PASTURE, FORAGE AND LIVESTOCK PROGRAM

Annual Report for 1990/1991

ICARDA

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

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

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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. Due to the tight production deadlines, editing of the report was kept to a minimum.

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Introduction

In the upheaval in PFLP caused by the departure of the Program Leader, Dr Phil Cocks, it was impossible to prepare the Annual Report for 1990 in time for publication in 1991. It was decided therefore to produce a combined report for 1990 and 1991. This has resulted in a Report that differs a little from the usual format.

Section 2 contains the results of Dr Al Abdul Moneim's final season of work in PFLP, before he transferred to the Legume Program, together with his technicians, Mustafa Bellar and George Zako. Their direct contribution to PFLP is sadly missed but we hope that, when Dr Moneim returns from sabbatical leave at the end of 1992, the cross-program efforts on selection breeding and evaluation of pasture legumes and annual forage legumes will continue with even greater vigour.

With Dr Moneim's departure, PFLP also lost its Training Scientist. This gap was filled by Dr Habib Ibrahim, the LP Training Scientist, on his return from sabbatical leave in October 1990. We thank Dr Ibrahim for his energetic guidance of PFLP's training programme in 1991, which is reported in section 8.2.

The work on biological nitrogen fixation by the Microbiology Group was prepared in two separate sections (3.1 & 3.2) relating to the years 1990 and 1991 before Dr Materon departed for sabbatical leave in July 1991.

Sections 4-8 cover most of the remainder of the work of the Program. It may be useful to comment on two omissions. Section 4.1 on fallow replacement, which was written at a time when the major analysis of this large experiment was being made, reports only the results for production of wheat from the different rotations and omits discussion of the results for medic, lentil and animal production, which required further and more detailed analysis. No reference is made in section 7 to the work on the effects of internal parasite infections on the productivity of ewes in northern Syria, which was completed in May 1991. The first two years of this work was reported in detail in the 1989 Annual Report and the final results are now being prepared for publication.

Senior Staff

In October 1990 Dr Phil Beale, Pasture Scientist in North Africa returned to Australia. Dr Phil Cocks, the Program Leader, left to take the chair of Crop and Pasture Science at University of Western Australia in May 1991.

The following joined the Program: Dr S. Christiansen, Grazing Management Specialist (January 1990), Dr T. Treacher, Livestock Scientist (April 1990), Dr T. Nordblom, Livestock Economist (transferred from the Farm Resource Management Program, September 1990) and Dr A. Goodchild, Ruminant Nutritionist (June 1991).

Acknowledgments

The scientists responsible for conducting each piece of research are acknowledged at the end of each section in the Report. We wish to thank the assistants, technicians and regular laborers for their dedicated contribution to the Program's work.

We also wish to thank several organizations; the Japanese International Cooperation Agency and the UN Food and Agriculture Organization for supporting research on internal parasites, the Italian Government for supporting research on Mediterranean grasslands, the Overseas Development Agency of the UK Government for a post-graduate studentship to study pea palatability, BMZ (Federal Ministry for Economic Cooperation) of the German Government for supporting research with the University of Hohenheim on Land Use Management for Marginal Lands

Finally, I must thank Parvin Damania and Sonia Noaman for final preparation of the Report. - **T T Treacher**

2. Selection of Widely Adapted Legume Crops: Results for the 1989/1990 Season

Forage legumes are grown for grazing, hay, grain, or straw. They are one of the three alternatives that ICARDA is experimenting with to improve crop rotations, the others being food legumes and the self-regenerating pasture legumes. They differ from the food legumes only in end use - they are used to feed livestock, whereas food legumes are for human consumption. They differ from pasture legumes in the need for re-sowing each season.

The objective of our research is to find legumes to grow in drier areas, 250-300 mm rainfall, than the food legumes. Because human preferences are not involved, researchers can choose from more genera, which greatly increases the chances of success.

In spite of the diversity of legumes in the Mediterranean basin, few are used as crops, and even fewer have received attention from plant breeders. Our first goal is to improve those species now being used, and the second is to look more widely for potential crops. The emphasis is on selection from available diversity and using hybridization only where the required diversity is not available.

