, but men direct them (Table 6). In 50–60 percent of the households, however, women do this activity under their own direction. The off-farm activities of men and their related part-time absence from the household influence the degree of responsibility and decision making possibilities for women. If, through the involvement of men in off-farm earning activities, the responsibility for deciding the amount and mixture of feed increases for women, it becomes more important that women have access to information on feeding management.

Table 6. Household member who decides about the amount and mixture of supplementary feed stuff in sampled farms of the study area.

Decision making household member	*Permanent*	*Transitional*	*Pastoral*
Women	59%	60%	50%
Women if men work off-farm	18%	5%	5%
Men or oldest son	20%	30%	40%
Shepherd	3%	5%	5%

Milk processing and marketing

The main products processed from milk are yogurt, cheese and ghee (clarified butter). The main marketed livestock product (except for lambs) in all three farming systems, is cheese. The sale of milk and milk products is organized by men. They transport the cheese and other products to a cheese dealer in the city every two or three days during the milking season. In the pastoral system, some farmers sell their milk to mobile cheese makers who set up operations near Bedouin camps. The preferences of women in selling unprocessed milk is reflected in Table 7. More than 50 percent of the women would prefer to sell the milk unprocessed, and only 19 and 30 percent, respectively, believe that it is more profitable to sell milk products.

Table 7. Women's opinion on milk versus milk product sale in sampled households of the study region.

Women's answers	Permanent	Transitional	Pastoral
Would rather sell milk unprocessed.	59%	71%	50%
Selling milk products is more profitable than selling milk.	-	19%	30%
Do not sell anything because amounts are too small.	15%	-	-
Sell milk only.	26%	10%	20%

Future Development of Farming Systems and Implications on the Role of Women

The small herd size and cultivated area of farmers in the permanent system lead to many family members seeking employment off-farm, and a more sedentary lifestyle that increases women's workload and responsibilities. It also gives women the opportunity to go to the market, and thereby control some of the household expenditures. In all three farming systems, it is mainly the women who are responsible for fodder mixing and hand-feeding sheep. Their expertise and practices should be considered in research and extension efforts to improve flock feed management. To ease women's workloads during the milking season, the milk marketing system should be improved. Agricultural cooperatives could be used to organize farmers interested in marketing milk instead of milk products.

The interview technique used in this study (interviewing the women apart from the men) has been very successful in obtaining information and opinions from the women without men's interference. This is an important precondition in creating an open and trustful interview atmosphere and is, therefore, beneficial to the quality of information.

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The Dynamics of the Agro-pastoral Population in the Northern Syrian Steppe

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Introduction

Nomadic Bedouin based in the semi-arid and arid areas of Syria continue to herd livestock, as a lifestyle and a major source of income. However, there have been many changes in these production systems during this century, due mainly to external factors. For instance, the Middle East oil boom has affected Syria, which has become an exporter. Syria has also benefited from the migration of laborers to the Gulf States and the flow of remittances back into the country. Syria is becoming more urbanized: Currently about 50 percent of its population live in towns and cities.

Further, improvements in living standards and in health services have resulted in decreasing death rates. Syria has one of the highest population growth rates in the world, currently estimated at 3.6 percent/year (World Bank 1993). The demand for food is, therefore, greater than ever, and the higher standards of living have especially increased the demand for animal products, particularly meat (Metral 1993).

Sheep are the most important livestock in Syria, and about three quarters of the country's 15 million sheep are herded by Bedouin based in the steppe (Treacher 1993). The steppe, defined here as the area receiving an annual rainfall of less than 200 mm, covers some 55 percent of the country. Therefore, Bedouin production systems are a vital part of the country's economy. Sheep based in the steppe are mostly of the Awassi race, a fat-tailed sheep weighing around 50 kg. The average production for a ewe is just under one lamb, 60 kg of milk (after weaning) and two kg of wool per year (Leybourne 1993).

Sheep numbers have risen dramatically since the early 1960s, when Syria's sheep population totaled three million. This has placed undue pressure on natural grazing resources, resulting in a process of degradation. At the same time, the area under barley cultivation has increased. In drier areas, such cultivation has encroached on land previously used for pasture, contributing to natural resource degradation in three ways. First, grazing pressure has increased on the reduced area of pasture. Second, barley cultivation destroys native vegetation that will not normally regenerate (Thalen 1979). Third, after harvest and grazing of the cereal stubble, the bare land is exposed to wind and water erosion, which further lowers its potential to recover. The only solution then is to continue to cultivate, but with continued cultivation, even with short periods of fallow, yields decline (ICARDA 1982).

Bedouin based in the steppe are mostly semi-nomadic agro-pastoralists. They are considered semi-nomadic because they tend to have a home base, with a house, where they remain for part of the year and cultivate barley. During the remainder of the season they migrate as a family with their flocks to different grazing sources. During the migratory period they live in their traditional black goat-hair tents. Their production systems are centered on their sheep, but recently, in response to change, greater emphasis is being placed on off-farm sources of income.

These steppe-based production systems are dynamic. Despite adverse changes in the system, particularly the rapidly disappearing natural grazing sources, the agro-pastoralists have managed to continue to herd sheep. This paper outlines the dynamics of the agro-pastoral population in the Syrian steppe by showing how the population has responded to change in their production systems, and the problems that have resulted.

Study Area and Methods

We have defined the steppe as the area of land receiving, on average, an annual rainfall of less than 200 mm. This limit is used by the Syrian government to define its driest agricultural zone (zone 5[2]), and thus governmental decisions on land use in zone 5 apply to the steppe.

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[2] Due to the range and variability of rainfall levels in Syria, a number of zones have been classified by the Ministry of Agriculture and Agrarian Reform to determine the type of agriculture permitted in each zone. Five Agricultural Stabiltiy zones have been identified, the first being divided into two sub-zones. They are defined as follows:
Zone 1a: Average rainfall over 600 mm.
Zone 1b: Average rainfall between 350 and 600 mm.
Zone 2: Average rainfall between 250 and 350 mm and not less than 250 mm in two years out of three.
Zone 3: Average rainfall between 250 and 350 mm, and not less than 250 mm in one year out of two.
Zone 4: Average rainfall 200 to 250 mm and not less than 200 mm in one year out of two.
Zone 5: Below 200 mm, and covering the rest of the country.

Rain falls mostly during the winter months—November to March—although heavy spring showers can occur in April and May. The climate is semi-arid and arid Mediterranean: the summers are hot and dry; and the winters mild, although snow can fall. The mean minimum and maximum temperatures of the warmest month (August) are about 20° C and 38° C and those of the coldest month (January) are about 1° C and 11° C (FAO 1987).

The steppe is generally flat, with some hill ranges. The natural vegetation is *xerophilous,* and the soils are gypsiferous or calcareous. Other than the Euphrates River, there are no permanent water sources, but after rain, *wadis* may temporarily fill, and there are both government and private wells dotting the 10.2 million ha of steppe. Some of the wells date from Roman times.

Current numbers of the Bedouin, or pastoralists, based in the Syrian steppe are unknown. Various estimates of the pastoral population in Syria include: 400,000 in 1967 (Abdallah 1978); 80,000 in 1970 (Meyer 1982); and 35,000 families in the 1980s (Hopwood 1988). The last census, in 1981, registered 21,000 "nomads" and "semi-nomads," much less than the number registered in the 1970 census, when 225,000 people were registered as being nomadic or semi-nomadic (Metral 1994). The problem of definition is evident here; it seems possible that the two censuses used different definitions. Possibly the 1981 figures do not consider the nomadic population that does not reside permanently in Syria. The Syrian steppe runs into that of both Jordan and Iraq (and down into Saudi Arabia), and there is movement (both official and unofficial) across the borders.

However, the sheep production systems based in the Syrian steppe are fairly homogenous. There are differences in migration patterns, which appear to be tribal (Leybourne 1993), and differences in the relative value of sheep production in an individual family's total income, depending on the amount of land available for cultivation, sources of water, possibility of cultivating irrigated crops, and outside sources of revenue. Nevertheless, the sheep production systems are generally remarkably similar throughout the steppe.

From 1978 to 1981 a survey was undertaken by ICARDA on agro-pastoral Bedouin production systems in three villages of northern Syria

(Thomson *et al.* 1989). One village, Mouhaseneh, is situated just outside the steppe and receives an annual rainfall of about 250 mm. It was first established about 50 years ago. The other two villages are inside the borders of the steppe: Hazm Alsurr (average rainfall about 200 mm) and Bir Amaleh (average rainfall about 150 mm). Both villages have been settled more recently than Mouhaseneh; cultivation first began about 40 years ago.

In 1991/1992 we returned to the same farmers to study changes that had occurred in their production systems in the 10-years between the two surveys. During a 15-month period, each family was visited, on average, once every three weeks. The study concentrated mainly on migration and feeding patterns and on changes in the social organization of the production systems.

Much of the discussion in this paper will focus on the results of these two surveys, but we will also draw on other studies from the marginal areas of Syria.

Changes in the Traditional Production

Most Bedouin in the Syrian steppe were fully nomadic until the 1940s. Some cultivated small areas of land each year, and they all moved in fairly fixed annual migration patterns as seasonal sources of grazing became available. Sheep were already the principle animals herded, as the camel had declined in popularity earlier in the century with the appearance of motorized transport (Lewis 1987).

Pasture lands in the steppe were held under Bedouin tribal control, with access obtained only through tribal rights. Raids and other conflicts for territorial control largely ceased during the French Mandate (1918–1946), during which time the *Controle Bedouin* system was introduced to improve security in the steppe. All movement by the Bedouin had to be authorized by the French authorities. At the same time, land was given to tribal leaders to encourage them to settle. Raids and the *khuwa* system (payment by villagers to the Bedouin in return for protection from raiding) were abolished, and the Bedouin were forbidden access to the cultivated lands at the margins of the steppe (Denis 1989).

In the middle of the 1940s, mechanized cultivation was introduced, and large areas of land came under cereal cultivation. This was made possible through investment from private entrepreneurs, in partnership with the Bedouin, usually tribal leaders. The entrepreneurs provided seed, machinery and capital and the Bedouin received 25–50 percent of the crop, as well as the straw and stubble. After a few years, the tribal leaders were able to purchase their own tractors and plow the land themselves. By 1946 and until 1958, Syrian agriculture was dominated by large property holders and private investors, who actively extended cultivation, to the detriment of natural rangeland. Most of the land in the steppe had been officially classified as *mawat* (literally "dead" or "empty") and by plowing and cultivating it for 10 years, one could claim ownership (Hamide 1959).

In 1958, the Syrian government initiated agrarian reform. Land was expropriated from owners of large tracts and redistributed as small plots to individual families. At the same time, the government abolished tribal law and encouraged sedentarization through Law 166 (1958) which officially proclaimed sedentarization and conformation to civil law by all the Bedouin (Denis 1989).

Until the Bedouin became involved in cereal production, they had remained nomadic. Cultivation fixed them to the land during the periods of sowing and harvest, and their movements were reduced. After harvest, their flocks could graze the cereal stubble, allowing them to remain longer in one place. They began building houses, both to improve the quality of their life and to make a claim on land that had never seen a cadastral survey. In addition, after the agrarian reform, it became necessary to have a house to enable migration anywhere they wished in the steppe.

Soon, villages such as Hazm Alsurr and Bir Amaleh were established deeper in the steppe. Agro-pastoralists based in these areas had land to cultivate, and they were surrounded by natural rangeland, which they exploited.

Degradation of the Steppe

Cultivation and settlement both accelerate the process of degradation. Barley cultivation in the steppe is risky: on average only one year in four will give a good crop (farmer interviews 1992). In the other three years, part of the crop may be harvested, and anything not harvested is grazed *in situ*. Fertilizers are not used, and once land is cropped, it may take up to 15 years for the natural vegetation to regenerate (van der Veen 1964).

Settlement has fixed the pastoralists in one place for extended periods of time. Land surrounding the settlements is heavily used, and pasture land is not given time to recover. The agro-pastoralists usually remain in their villages in the winter, at the beginning of the growing season. As plants germinate on the rangeland, they are grazed off.

Motorized transport has also become an integral part of the production systems. Trucks can be used to transport water, feed and sheep. This eliminated the necessity of grazing near a water source, and means that flocks can be kept on pasture even when there is not enough dry matter available for their needs. Their diets can be supplemented by hand-feeding with straw, grain, bran and cotton seed by-products.

Before 1958, stock numbers tended to decrease in dry years. In wetter years, numbers increased again. From 1958–1961, Syria experienced a period of drought, and the sheep population halved from six to three million. It was during this drought that hand-feeding was introduced on a large scale, and it continued after the end of the drought. Sheep numbers quickly re-established themselves, and an increasing use of supplementary feeding practices stabilized sheep numbers, as well as allowing them to continue to increase. The greatest increases occur during two wet periods: in the 1960s; and in the late 1970s and early 1980s. During the intervening, drier years, sheep numbers tended to stagnate, but they did not decrease as they had before the 1958–1961 drought.

The dependence on sources of feed other than natural grazing has continued to increase, and is one indication of degradation. In 1974, it was estimated that 65 percent of the annual metabolizable energy requirements for sheep in Syria came from natural grazing. Only 10 years later, in 1984, this had reduced to 33 percent (Bahhady 1981). The 1978–81 survey showed that 54 percent of annual ME requirements came from supplementary feeding, and 28 percent from stubble and crop residue grazing. Only 18 percent came from natural pasture grazing (Bahhady 1981; Thomson *et al.* 1989). In 1991/92, natural pasture grazing contributed to only 2.5 percent of the studied flocks ME requirements (Leybourne 1993).

Between 1974–1984, the national flock doubled in size, from six to 12 million. With the decrease in the amount of natural grazing in the flock's diet, we can estimate that within this 10-year period, the amount of biomass produced by the steppe decreased by half. This indicated a process of degradation.

Le Houerou (1972) suggested that in areas with rainfall between 100–250 mm, the stocking rate should not exceed 0.25 sheep/ha. As the Syrian steppe, covering 10.2 million ha, is the base for over 10 million sheep, the stocking rate is less than one sheep/ha.

Barley cultivation has probably been the most destructive force causing degradation in the Syrian steppe, with large areas cultivated down to and beyond the 150 mm isohyet. A particularly large increase in the area cultivated in barley in the late 1980s has left large areas devoid of vegetation.

The Syrian government classifies most of the steppe as rangeland, and has no figures on the amount of land cultivated in barley, as there is a considerable amount of illegal cultivation. However, the evolution in the area of land planted in barley for the whole country gives some indication of the increasing importance of this crop. Increases in the area cultivated each year have come partly from dropping fallow periods, but mainly from the extension of barley cultivation into the drier areas.

In 1950, only 0.3 million ha were cultivated in barley. The area planted in barley increased steadily until the 1986/87 season, with 1.6 million ha. The following year was exceptionally good, climatically, and the barley planted area increased by 18 percent. Following very high yields that year, the barley planted area in Syria increased to 2.9 million ha in 1988/1989 (Cooper *et al.* 1990; FAO 1992).

In 1989, the area planted in barley dropped back to the 1986 level. The 1988/89 season was poor, and most barley was not harvested. But land where barley was once cultivated is now bare, or is slowly being invaded by unpalatable species such as *Noaea mucronata Forsk.* and *Pegamum harmala L.*

The Bedouin do not readily acknowledge that barley cultivation destroys the vegetation, as they link vegetation growth to rainfall levels. This attitude is still shared by some government officials (Masri 1991). In addition, the Bedouin cultivate barley primarily for economic gain. Yields, in a good year, can be very high, and even in a bad year unharvested barley provides very good grazing. Moreover, cultivating the land guarantees the right to graze it, as no-one else is liable to trespass (Leybourne *et al.* 1994). (Note that fallow land or land planted in fodder shrubs is not considered a crop.)

Settlement: A Case Study of Three Villages

A village at the margin of the steppe

The three villages in our study show fairly typical patterns of evolution for steppe-based production systems. Mouhaseneh has a slightly higher rainfall than the other two villages. Like many other villages in the area (Jaubert and Oglah 1985; Lewis 1987), it was settled in the early to mid part of this century. The village was developed on a compact basis, with fields and initially pasture land lying around the core group of houses. All the land is now cultivated, and no pasture land remains.

Until the mid-1980s, families still migrated into the steppe with their flocks, but reductions in available grazing have stopped this movement, and flock sizes have tended to decrease. At Mouhaseneh, the average flock size decreased from 100 to 48 sheep per family in the 10 year period between 1981–1991.

Production systems are now mostly crop based. Some villages have access to sources of water and concentrate on irrigated agriculture. In others, some members of the family work off-farm. At Mouhaseneh there is no irrigated agriculture, but all families in the study had members working outside the village on a part-time basis.

Families in these villages have therefore diversified their systems. They are more settled, and their family income is from a variety of sources: cultivation (rainfed and/or irrigated), off-farm employment (locally, for example on government farms, or through migration) and sheep production, which is now primarily for family consumption, with only the excess sold.

Villages deeper in the steppe

Hazm Alsurr and Bir Amaleh, like other settlements deeper in the steppe, have developed more recently. The houses are much more scattered, with barley fields and natural pasture lying between small groups of dwellings or individual houses.

Families settling in these areas began cultivating barley while they still lived in tents. When they began building homes, for some families it was the first time they had lived in a house; during the 1980s, homes were constructed on their own cultivated land, rather than grouped together.

Flock sizes are becoming larger. In the sample group, the average flock size was 229 in 1992. This was a slight decrease over the 1981 value, due to a series of dry years from 1989–1992, when flock sizes were reduced. The families rely, much more than in villages such as Mouhaseneh, on sheep for their income, and off-farm employment is less common, although a young man may leave for a season to earn enough money to be married or to build a house.

Losses of natural grazing have particularly been felt by agro-pastoralists in these villages. The situation is more critical for them, as they cannot rely on cultivation (too dry). Moreover, off-farm income is less accessible (unless they migrate to work) as one moves further away from the towns. They have been forced to adapt their production systems towards more profitable sheep raising. It is this dynamism that we will examine in the next section.

The dynamics of the Pastoral Population

The pastoral population in Syria has shown a remarkable adaptability to changing conditions in their production systems. After mechanized agriculture was introduced in the 1940s and 1950s, the Bedouin quickly began cropping the land and using motorized transport to move around more quickly. Sheep, water and supplementary feed were easily transported, opening up the possibility of greater exploitation of pasture lands. Tractors or pickups were used to scout for new pasture land, or to negotiate with landowners for grazing rights. Today, if there is an opportunity to sink a well and undertake irrigated agriculture, the Bedouin will do so, despite their reluctance, before the 1940s, to become involved in any form of crop agriculture (Lewis 1987).