The legume genera used are <u>Vicia</u> and <u>Lathyrus</u> (vetches and chickling, respectively). Of the vetches we are selecting or developing genotypes from <u>Vicia</u> <u>sativa</u> (common vetch), <u>V</u>. <u>villosa</u> ssp. <u>dasycarpa</u> (woolly pod vetch), <u>V</u>. <u>ervilia</u> (bitter vetch), and <u>V</u>. <u>narbonensis</u> (Narbon vetch). Of the chicklings we are working with <u>Lathyrus</u> <u>sativus</u> (common chickling or grass pea), <u>L</u>. <u>cicera</u> (dwarf chickling), and <u>L</u>. <u>ochrus</u> (ochrus chickling). Although the amphicarpic legumes (<u>V</u>. <u>sativa</u> subsp. <u>amphicarpa</u> and <u>Lathyrus</u> <u>ciliolatus</u>) are self-regenerating pasture legumes, they are included in this chapter because of their close relationship with the other vetches and chicklings.

The breeding procedure uses germplasm evaluation and seed multiplication in nursery rows, evaluation of selected genotypes in microplots, evaluation of promising genotypes in advanced yield trials at Breda (mean rainfall 280 mm) and Tel Hadya (320 mm), and testing of the most promising genotypes in a range of ecological zones. Hybridization is used to overcome specific weaknesses such as pod shattering, lodging, lack of leaf retention, susceptibility to major foliar and root diseases and to nematodes, and high levels of neurotoxins and anti-palatability factors. Nutritive value and the presence of toxins are monitored in both the laboratory and in experiments with sheep.

In 1989/90 the three Lathyrus species were evaluated in nursery rows, and advance yield trials at Breda and Tel Hadya. V. sativa, V. ervilia, V. hybrida and V. palaestina were evaluated in microplots, and V. narbonensis reached the advanced yield trials at Breda and Tel Hadya. Genotypes of V. sativa incorporating non-shattering genes with other desirable traits such as leafiness, erect growth habit, and early maturity have been isolated in the BC4 generation.

The 1989/90 growing season had severe frosts in winter and spring and low total rainfall. The annual rainfall at Tel Hadya was only 233 mm and there were 55 days when the minimum temperature fell below 0°C, including nine in late March and early April. At Breda the total rainfall was 184 mm with 48 days below zero, including eight days in late March and early April. These conditions resulted in generally low yields for all species, but provided a strong selection pressure in favour of cold and drought tolerance. All temptations to irrigate the plots were resisted.

2.1. Assessment of Germplasm in Nursery Rows

Eighty-one accessions of the three Lathyrus species were assessed in nursery rows: 48 of L. sativus, 13 of L. cicera, and 20 of L. ochrus. A cubic lattice design was used with three replicates. The accessions were scored on a scale from 1 to 5 (1=poor, 5=good) for establishment, seedling vigour, winter and spring growth, leafiness, growth habit, and plant vigour. Frost damage in February and March was also assessed on a scale of 1 to 5 (1=no damage, 5=all plants killed). The number of days to flowering and to maturity were measured, and the seed yield assessed.

Variability for all attributes was wide (Table 2.1). Some genotypes in all species were identified with better than average frost tolerance, although all accessions of L. ochrus succumbed to the severe frost. In that species we must collect further, and search for greater frost tolerance, if it is to be useful beyond the coastal areas. Promising genotypes will be used for further evaluation.

Table 2.1. Range of variability of seven attributes of Lathyrus sativus, L. cicera and L. ochrus.

	L. sativus		L. cicera		L. ochrus	
	Min.	Max.	Min.	Max.	Min.	Max.
	48 accession		13 accession		20 accession	
Frost damage[1]	1.0	1.0	1.0	1.0	1.0	2.0
Frost damage[2]	2.0	4.0	1.5	3.0	4.0	5.0
Leafiness	1.0	5.0	2.0	5.0	1.0	1.0
Days to 1st flowering	99	124	105	118	106	120
Days to 100% flowering	111	134	113	125	113	126
Days to maturity	146	164	143	155	142	160
Seed yield (g/6m^{2}plot)	0	604	42	506	0	188

Frost damage[1] measured on February 2, and Frost damage[2] on March 3, on visual scale where 1 = no damage; 5 = all plants killed by frost.