The traditional camel herding tribes, such as the *Aneza* and the *Sham-*

mar, also quickly converted to sheep herding when it became more profitable (Chatty 1974; Lancaster 1981; Lewis 1987), despite the earlier stigma attached to sheep herding. Bedouin tribes had always considered camel herding more "noble" (Khaldun 1967).

However, the pastoralists have shown the greatest dynamism in their adaptability towards their migratory cycles. We have already seen that natural steppe grazing is no longer an important part of the flocks' diet. By the end of the 1970s, sheep at Hazm Alsurr and at Bir Amaleh were remaining in the steppe for large parts of the year. The families had become fairly sedentary, staying in the steppe from autumn, when barley was cultivated, until the end of spring or early summer. During the early part of winter, the flocks remained in the villages and were hand-fed. At the end of winter and in spring they would graze natural pasture near the villages or farther out in the steppe. Their diets were strengthened with supplements when grazing was not sufficient.

After harvest at the end of May, the flocks grazed the stubble. Then people and animals would move out of the steppe for the summer and early autumn, usually moving on a tribal basis, heading for higher rainfall areas to graze rented stubble and crop residue. Flocks from Hasm Alsurr tended to move to the Breda area in the western part of Aleppo Province, and those from Bir Amaleh to El Bab, north of Aleppo. This meant that the families were moving less than five times a year, and lived in the steppe for much of the year, mostly in their own houses.

The trend towards sedentarization is evident in the construction dates of their newer buildings. In 1988 there was an increase in the number of buildings at both Hazm Alsurr and Bir Amaleh. Families added rooms to their houses and constructed separate feed stores, particularly at Bir Amaleh. The harvest in 1988 had been especially good, and they could afford to construct new buildings.

But by the beginning of the 1990s, the Bedouin had once again become more mobile, spending very little time in their villages. Following 1989, a series of dry years produced very little vegetative growth. Natural steppe pasture was unable to sustain the sheep, and supplementary feed was offered. However, the period in the steppe was reduced, and alternative sources of grazing have been found. This has transformed the migration patterns. The Bedouin from Bir Amaleh are spending longer periods of time in the Aleppo Province near El Bab and Deir Hafer, and those from Hazm Alsurr have begun moving to the Mediterranean coast in large numbers.

The major difference in the migration patterns is the new direction of movement out of the steppe. In the past, most of the movement was directed into the steppe. In addition, some Bedouin are attempting to establish new bases outside the steppe. Those from Hazm Alsurr from the Haddiddiin tribe have long-standing relationships with villages in the Breda area. Many families from Hazm Alsurr now have second houses there, and tend to spend more time in these second villages than in the past.

They also spend much time on the Mediterranean coast. Some stay the whole winter there, with their sheep grazing mountain pasture as well as receiving supplements. The families are then in a favorable position to negotiate grazing rights on plots of irrigated vegetables as they become available in late spring and summer, by which time there is an influx of Haddiddiin to the coast, and grazing prices increase with the rise in demand.

The decision of when to go to the coast depends on alternative sources of grazing near the family's village. If the family has planted a large amount of barley, it tends to remain near the village to take advantage of stubble grazing before moving to the coast.

The Bedouin from Bir Amaleh, from the Wahab Tribe (the Shammar Confederation) have relationships with people living in villages near El Bab. In fact, the Sheik, Haj Awad Morai, has recently constructed a second house at Bouhedji in the El Bab district. The Bedouin now spend the summer there, renting the fields of cereal stubble for grazing. In the autumn they move to Deir Hafer and rent irrigated crop residues. This grazing source has become more available since 1986 due to a Syrian government irrigation project channeling water from the Euphrates River.

When the sources of crop residue dry up in early winter, many Bedouin opt to remain near Deir Hafer for the winter, rather than returning to Bir Amaleh. The men will go to Bir Amaleh for a few days to plant barley, but otherwise the families try to remain in the irrigated areas if possible.

They are nearer to the market (where they buy supplements) so their transportation costs are reduced. In addition, there is no need to truck water.

In 1992, one group of Bedouin from Bir Amaleh constructed a small feed store on the land where they were camping. This was an effort to claim the land as their own, even just for camping purposes. It also helped them claim priority over the grazing of irrigated crop residues in the two villages nearby. The roadside land they camped on was next to a village.

Not only are feed sources changing, but also the types of feed, particularly supplements. In 1991/92, barley grain—the preferred supplementary feed—was SL 10/kg (about .22 US$). It was the most expensive feed, so the Bedouin did not use it. Rather, they switched to wheat bran and bread, both of which were around SL 5/kg. Despite these changes, they managed to maintain adequate dietary balances in crude protein and metabolizable energy levels (Leybourne 1993).

They will also buy other types of feed if the prices are competitive. Sheep have been fed potatoes, sugar beet roots and chopped residues from peanut crops.

Migration Incentives

The cost of feed is the major factor pushing the Bedouin to revert to a more nomadic existence. Supplements as the sole source of feed is the most expensive means of keeping a flock, particularly in the steppe when all feed and water has to be trucked in. However, natural pasture grazing is the cheapest feed source—it is free. This explains why the Bedouin utilize it at every opportunity.

In 1992, residue from irrigated vegetable crops was one of the cheapest sources of feed. This is why the Bedouin from Hazm Alsurr migrate to the coast in the summer. The cheap feed source compensates the cost of transporting the sheep to the coast. Cereal stubble is also inexpensive, while the grazing of residue from irrigated cotton crops is the most expensive feed source after supplements. In 1992, the cost was SL 6000/ha (about 140 US$). This amounts to about SL 6/sheep/day, as one hectare of cotton residue provides a grazing off-take of about 1000 days. However, cotton residue is still cheaper than supplements, which cost, on average for surveyed flocks in 1992, SL 6.3/sheep/day (SD 1.7).

Although the feed cost is the most important factor in deciding where to graze, there are other factors, such as access. The Bedouin from the two villages move to different areas, although their feed sources are similar. The only Bedouin tribe found at the coast is the Haddiddiin, yet the feed there is cheaper than in Aleppo Province. The reason is due to tribal affiliations. Although pastoral families now migrate more individually rather than in family groups, they tend to retain tribal links. Members of other tribes have no affiliations on the coast. The cost of trucking a flock to the coast prohibits such a move unless grazing can be guaranteed.

Sometimes the cost of the feed is not considered. Some families choose to move into the rangeland early in the season, before there is any vegetation growth. It costs them much more to transport feed and water, but they rationalize that they are able to take immediate advantage of any available grazing. They may also opt to remain in the steppe during the summer. One family we studied in 1992 preferred hand-feeding to moving its flock onto irrigated cotton residue, despite the increased cost, because he feared health problems in his sheep from irrigated land. There was no evidence to support his argument, but he made his decision on this basis.

Consequences of recent changes in the production systems

Production systems now rely more on purchased and rented feed sources, which increase production costs. In 1991/92, 58 percent of sheep production expenses in the surveyed group was for supplements, and a further 16 percent for grazing fees. Transport claimed five percent, mostly incorporating the transport of feed and water to the steppe (Leybourne 1993). Thus the systems rely heavily on purchased feed sources and cheap fuel, as diesel is subsidized by the Syrian government. In 1992 it cost SL 4/liter (0.10 US$). The Bedouin also expect to cultivate barley in the steppe, both for potential economical benefits and to secure grazing. However, land is degrading and the government is beginning to prevent cultivation. Prices are increasing, including that of diesel, which had increased by 50 percent to SL 6/liter by mid-1994.

Increasing migration out of the steppe is reversing the process of sedentarization (D'Honte 1991). While it could be argued that the pastoralists should perhaps not have been so enthusiastically encouraged to settle, the reversal of the process of sedentarization can have adverse effects on their production systems and their lives. When settled, schooling is made easier. The Syrian government has a mobile school system, where a teacher will live and teach out of a caravan. He follows groups of Bedouin during their migratory cycle. But not all groups are catered for; the system is difficult to manage and teachers are generally unwilling to undertake the work (teacher interviews 1992). In addition, Bedouin groups tend to be much smaller, with many families migrating alone. These children simply do not attend school.

Health services are also rendered more difficult. Living conditions in a tent can be more difficult than in permanent housing.

As the Bedouin spend longer periods outside the steppe, they attempt to establish a base in more favorable areas, such as the feed store near Deir Hafer. This may eventually cause conflict between the Bedouin and the local inhabitants, who may see it as attempts to invade their land. They may begin to refuse grazing rights on their crop residues. A trend has already developed in some parts of northern Syria where farmers burn their cereal stubble rather than rent it out to the Bedouin. They claim that the Bedouin allow their sheep to wander onto unharvested crops at night. If this trend continues, there may eventually be a shortage of available grazing, and rents will increase, adding to sheep production costs.

Such a phenomenon has already occurred on the Mediterranean coast. In the 1980s, before movement to the coast by the Haddiddiin had accelerated, vegetable crop residue grazing was free. Farmers living on the coast welcomed the Bedouin, who cleared their land for free, as well as adding organic fertilizer from sheep manure. During the peanut harvest, the Bedouin were paid for their labor and received the residue free as feed.

By 1992, competition for grazing rights was so great that the Bedouin were paying up to SL 2500/ha (US$ 60). They were also harvesting peanuts for free.

Pressure will not ease on the pasture lands. When the Bedouin leave the steppe, the land they normally use is not protected. Trespassers may allow their flocks to graze what is available. As the Bedouin remain outside the steppe for longer periods of time, more trespassing may occur. This limits the possibility of rehabilitating the degraded vegetation through the replanting of fodder shrubs such as *Atriplex* spp. The Syrian government began a program of research and fodder shrub plantation establishment in 1973 (Sankary 1978), and in 1983 began distributing seedlings to the Bedouin with barley cultivation licenses in the steppe. However, most of the private plantations failed. One of the main reasons cited was trespassing (Leybourne *et al.* 1994).

Conclusions: Where Do We Go From Here?

The pastoral population in Syria has shown dynamism in its sheep production systems in the steppe. Agro-pastoralists adapt themselves to changes beyond their control, such as political decisions, technical advances and population growth, as well as the problems of environmental degradation. However, their systems are also causing further degradation through barley cultivation and increasing numbers of animals. They are being forced into becoming more nomadic, which is creating a number of new problems, and their systems now rely heavily on purchased feed and rented grazing, as well as subsidized fuel. Off-farm income is also increasingly being used to make up short-falls in Bedouin family revenue. What will happen to their production systems in the future? How will the agro-pastoralists adjust to changes in subsidies and the decreasing amount of land able to be cultivated, plus the ever-decreasing amount of natural grazing available? How can the process of environmental degradation be halted in the Syrian steppe, and how can the agro-pastoral production systems become sustainable?

—Marina Leybourne

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The Extension of Barley Cultivation in the Arid Zones of Northern Syria

Introduction

Barley is one of the most important forage crops in the steppe-based sheep production system. As with grain and straw, it provides winter supplementary feed. After harvest, its stubble can be grazed; barley stubble is the principle grazing source during four months each summer for steppe-based flocks. Finally, barley can be grazed—in the higher rainfall areas—during the growing phase (Mazid and Hallajian 1983), or, in the drier areas in a bad year, as a standing forage crop.

Greater areas of Syria are being cultivated in barley (FAO 1992), which is both a cause and a result of degradation. In arid areas such as the steppe, barley cultivation causes soil degradation and wind and water erosion (Thalen 1979), but the agro-pastoralists also resort to cultivation to claim grazing rights and gain some profit from the land. This increases their dependence on barley production.

There are no accurate data available on the extent to which barley has encroached on the natural grazing areas of the steppe. There appears to be a decreasing amount of rangeland available, and this is, perhaps, primarily due to the extension of barley cultivation.

The cultivation of barley in Syria as a whole has expanded since 1950, when the barley area was 0.3 million ha. There is a strong correlation (Spearman's Correlation Coefficient=0.84) between the year and the area planted to barley, using the figures from 1960–1990. The area sown to barley had increased to about 1.55 million ha by 1986/87. In 1988, following an exceptional harvest, there was a further 18 percent increase. Increased barley cultivation has come from new cultivation, but also from the dropping of fallow periods in the cereal rotation.

A pilot survey was undertaken in spring 1994, in the northern Syrian steppe about 100 km southeast of Aleppo (from N 35°46' E 37° 44' to N 35°30' E38°02') to examine the following questions:

- To what extent has barley cultivation encroached in the steppe? What percentage of the land is now permanently cultivated in barley?

- *How great a role does opportunistic* cultivation play? How much land has been cultivated for one or two years and then abandoned?
- How do agriculturists in the steppe decide what areas to plant each year? Who cultivates the land, and who pays for its cultivation? Who profits?
- Why do the agriculturists plant barley? What are the alternatives, and which would be acceptable to them?
- How have yields changed over time?

Study area and survey methods

The study area is located in an area called Hazm Alsurr in the Aleppo Province. Most inhabitants in the area come from the Haddiddiin tribe (Bedouin), which is divided into a number of sub-tribes. The two main sub-tribes in the study area are Tweimaat and Bou Kurdi. A couple of other tribes are represented, such as the Adwan (from Nejd) and the Heb.

The climax vegetation in the study area is dominated by *Noaea mucronata*, which is called *surr* in Arabic (from which comes the name Hazm Alsurr, meaning literally "a package of *surr*").

Hazm Alsurr was chosen as the study area for two reasons. First, a satellite image was available of the area, and second, Hazm Alsurr is one of three villages extensively studied by the author in 1991/92 (see Leybourne 1993). It had also been part of an earlier ICARDA survey from 1978–1981 (see Thomson *et al.* 1989).

The field work for this research project was divided into three phases. An initial survey was carried out on a number of families. This was followed by a vegetation and land-use mapping exercise of the study area. Finally, a second formal survey was undertaken after harvest in late spring. In total, 25 families were surveyed.

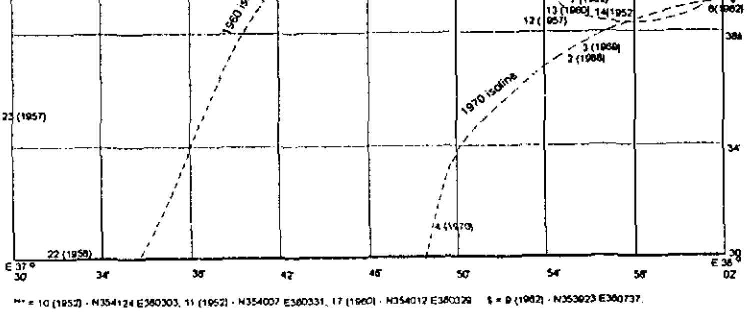
The vegetation/land-use map was done with the aid of a false color satellite image dated April 1991, and a GPS (Global Positioning System). The satellite image was used as a starting point to determine areas of interest to visit, as it showed three clear areas with different land-use patterns. The longitude and latitude of surveyed locations (barley fields and vegetation locations) were recorded.

For the third phase of the study—the second formal survey—the satellite image included coordinate points, which helped locate barley fields for the survey. It had been planned to survey sites along the NW-SE axes of the image perpendicular to the isohyets, but the location of farmers proved difficult since in the study area, the 1993/94 season was dry. Many families had left their bases early with their sheep flocks. (Survey results showed that even among families who remained in the steppe the whole spring, little barley was harvested).

Results

Barley cultivation

The location of each sample site is given in Map 1, showing the approximate isolines of the front of barley cultivation. Areas of early cultivation (sites 6, 7, 14 and 15) are located around the center of the village of Hazm Alsurr, where settlement in the study area first began in the early 1950s. Barley cultivation first began in 1952, with 1960 (SD 8.9) the mean year among the study group. The median year is 1958.



Map 1. The location of each surveyed location, with isolines of approximate cultivation fronts.

Combine harvesting began in the study area in the 1950s, when barley was first cultivated, but families who began cultivation in the 1960s generally reported that they hand harvested until 1970 or 1975. Hand harvesting still takes place in dry years, unless barley growth has not been adequate for any harvesting at all, and is grazed off. Only 20 percent of the study group harvested barley in the 1993/94 season, and many families reported that they had had no harvest since 1988.

The stubble, or the whole plant if the crop is not harvested, is always grazed, either by the family flock, or rented out to other herders. Only one sample reported having burned stubble.

Nearly half those surveyed (43 percent) said yields had been decreasing since the land was first cultivated. The remainder said there had been no change. Of those who said yields had been decreasing, all but two attributed the problem to changes in rainfall levels. The two remaining stated that "the land is tired" and that "the blessing of Allah is weaker."

Villages were first established in the study area in the 1950s. Families settled and built houses to claim land and cultivate barley. In the early 1960s, there was a large extension of barley cultivation by people coming from outside the steppe to cultivate by tractor. They formed a partnership with Bedouin families settling in the area, who received 20 percent of the harvest in payment for providing the land. Interviewed families commented that this partnership helped develop their agriculture, as, after three or four years, they were able to afford their own tractors and cultivate the land themselves.

However, some areas first cultivated in the 1950s and 1960s are no longer cultivated. Some of these plots were surveyed during the vegetation/land-use field work phase, and they were generally barren of perennial vegetation (as the vegetation/land-use survey took place in January, it was too early for much annual vegetation to be visible). Families interviewed stated that it was better for them to cultivate new land, rather than try to obtain yields from land previously cultivated, as there was less risk of crop failure.

More land was cultivated in 1988/89 than in earlier years. Some families reported that the cultivated area in their village doubled from 1987/88 to 1988/89, before diminishing again the following year. This corresponds with the trend shown in the FAO barley cultivation figures for Syria. Furthermore, the field survey of land use showed many areas of land that had previously been under cultivation, but that had not been cultivated for at least three or four years, even in the *wadis*. This may also be due to the spate of dry years.

While barley cultivation is not restricted to *wadis*, in areas where natural rangeland still dominates, only the *wadis* are cultivated. This is particularly visible to the southeast of the study area. Some of the families surveyed reported illegal cultivation practices.

Vegetation/Land-use Map

Table 1 gives a description of the types of vegetation and land use for some of the surveyed sites in the study area. Most of the land showed no annual vegetation (although the vegetation/land-use survey was largely carried out in the winter, when annuals may not yet have germinated). Much of the land was also devoid of perennial shrubs as well, except in areas where *Noaea mucronata* was the dominant species. *N. mucronata* is an unpalatable shrub, and tends to invade degraded areas when everything else is grazed down.

Many of the sites surveyed showed evidence of recent grazing (fresh feces) and there were many flocks present in the study area in January, despite almost no vegetation for grazing. (The flocks were being hand-fed with supplements.)

One pastoralist had moved his tent onto the rangeland to wait for rain, after which the annuals would grow. He was already there to take immediate advantage of any growth. In the meantime, his flock was picking at anything visible.