2.2. Evaluation of Vetches in Microplots

V. sativa, V. ervilia, V. hybrida, and V. palaestina were sown in microplots (3.5 m^2) arranged in a triple lattice design with three replicates. For all species the seed rate was 100 kg/ha and superphosphate was applied at 40 kg/ha of P_2O_5. The experiments were duplicated, one being harvested at 100% flowering to determine herbage yield, and the other being harvested at maturity to measure grain and straw yield.

2.2.1. Vicia sativa (common vetch): there were 25 selections tested; the results from the best 10 are shown in Table 2.2. The herbage yield of all 25 selections ranged from 1900 to 2820 kg/ha, grain yield ranged from 546 to 930 kg/ha, and harvest index from 20% to 32%. The experiment was slightly affected by frost, and severely affected by drought. Two selections (2484 and 2502) had high harvest index and resisted lodging.

Table 2.2. Dry herbage yield at 100% flowering, seed and straw yields, harvest index and frost effect for the best 10 lines of V. sativa in microplot trials at Tel Hadya.

Selection no.	Herbage yield (kg/ha)	Seed yield (kg/ha)	Straw yield (kg/ha)	Harvest index (%)	Frost effect+
2484	2544	910	2153	30	1.5
2486	2490	743	2554	22	2.5
2488	2241	602	1877	25	2.6
2493	2282	811	2151	27	2.7
2494	2711	792	2104	27	2.6
2497	2314	784	2381	25	2.0
2499	2483	786	2083	27	2.6
2501	2815	739	2254	25	2.0
2502	2410	927	2058	31	2.0
2503	2524	845	2152	28	2.0
Grand mean[1]	2408	743	2117	25.9	2.6
SE (±)	257	89	138	2.3	0.2

[1] Mean for all 25 selections.

2.2.2. Vicia ervilia (bitter vetch): there were 16 selections of bitter vetch in the experiments, the yields from the best six being shown in Table 2.3. Herbage yield ranged from 2650 to 3370 kg/ha, grain yield from 800 to 1450 kg/ha, and harvest index from 26% to 40%. These yields are substantially better than V. sativa, and it is clear that this neglected species deserves further attention.

Table 2.3. Dry herbage yield at 100% flowering, seed and straw yields, harvest index and frost effect of the best selections of V. ervilia in microplot trials at Tel Hadya.

Selection no.	Herbage yield (kg/ha)	Seed yield (kg/ha)	Straw yield (kg/ha)	Harvest index (%)	Frost effect+
2508	3227	1262	2419	34	1.6
2509	3125	1229	2452	33	1.5
2510	3191	1219	2443	33	1.6
2516	3152	1449	2365	38	1.0
2518	2980	1437	2216	40	1.0
2521	3047	1090	2572	30	1.4
Grand mean[1]	3086	1175	2322	33	1.8
SE (±)	254	66	96	2.0	0.2

[1] Mean for all 16 selections.

2.2.3. Vicia hybrida: there were 16 selections of this species, and the best six are shown in Table 2.4. Herbage yield ranged from 1250 to 2090 kg/ha, grain yield from 120 to 370 kg/ha, and harvest index from 6% to 17%. V. hybrida is prostrate and compact, with slow winter growth followed by rapid spring growth. It is more suitable as a pasture species than as a grain crop, though for the former purpose it will be inferior to V. sativa subsp. amphicarpa. Its low harvest index and low grain yield is due in part to its prostrate habit that made seed harvest difficult.

Table 2.4. Herbage yield at 100% flowering seed and straw yields, harvest index and frost effect of the best selections of V. hybrida in microplot trials at Tel Hadya.