There are a large number of permanently abandoned houses in the study area. Some families have moved north and west to farm irrigated land. In fact, according to the families interviewed, one of the major problems at Hazm Alsurr is the lack of an adequate water supply. Most water must be trucked in. There are some wells, but most are rainwater collectors. Others have dried up, and some villages have no wells at all.

Analysis of vegetation in Table 1 shows that land near the settlements tends to be more degraded than land away from the settlements. The land is either degraded through cultivation, or through overgrazing; rangeland near settlements tends to be used more intensively. To the southeast of the study area there are few settlements, and the rangeland, although dominated by *Noaea mucronata*, is in a better condition generally.

Table 1. Location and description of some of the surveyed sites*

	Site	Location	Area Description
1	N 35 32 48	wadi	Good ground cover with *Anabasis hausknechtii*. Some land cultivated earlier lies just outside the wadi.
2	N 35 34 18	sev. km^2	Degraded rangeland. Only *Noaea mucronata* in evidence. A wadi was cultivated in 1992.
3	N 35 34 37	sev. km^2	Degraded rangeland, *N. Mucronata* and *Haloxylon articulatum*.
4	N 35 35 14		Forage and watering point. On one side of the road, old cultivation invaded by *N. Mucronata*, on the other side, very degraded rangeland, almost 100 percent *N. Mucronata*.
5	N 35 35 26	sev. km^2	Rangeland in good condition, with *N. mucronata*, *H. articulatum*, *Pao bulbosa* and *Carex tenophylla*.
6	N 35 35 52	crossroad	Four different types of vegetation cover converge at this point: Unharvested barley (June 1994) which grew to only 30cm in height; degraded rangeland; land cultivated in barley in 1992 (not in 1993) with just furrows; land cultivated in barley in 1992 showing some barley regrowth and a lot of *N. mucronata*
7	N 35 36 19	25 ha	Cultivated in barley in 1992. Flat land. Not cultivated in 1993, but barley regrowth evident. Possible crop.
8	N 35 37 04	low ground	*N. mucronata*-dominated rangeland in good condition, with a large patch of *Filago pyramidata*.
9	N 35 37 28		A small patch of rangeland, dominated by *Noaea mucronata* but in very good condition (annuals and good cover), surrounded by degraded rangeland.
10	N 35 38 27	wadi	Cultivated in the past. No furrows remaining, no ground cover.
11	N 35 38 42		Totally degraded stony rangeland. Three wadis nearby. One cultivated in 1993, one in 1992, one uncultivated.
12	N 35 38 50		Very degraded rangeland with no perennials: no ground cover at all (apparently never cultivated).
13	N 35 38 51	wadi	Cultivated in the past. No furrows remaining, no ground cover except some sparse *N. mucronata*.
14	N 35 38 58	100ha	Degraded and overgrazed rangeland (fresh feces present, Jan 1994) and firewood collection evidence (uprooted shrubs). Main species *N. mucronata*, but there is some very degraded *Achillea fragrantissima* and a little *C.*

	Site	Location	Area Description
			tenophylla.
15	N 35 39 01	40ha	Old *Atriplex* plantation. No *Atriplex* species present. About 30 percent ground cover, mainly *N. mucronata* and Artemisia herba-*alba*, with some *Achillea fragantissima* and Girgensohnia oppositifolia.
16	N 35 39 17	80ha	Very degraded rangeland with about 25 percent ground cover. New feces present. Plant species: principally *N. mucronata*, with some ,*G. oppositifolia Onobrychis* spp., *A. fragantissima* and *Sisymbrium septulatum*.
17	N 35 39 17	wadi	Mixture of land uses. Mostly land cultivated in 1992 (and badly invaded by rodents, av. 1–2 holes/m^2). Some land cultivated in 1993, and some land cultivated earlier and re-established as rangeland, having been invaded by *N. mucronata* and some *G. oppositifolia*.
18	N 35 39 37	50ha	Land first cultivated in 1960, now rangeland. Has not been cultivated since the 1960s. Fresh feces present, almost no perennial (only a few *N. mucronata*). Also some *P. bulbosa* and *Sirato falcatos*, but very overgrazed.
19	N 35 40 12	village	Area surrounding village (16 scattered houses) is a mixture of 1993 barley and fields cultivated in the past. No perennial at all.
20	N 35 40 37	village	Two abandoned houses, surrounded by stony rangeland.
21	N 35 41 11	20ha	Two Atriplex plantations, one with *A. canescens*, the other a mixture of *A. canescens*, *A. halimus* and *A. nummularia*. All the leaves are falling off the shrubs, which are in very good condition. There is no ground cover (recently been grazed).
22	N 35 41 17		Stony rangeland, slight hill, with some 15 settlements (1–3 houses) surrounding it, many abandoned. No vegetation.
23	N 35 41 47	village	Small village surrounded by totally degraded rangeland. Some barley in a wadi.
24	N 35 42 00	village	Totally abandoned village. A second abandoned village lies about 2 km away. The people from the village still cultivate here, but have all moved to the Meshaneh area to farm irrigated land.
25	N 35 42 01	1 ha	Barley cultivated in a wadi with rows of transplanted almond trees.
26	N 35 43 39	village	Three empty houses, but they are well-constructed, one with a garage and roll door. Barley is cultivated all around the village.
27	N 35 44 00	village	About 20 houses, although about half are abandoned. Most of the land around the village has been cultivated in the past (not recently).

* Not all surveyed sites are listed in this table.

Discussion

The extension of barley cultivation has been characterized as an encroachment into the natural grazing areas of the Syrian steppe (Jones 1993:135). The argument implies that barley cultivation is not suitable to conditions in the steppe, and tends to lead to soil and vegetation erosion (Thalen 1979). Climatic conditions in the steppe, particularly rainfall, are highly variable, and this has a high impact on productivity (Dennett *et al.* 1993). The average annual rainfall is under 200 mm, and the coefficient of variation can be as high as 45–50 percent (Sanlaville 1993).

According to Thalen (1979), the period of pre-mechanization nomadic cultivation which took place was harmless, due to the small area involved and the primitive equipment used—which did not plow deeply into the soil. Many of the deeper rooted shrubs survived and later sprouted.

Observations of a small field (tractor plowed in 1960) on the edge of a Syrian steppe flood plain, with 150 mm annual rainfall, showed that four years later (three years of above-average rainfall) the grazing value of the land was still extremely poor. It was estimated that it would take between five and 15 years for the natural vegetation to regenerate—if the land was not grazed (van der Veen 1964). This argument has been largely borne out by this year's research, as large areas were surveyed that had not been cultivated for many years—in many cases since the 1960s. The land has remained void of vegetation cover, or has been invaded by *N. mucronata.*

Therefore, once an area has been plowed, the land needs to be cultivated, or left for long periods to regenerate, as sheep numbers have increased markedly (for Syria, the sheep population has increased threefold, to around 15 million in the past 30 years—FAO 1992). However, continued cultivation results in declining yields (ICARDA 1982).

Nearly 50 percent of those interviewed said yields had declined, and that on average, a good harvest tended to occur only once every four years. Several families commented that they had not harvested any barley since 1988. During visits to the study area in June 1994, a number of unharvested fields were observed.

With declining yields and the high risk of crop failure, why do the agro-pastoralists cultivate barley? In fact, they do so primarily for economic gain. In a good year, with abundant and timely rain, yields can be high and profits good. Significant barley production from annual rainfall as low as 150 mm is not uncommon; barley has an inherent capacity to be productive in marginal environments (Jones *et al.* 1993). While the crop may only be harvested once every four years, that one year can compensate the losses during the other three. A survey of 11 agro-pastoralists based in the steppe showed that the average profit/ha of barley planted in 1987/88 (the best year in their memory with an average yield/ha of 1150 kg) was SL 9,630 at 1991/92 prices (Leybourne 1993).

Even when the crop is not harvested, the loss is not high, as the barley can be grazed *in situ*, and provides a good, multi-purpose forage for sheep (Thomson and Ceccarelli 1990). The revenue and costs for the 11 farmers surveyed in 1991/92 showed a loss of SL 134/ha. This very small loss, due to the gains obtained from grazing (standing barley or the stubble after harvest), explains why the agro-pastoralists will risk cultivation, despite the possibility of being unable to harvest the grain, although the cost of grazing the unharvested crop is quite high.

The cultivation of barley, therefore, is a form of security for the agro-pastoralists. In a good year, they may make a good profit, either through monetary gain (from selling the grain), or through increased amounts of barley grain for winter feed. If the barley is not harvested, or harvested only in part, they secure some grazing for their flock. The barley crop, if harvested, also provides grazing as stubble.

Agro-pastoralists also tend to respect crops belonging to other people. While they may allow their sheep to graze another's rangeland (or even rangeland improved through the planting of fodder shrubs), normally they will circumnavigate land cropped by another. Therefore, cultivating land also helps lay a claim to it.

Before Syria's agrarian reform in 1958, most of the land cultivated in the drier parts of the country—including the steppe—was in partnership between pastoralists and entrepreneurs. For the latter, it was principally opportunistic cultivation. Land brought into cultivation for the first time tends to yield better due to the store of nutrients in the soil.

As yields declined, the land was abandoned. In the study area, this phenomenon is evident at a number of sites. A number of abandoned houses were also observed, also indicating that the land there has been abandoned. There were no furrows remaining, suggesting that it has been many years since the land was last plowed. (Furrows are still visible on land cultivated in 1988/89 and then abandoned.) The increase in area planted in barley in 1988/89 could suggest a renewal of interest in opportunistic cultivation, but as that year was particularly disastrous (average country-wide yields were less than 200 kg/ha) interest probably declined again. The cultivated area decreased again the following year.

There are still instances of partnership between agro-pastoralists and entrepreneurs, but they appear to be less common now. None of the 25 surveyed families had entered into partnership for barley cultivation in recent years.

Modeling the Extension of Barley Cultivation

It is obvious from data from the Syrian Ministry of Agriculture and Agrarian Reform, from FAO, fieldwork and estimations from a large number of sources, that, over time, barley has extended, or encroached, into the Syrian steppe. One of the objectives of this study was to determine the extent of encroachment, and to analyze the amount of land permanently cultivated in barley.

From the 25 surveyed families/sites, we have developed a model to determine the movement of the line of cultivation since 1960. This was developed in two ways.

To begin with, we tried a regression analysis using the year the land was first cultivated as the dependent variable, and the latitude and longitude points, transformed into degrees, as independent variables. The results were as follows:

Regression Output 1

Constant	3215.6982
Std Err of Y Est.	8.8142907
R Squared	0.0956519
No. of Observations	25
Degrees of freedom	22

X Coefficient(s)	-46.37139	10.512467
Std Err of Coef.	30.487506	13.669588

These results were not significant. We decided to exclude the four sites first cultivated in the early 1950s, which surround the earliest settlement in the study area (see Map 2). This added a third independent variable, that of the village. The results were as follows:

Regression Output 2

Constant	3276.0542		
Std Err of Y Est	7.9902653		
R Squared	0.2906185		
No. of Observations	25		
Degrees of freedom	21		
X Coefficient(s)	-52.07806	14.339	-0.56393
Std Err of Coef.	27.739199	12.493329	4.3971954
Student's t	-1.877417	1.1473244	-2.402424

These results are significance for the year and the place in which barley was first cultivated. To model the barley isolines, we adopted the formula:

$$\text{Year}=3276.05-52.08(N_{deg})+14.33(E_{deg})$$

Discounting the effect the third independent variable (the village) would have on the model, in all but four cases the result would be zero. Figure 1 shows the model, which has been graphed using the most westerly and easterly longitude degrees in the study area. It extends out of the study area to the north and south:

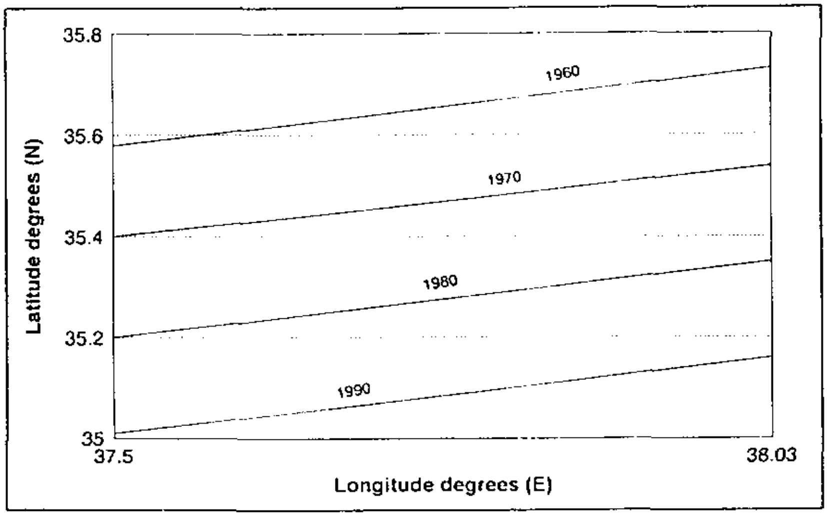


Figure 1. Model of barley isolines in the Syrian steppe between E 37° 30' and E 38° 02'.

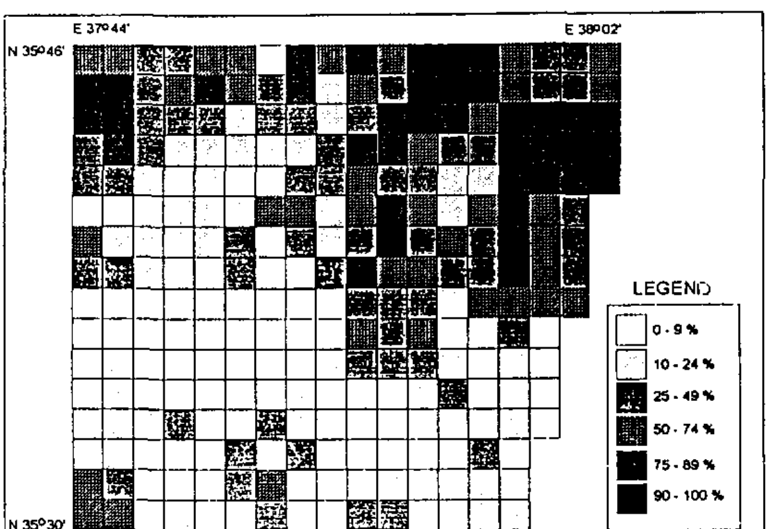


Figure 2. Visual estimation of barley cultivation in the study area (percentages are the estimated amount of land cultivated in barley in each cell in April 1991).

The lines for 1960 and 1970 correspond well with the isolines of approximate cultivation fronts in Map 1. However, the 1980 and 1990 lines may not correspond to reality. Land farther to the southeast has been cultivated, and was brought into cultivation during the 1980s, during which there seems to have been a cultivation acceleration. However, not all land is cultivated, and as one moves southeastwards, natural rangeland is more in evidence. The model helps to confirm the hypothesis that barley cultivation has extended into the steppe, and the barley isolines correspond roughly to the isohyets.

It is difficult for this study to determine the percentage of land that is permanently cultivated in barley. The amount of cultivated land changes each year in response to weather conditions, the amount of grain the agro-pastoralists have to cultivate and the land available. If there is a significant amount of early rain, it is likely that more barley will be cultivated in anticipation of a good year. A greater amount of grain available will encourage more cultivation as well. Some families have commented that they would have cultivated more land had they had the seed to do so.

The only accurate way of knowing how much barley is cultivated is through computer analysis of satellite images. This technique has not been available to us; we only have a false color image of the study area dated April 1991. It has been assumed that the red color in the image corresponds to barley. A visual estimation on a cell-by-cell basis (each cell corresponding to 1x1') shows that 30.6 percent of the study area was cultivated in 1990/91.

The northeastern part of the image is the most densely cultivated. There are several large wadis permitting cultivation. To the northwest, large areas have been cultivated in the past and are now barren. In addition, the land is very stony (see Map 1) and unable to be cultivated. As one moves farther southeast, the soil is less stony.

Areas of earlier cultivation do not show on the satellite image, as they cannot be distinguished from overgrazed rangeland. The only means of accurately calculating the evolution of cultivation over time is through an analysis of time series images.

Conclusions and Suggestions for Further Study

This survey has not served to answer all the questions posed at its beginning, but it has helped to provide information about barley cultivation in the steppe. It has not been possible to gauge exactly how much barley has encroached into the steppe; however, in the study area, at least one-third of the land is cultivated.

While opportunistic cultivation was certainly a catalyst for barley cultivation in the steppe, and some areas first cultivated in the 1950s and 1960s have since been abandoned, it appears that barley is now largely cultivated by the locals for their own use. This is an important point when considering possible actions for development and/or rehabilitation of the area. However, another important point to consider is that the local population wants to cultivate as much barley as possible; the potential gains are important. Any alternative strategy would have to be equally or more profitable than barley.

Yields have decreased over time. Most of the agro-pastoralists recognize this, even if they do not admit it, or attribute it to weather conditions. Land abandoned after some years of cultivation is another proof that yield has declined.

At present, the agro-pastoralists see no alternatives to planting barley. They are unlikely to accept or adopt alternatives unless it can be proved beneficial to them. It needs to be recognized that the agro-pastoralist is acting rationally when he cultivates barley, and that direct intervention will not work. There is a considerable amount of illegal cultivation that will continue as long as the land has no clear owner. As the agro-pastoralists move around, it is difficult to pinpoint exactly who has cultivated what areas.

One of the values of this study has been to test the use of satellite images combined with ground truth surveys. The two methods in combination have given a fairly clear picture of the study area, given the limited time and resources.

—Marina Leybourne

Acknowledgments

I would like to thank Dr. Anthony Goodchild for his considerable help in developing the barley extension model, and George Arab, Nabil Batticha and Ali Rajab for their help during the study's field work phase.