Selection no.	Herbage yield (kg/ha)	Seed yield (kg/ha)	Straw yield (kg/ha)	Harvest index (%)	Frost effect+
2546	1665	366	1791	17	2.0
2547	1919	341	1755	16	3.0
2549	1722	359	2135	14	3.0
2550	2086	350	1741	17	2.0
2551	1742	356	1921	16	2.5
2552	2090	273	1825	13	3.0
Grand mean[1]	1606	257	1613	18.5	3.5
SE (±)	132	36	95	1.2	0.2

[1] Mean for all 16 selections.

2.2.4. Vicia palaestina: 16 selections of this species were evaluated, the herbage and grain yields of the best seven being shown in Table 2.5. Herbage yield ranged from 790 to 2070 kg/ha, grain yield from 180 to 720 kg/ha, and harvest index from 16% to 28%. We observed that V. palaestina was able to recover quickly after frost damage. Although the yields of this species were poor, it grows in areas receiving only 250 mm rainfall. It is a sprawling vetch that needs much selection and hybridization before becoming an acceptable grain legume. In view of its origins, however, it would seem worth persevering with V. palaestina.

Table 2.6 summarizes the results from testing the four vetch species in microplots. It illustrates some of their potential uses, especially that of V. ervilia that seems suitable for the production of grain and straw. V. sativa also could be used for hay-making, while if the other species have a use in their present forms it would be for grazing.

Table 2.5. Dry herbage yield at 100% flowering, seed and straw yields, harvest index and frost effect of the best lines of *V. palestina* in microplot trials at Tel Hadya.

Selection no.	Herbage yield (kg/ha)	Seed yield (kg/ha)	Straw yield (kg/ha)	Harvest index (%)	Frost effect+
2523	1751	551	1448	27	2.7
2524	1721	602	1483	28	2.0
2529	1931	609	1576	27	2.5
2530	1593	647	1663	28	2.8
2531	2069	721	1953	27	3.0
2532	1627	474	1879	20	3.3
2534	1932	485	1639	23	3.1
Grand mean[1]	1560	444	1427	23	3.9
SE (±)	205	75	151	2.0	0.2

[1] Mean for all 16 selections.

Table 2.6. Range of the major attributes of four feed legume species evaluated in microplot field trials at Tel Hadya.

Attributes	*V. sativa*	*V. ervilia*	*V. hybrida*	*V. Palestina*
Frost effect[1]	1.5-3	1.0-2.0	1.0-3.5	2.0-4.0
Days to 100% flowering	105-115	105-110	105-113	105-112
Herbage yield (kg/ha)	1900-2800	2650-3370	1250-2090	790-2070
Grain yield (kg/ha)	565-930	800-1450	120-340	180-720
Biological yield (kg/ha)	2470-3310	2970-3810	1300-2490	1060-2670
Harvest index (%)	20-32	26-40	6-17	16-28

[1] On a visual scale where 1 = no damage; 5 all plants killed by frost.

2.3. Advanced Yield Trials with Chickling and Narbon Vetch

Selected lines of the three chicklings and Narbon vetch were tested at Tel Hadya and Breda. The plots were managed in the same way as micro-plots, except that they were 28 m^2 in area instead of 3.5 m^2. Two lentils, accessions ILL 4401 and ILL 5582, were included in each experiment to compare the forage legumes with the best food legume for dry areas.

2.3.1. *Lathyrus sativus* (common chickling or grass pea): there were 16 chickling lines in the advanced yield trials. Total biological yield ranged from 1130 to 1850 kg/ha at Tel Hadya, and from 720 to 1300 kg/ha at Breda (Table 2.7). Mean grain yields were 990 and 180 kg/ha at Tel Hadya and Breda, respectively. Harvest index ranged from 19% to 34% at Tel Hadya and from 14% to 24% at Breda.

Frost depressed yields moderately at Tel Hadya, and severely at Breda, and the frost effect was aggravated by drought at both sites.

2.3.2. *Lathyrus cicera* (dwarf chickling): there were 10 lines of dwarf chickling (Table 2.8). Biological yield ranged from 1530 to 1810 kg/ha at Tel Hadya, and from 1020 to 1360 kg/ha at Breda. Grain yield ranged from 400 to 530 kg/ha at Tel Hadya, and from 200 to 395 kg/ha at Breda. In a dry year dwarf chickling, because of its early maturity and frost tolerance, was generally more productive than common chickling at both sites.