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Training and Technology Transfer

PFLP Training List

Headquarter Group Training Courses

Practical Diagnosis of Sheep parasites/PFLP 20–24 March 1994

Sponsored: ICARDA

1)	Samir Abdulrahman Sherie	Syria
2)	Ms. Samia Mohamed Alhmar	Tunisia
3)	Ahmed Saad Kaasim	Yemen

In-country, Sub-regional and Regional Training Short Courses

Forage and pasture in Morocco/PFLP (21–24 March 1994) held at: Tangiers, Morocco

Sponsored by: INRA/ICARDA

1)	Hamadahe Abdelmadjid	Algeria
2)	Zeghida Ali	Algeria
3)	Tibaoui Gouider	Morocco
4)	Janidi Bouzekri	Morocco
5)	Jaber Abdelaziz	Morocco
6)	Ms. Ali Noutfia	Morocco
7)	Ayadi Mohammed	Morocco
8)	Benoudifa El Mustapha	Morocco
9)	Tsouri Mohamed	Morocco
10)	Akhazzan Mohamed	Morocco
11)	Moumen Idriss	Morocco
12)	Abarou Mohamed	Morocco
13)	Miskine Driss	Morocco
14)	Mallouk Ahmed	Morocco
15)	Alaoui Mohamed	Morocco
16)	Zardoune Mohammed	Morocco
17)	Ghalim Ahmed	Morocco
18)	Benali Omar	Morocco
19)	Kettani Rajae	Morocco
20)	Ouardini Mohamed	Morocco
21)	Leghzali Hamid	Morocco
22)	Ms. Ben Salem Lamia	Tunisia

Sheep nutrition and management/PFLP (12–21 April 1994) at Amman, Jordan

Sponsored by: UNDP/AFESD/ICARDA

1)	Fathi F. T. Mostafa	Iraq
2)	Fawzan Salman Zaydan	Iraq
3)	Ghazi K. Khattab	Iraq
4)	Hani M. Amin	Iraq
5)	Hashim Al-M. Hamad	Iraq
6)	Mahmoud Ahmed Abu-Rabeiha	Iraq
7)	Majed S. Farag	Iraq
8)	Faisal Salem Barakah	Jordan
9)	Tawfiek Muhammed Nserat	Jordan
10)	Abdul Kareem Mostaf Soltan	Syria
11)	Adnan Al Asaad	Syria
12)	Fayez Al-Anbar	Syria
13)	Mohamed Ayman Daba	Syria

Individual Non-degree

Pasture Forage and Livestock Program/PFLP

1)	Ms. Joyce Mitri	Lebanon	Sown Pastures	09/04–28/07
2)	Mahasin Hassin Tammam	Sudan	Parasitology	03/07–31/08
3)	Abdal Elah Al Eter	Syria	Marginal Land and Range Land Improvement	30/04–31/08
4)	Mohamed Ali Madarati	Syria	Marginal Land and Range Land Improvement	02/09–31/12
5)	Radwan Zubaydeh	Syria	Marginal Land and Range Land Improvement	09/01–30/04

Individual Degree

Pasture Forage and Livestock Program

	Name / Country / Funding	Uni.	Level	Period
1)	Mustafa Darwich/Syria	Cukurova Uni.	PhD	-
2)	Ghufran Abdu Kattach/Syria	Giessen	PhD	-
3)	Andree Pape/Germany	Hohenhiem	PhD	-
4)	M. Leybourne/Canada	Geneva, Switzerland	PhD	-
5)	Undine Opitz/Germany	Leipzig	PhD	-
6)	Adel El Awad/Sudan	Cukurova	MSc	-
7)	Safouh Rihawi/Syria	Reading	PhD	-
8)	Fahim Ghassali	W. Australia	PhD	-

PFLP Degree-related Training

Name	Topic	Nationality	Degree	University	Up to
S. Rihawi	Animal nutrition/Grop Residue	Syria	PhD	Reading, UK	1995
G. Khattach	Marginal land/Annual Legumes	Syria	PhD	Giessen, Germany	1995
M. Leybourne	Socio-geographical changes in the steppe	New Zealand	PhD	Lyon, France	1995
A. Al-Awad	Animal nutrition/Milk	Sudan	MSc	Cukorova, Turkey	1995
M. Darwish	Agr. Economics/Bedouing	Syria	PhD	Cukorova, Turkey	1995
A. Pape	Economics of farming system/Women	Germany	PhD	Hohenheim, Germany	1997
U. Opitz	Increasing small ruminant productivity in the El Bab in north Syria	Germany	PhD	Leipzig, Germany	1997
F. Ghassali	Marginal land improvement/Reseeding	Syria	MSc	W. Australia	1996
D. Dauro	Les Trefles Annuels des hauts plateaux Ethiopiens: Etude de la regenerarion des peuplements et Utilisation Agronomique.	Ethiopia	PhD	Montpellier, France	1994 (Completed)
R. Wachholtz	Socio-economics of Bedouin farming systems	Germany	PhD	Hohenheim Germany	1995

Training Activities Related to PFLP Research Projects

Title	No of Participant	Country (Location)
Small ruminant production and management		
1) Practical Diagnosis of Sheep parasites.	3	SYR/TUN/YEM (Syria)
2) Sheep Nutrition and Management.	13	IRAQ/JOR/SYR (Jordan)
Sown pasture and forage production		
Forage and Pasture in Morocco	22	ALG/MOR/TUN (Morocco)
Rangelands		
Marginal Land and Range Land Improvement	3	SYR (Syria)

Annexes

Annex I: PFLP Staff List

Gustave Gintzburger	Program Leader
Zuka Mousattat	Secretary
Sonia Noaman	Secretary

Improvement of Small Ruminant Production

Timothy Treacher	Livestock Scientist (up to May 1994)
Euan Thomson	Livestock Scientist (from September 1994)
Anthony Goodchild	Ruminant Nutritionist
Hiroaki Nishikawa	Veterinary Consultant (JICA-Japan)
Faik Bahhady	Asst. Livestock Scientist
Safouh Rihawi	Research Associate
Sadallah Filo	Research Assistant
Adnan Termanini	Research Assistant
Ibrahim Saeed	Research Assistant
Hisham Hreitani	Research Technician
Mohamed Heilani	Technician
Ahmad Sawas	Technician
Saleh Agha	Shepherd
Mahmoud El Razzouk	Shepherd

Improvement of Sown Pasture and Forage Production

Scott Christiansen	Grazing Management Scientist
Nerses Nersoyan	Research Associate
Hanna Sawmy	Research Associate
Akram Semaan	Senior Technician
Walid Bou Moghlebay	Senior Technician
Alaa Badenjki	Technician

Improvement of Native Pasture and Rangelands

Ahmed Osman	Pasture Ecologist
Amin Khatib Salkini	Research Assistant
Fahim Ghassaly	Research Assistant
Ali El Rajab	Technician
Adel Nassar	Senior Technician (Terbol station, Leb.)
Rukoz Abu Nakad	Technician (Terbol station, Leb.)
Ghuffran Kattach	PhD Student (Aleppo University, Syria)
Undine Opitz	PhD Student (Leipzig University, Germany)

Microbiology and Nitrogen Fixation

Luis Materon	Microbiologist
Michel Obaton	Microbiologist (on sabbatical, Institut National de la Recherche Agronomique, Laboratoire des Symbiotes des Racines, Montpellier, France)
Monika Zaklouta	Research Associate
Bakri Abu Dan	Research Assistant
Elias Khoudary	Research Assistant
Sahar Sabbouni	Technician

Agro-environmental Land Resource Evaluation and Conservation

Haru Fujita	Land Resource Information Scientist (JIRCAS-Japan)
Masahiro Hirata	PhD student (JICA volunteer, Japan)
Hitoshi Shinjo	PhD student (JICA volunteer, Japan)

Socioeconomics

Thomas Nordblom	Livestock Economist
Farouk Shomo	Research Associate
Andrea Pape	Research Fellow (Hohenheim Uni. Germany)
Marnie Leybourne	PhD Student (Lyon II, France)

Annex II: List of PFLP Consultants

Name	Consultation theme	From	PFLP Staff	Duration
D. Marx	Long-term Trial / Statistics	USA	SC	15–30 Jan
A. Zeghida	Data analysis for long-term trials at ITGC El Khroub	Algeria	SC & GG	16 Jan–2 Feb
M. Theodorou	To install Pressure Transduces Technique system in Forage Lab and train the Technicians	UK	TG	26 Feb–10 Mar
M. Bounejmate	Reviewer, Internally Managed	Morocco	GG	10–12 Oct
E. Coreal	External Review.	Spain	GG	10–12 Oct
G. Pollot	Assist and report an internal review as exxternal observer.	UK	GG	10–12 Oct
M. Abu Zanat	To develop a simple rangeland hand-held seeder with Mr Peter Eichhorn	Jordan	GG & AO	3–9 Sep
S. Hammadeh	Livestock Survey in the Bekaa valley	Lebanon	TN & AO	27–29 Sep
M. Ewing	Potential Collaboration with CLIMA on crop rotation	Australia	GG & SC	1–7 Dec
G. Saint-Martin	Secretary—Comite Recherche Agronomique Internationale	France	GG	4–6 Dec

***PFLP staff working with consultant**

GG Gustave Gintzburger
AO Ahmed Osman
TN Tom Nordblom
TG Tony Goodchild
SC Scott Christiansen

Annex III: PFLP Publication List

A list of Publications by Pasture, Forage & Livestock Program Team Members and Affiliated

Articles in Journals

Aletor, V.A., Goodchild, A.V. and Abd El Moneim, A.M. 1994. Nutritional and antinutritional characteristics of selected *Vicia* genotypes. Animal Feed Science and Technology. 47:125–139.

Aletor, V.A., Abd El Moneim, A.M. and Goodchild, A.V. 1994. Evaluation of the seeds of selected lines of three *Lathyrus spp* for ß-N-Oxalylamino-L-Alanine (BOAA), Tannins, Trypsin Inhibitor activity and certain in-vitro characteristics. Journal of Science food Agricultural. 65:143–151.

Christiansen, S. and Cocks, P.S. 1994. Changes in seed bank size and botanical composition of medic pastures in rotation with barley in northwest Syria. Al-Awamia. 87:141–148.

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Gintzburger, G., Nordblom, T. and Osman, A.E. 1994. Agro-pastoral systems, feed calendars and feed resources in the Arab countries of the Mediterranean region. FAO/AOAD Expert consultation on management and sustainable dryland development of the Arab World. ICARDA. Aleppo. November 10–13, 1994.

Goodchild, A.V., El-Haramein, F.J. and Treacher, T.T. 1994. Predicting the voluntary intake of barley straw with near infra red reflectance spectroscopy. Animal Production. 58:455.

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Harris, H.C., Nordblom, T.L., Rodriguez, A. and Smith, P. 1994. Experience of the use of systems anslysis in ICARDA. In Opportunities, Use, and Transfer of Systems Research Methods in Agriculture to Developing Countries, eds. Goldsworthy, P. and F. Penning de Vries. Proceedings Systems Research

Methods in Agriculture in Developing Countries, Systems Approaches for Sustainable Agricultural Development, Vol 3. Kluwer Academic Publishers. 295–302.

Herbert, F., Thomson, E.F. and Capper, B.S. 1994. Effect of genotype on the morphological characteristics, chemical composition and feeding value of nine barley straws and responses to soya-bean meal supplementation. Animal Production. 58:117–126.

Materon, L.A. 1994. Delayed inoculation and competition of *Rhizobium meliloti* in annual *Medicago* species. Applied Soil Ecology. 1:255–260.

Newbold, C.J., El Hassan, S.M., Wallace, R.J., Chen, X.B. Goodchild, A.V. and Arthard, L. 1994. Influence of African multipurpose trees on activity of rumen protozoa and bacteria *in vitro*. Animal Production. 58:461.

Nordblom, T.L., Pannell, D.J., Christiansen, S., Nersoyan, N. and Bahhady, F. 1994. From Weed to Wealth? Prospects for Medic Pastures in the Mediterranean Farming System of Northwest Syria. Agricultural Economics. 11:29–42.

Nordblom, T.L. and Shomo, F. 1994. Food and feed prospects to 2020 in the West Asia/North Africa region. Workshop on Sustainable Agricultural Growth in the Major Ecoregions of the Developing World: Prospects to 2020. Warrenton, Virginia. November 7–9, 1994. IFPRI.

Nordblom, T., Shomo, F., Boughlala, M., Goebel, W., Harris, H., El Mourid, M., Ambri, A., El Oumri, M., the late Farihane, H., El Ouali, A. and Jmyi, A. 1994. Farmer interview methods and crop growth simulation for yield-gap estimation in Morocco. In Systems-oriented research in agriculture and rural development. eds. Sebillotte, M. *et al.* Symposium. Montpellier, France.November 21–25, 1994. 685–686.

Osman, A.E., Cocks, P.S. and Bahhady, F. 1994. Response of Mediterranean grasslands to phosphatic and stocking rate. Livestock production. Journal of Agricultural Science. Cambridge. 123:319–26.

Rihawi, S., Goodchild, A.V., Owen, E., Termanini, A. and Treacher, T.T. 1994. Grazing of barley stubble by sheep in Syria: effects of stocking rate and supplementation on selective intake of stubble fractions. Animal production. 58:478–479.

Treacher, T.T., Bahhady, F., Heritani, H. and Termanini, A. 1994. A comparison of the performance of Turkish and Syrian strains of Awassi ewes at two levels of nutrition. Animal Production. 58:478.

White, P.F., Nersoyan, N.K. and Christiansen, S. 1994. Nitrogen cycling in dry Mediterranean zones: changes in soil N and organic matter under several crop/livestock production systems. Australian Journal of Agricultural Research. 45:1293–1307.

Articles submitted or in press

Keatinge, J.D.H., Materon, L.A., Beck, D.P., Yurtsever, N., Karuc, K. and Altintas, S. 1995. The role of rhizobial biodiversity in legume crop productivity in the west Asian highlands: I. Rationale, methods and overview. Journal of Experimental Agriculture. In press.

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Materon, L.A. 1994. Delayed inoculation and competition of *Rhizobium meliloti* in nodulating annual *Medicago species*. Applied Soil Ecology.

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Ryan, J., Materon, L.A. and Christiansen, S. 1994. The network concept in technology transfer in the dryland west Asia-north Africa region. J. Natural Resources and Life Sciences Education. Submitted.

Newsletters and Networks

Christiansen, S. and Perret, P. eds. 1991–1993. Dryland Pasture and Forage Legume Network News. ICARDA/IBPGR. Issues 1–7. Distribution worldwide to over 1000 addresses.

Christiansen, S. and Adham, Y. eds. 1993–1994. Dryland Pasture and Forage Legume Network News. ICARDA/IPGRI. Issues 7–9. Distribution worldwide to over 1000 addresses.

Graduate Theses or Dissertations Produced with PFLP's Assistance

Darwich, Mustafa. Economics of non-arable pasture management in northern Syria. PhD dissertation program since July 1993. Department of Agricultural Economics. University of Cukurova. Adana, Turkey. (Supervisors, Prof Dr. Onur Erkan and Dr. T. Nordblom).

Dauro, D. 1994. Les Trefles annuels des hauts plateaux Ethiopiens: Etude de la regenerarion des peuplements et Utilisation Agronomique. These de Troisieme Cycle. Universite des Sciences et Techniques du Languedoc. Montpellier, France. (in French) in collaboration with ILCA (Addis-Ababa).

Nasser, S. 1994. Agricultural systems analysis in dryland areas: Al-Hassakeh Province. MSc Thesis. Dept. of Ag Economics. Agriculture Faculty. University of Damascus. With Dr. Iskandar Ismail and Dr. Noureddin Mona. Ford Foundation Graduate Research Training Grant support.

Opitz, U. 1994. Medic pasture establishment using pods sown into barley in the year prior to the pasture phase. Institut für Tropische Landwirtschaft. University of Leipzig. Germany. 20pp.

Pape, Andrea. 1994. The Contribution of Women to Labour and Decision Making Processes in Bedouin Families. An Example from Syria. MSc Thesis. Institute of Agricultural Economics and Social Sciences in the Tropics and Sub-Tropics. University of Hohenheim. Stuttgart, Germany. (Supervisors: Prof Dr. Werner Doppler and Dr. T. Nordblom). BMZ/GTZ research grant. University of Hohenheim for special project with ICARDA.

Thami A, I. 1994. Prospektion, selektion sowie Prüfung auf effektivitat von säuretoleranten *Rhizobium meliloti* stämmen für den anbau von annuellen Medicago-arten auf sauren und schwach sauren böden in Marokko. Faculty of Agriculture. Justus-Liebig University. Giessen, Germany. 117pp. In German.

Wachholtz, R. Socio-economics of Bedouin farming systems in the marginal areas of northern Syria. PhD Dissertation. Institute of Agricultural Economics and Social Sciences in the Tropics and Sub-Tropics. University of Hohenheim. Stuttgart, Germany. (Supervisors: Dr. Werner Doppler and Dr. T. Nordblom). BMZ/GTZ research grant. University of Hohenheim. Special project with ICARDA.

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1995

Christiansen, S., Abd El Moneim, A.M., Cocks, P.S. and Singh, M. 1995. A comparison of hardseededness and seed dormancy between two amphicarpic pasture legumes (*Vicia sativa* ssp. *amphicarpa* and *Lathyrus ciliolatus*) and two annual medics (*Medicago rigidula* and *M. noeana*). Journal of Agricultural Science. Cambridge. In press.

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Bahhady, F., Ferwawi, A., E. Thomson, F., Singh M., and Christiansen, S. 1995. On-farm trials with forage legume/barley compared to fallow/barley rotations and continuous barley in northwest Syria. Conference paper/poster Acquis et perspectives del la recherche agronomique dans les zones arides et semi-arides du Maroc. May 24–27, 1994.

Ryan, J., Materón, L.A., and Christiansen, S. 1995. The network concept in technology transfer in the dryland west Asia-north Africa region. Journal of Natural Resources and Life Sciences Education. American Journal of Agronomic Education. In press.

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Nordblom, T.L. Studies on the economics of nitrogen use in Syria. In Nitrogen research at ICARDA: accomplishments, current activities and future direction. ed. Ryan, J. ICARDA. Aleppo. In press.

Nordblom, T.L. and Shomo, F. Disaggregated food and feed trends to 2010 in the West Asia/North Africa region. In Roundtable on Population and Food in the Early 21st Century: Meeting Future Food Needs of an Increasing World Population. ed. Islam, Nurul. February 14–16, 1994. International Food Policy Research Institute (IFPRI). Washington, D.C. In press.

Hamadeh, S.K., Goodchild, A., Shomo, F. and Nordblom, T.L. (abstract accepted). The role of native pasture grazing in relation to other feed sources for sheep and goat flocks in the Beqa'a Valley of Lebanon. Proceedings of the Fifth International Rangeland Congress. Salt Lake City, Utah. July 23–28, 1995.

Nordblom, T.L., Shomo, Farouk and Gintzburger, Gustave (abstract accepted). Rangeland and Rising Feed Deficits in West Asia and North Africa. Proceedings of the Fifth International Rangeland Congress. Salt Lake City, Utah. July 23–28, 1995.

Nordblom, T.L. (manuscript in final preparation). Crop yield distributions from farmer interviews. In Agroecological Characterization. ed. Goebel, W. Proceedings of a workshop sponsored by IDRC and ICARDA. ICARDA. Aleppo. April 19–22, 1994.

Nordblom, T.L. (manuscript in final preparation). Yield gap analysis for allocation of research resources. In Agroecological Characterization. ed. Goebel, W. Proceedings of a workshop sponsored by IDRC and ICARDA. ICARDA. Aleppo. April 19–22, 1994.

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المركز الدولي للبحوث الزراعية في المناطق الجافة

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