Table 2.7. Biological and grain yields and harvest index of promising lines of L. sativus, grown at Tel Hadya (TH) and Breda in advanced yield trials.

Selection no.	Biological yield (kg/ha)		Grain yield (kg/ha)		Harvest index (%)	
	TH	Breda	TH	Breda	TH	Breda
347	1858	1219	635	295	34	24
504	1480	986	327	218	22	22
505	1340	722	259	137	19	19
508	1458	897	304	127	21	14
510	1128	885	304	133	27	15
516	1259	894	304	146	24	16
519	1293	862	321	178	25	21
520	1235	976	225	140	18	14
522	1571	1047	309	206	20	20
527	1386	932	260	173	19	19
528	1400	1066	288	160	21	15
529	1715	1133	322	206	19	18
530	1245	831	285	158	23	19
531	1834	1173	390	213	21	18
533	1325	883	280	187	21	21
535	1654	1300	381	212	20	16
Grand mean	1448	987	321	18	22	17
SE (±)	110	76	41	25	2.1	3.9

2.3.3. Lathyrus ochrus (ochrus chickling): this species was very severely affected by frost at both sites. Only a few individual plants survived, and seed from these was saved in the hope that they prove more tolerant to frost. Ochrus chickling is most productive in the right circumstances; only its great susceptibility to frost limits its use in localities like Breda. For this reason we intend continuing our research with the species.

Table 2.8. Biological and grain yields and harvest index of promising lines of _L. cicera_, grown at Tel Hadya (TH) and Breda in advanced yield trials.

Selection no.	Biological yield (kg/ha)		Grain yield (kg/ha)		Harvest index (%)	
	TH	Breda	TH	Breda	TH	Breda
536	1546	1022	434	207	28	20
488	1806	1220	560	302	31	25
489	1757	1209	512	380	29	31
491	1733	1279	505	394	29	31
492	1779	1267	605	405	34	32
493	1529	1216	444	846	29	28
494	1760	1329	508	366	29	28
495	1700	1365	407	390	24	29
496	1635	1211	531	373	32	31
500	1756	1222	447	340	25	28
Grand mean	1702	1234	495	350	29	28
SE (±)	126	90.4	77	24	2.8	3.0

2.3.4. _Vicia narbonensis_ (Narbon vetch): there were two experiments with Narbon vetch. In the first 14 lines were tested at both sites for the second season, and in the second, nine new genotypes were tested. In experiment 1 total biological yield ranged from 1670 to 2250 kg/ha at Tel Hadya, and from 877 to 1494 kg/ha at Breda (Table 2.9). Grain yield ranged from 520 to 970 kg/ha at Tel Hadya, and from 210 to 300 kg/ha at Breda. Harvest index ranged from 31% to 45% at Tel Hadya, and 18% to 33% at Breda. Total biological yield was 15% less than in the previous year, which however, was also well below average in rainfall. In experiment 2 yields were similar (Table 2.10).

Table 2.9. Biological and grain yields and harvest index, of promising lines of *V. narbonensis*, grown at Tel Hadya (TH) and Breda (second year advanced yield trials).

Selection no.	Biological yield (kg/ha)		Grain yield (kg/ha)		Harvest index (%)	
	TH	Breda	TH	Breda	TH	Breda
0067	2252	1375	773	277	34	20
2461	2063	909	907	259	44	29
2462	1671	1494	665	310	40	21
2464	1748	927	973	256	39	25
2465	2044	1016	793	254	39	25
2466	2053	976	714	229	35	23
2467	1910	920	696	208	36	23
2469	1710	877	619	234	36	27
2473	1958	1187	693	210	35	18
2474	1748	935	596	220	34	24
2475	1738	1163	712	252	41	22
2476	2139	956	955	392	45	32
2477	1510	940	552	307	37	33
2478	1701	882	519	252	31	29
Grand mean	1874	1040	719	255	37	25
SE (±)	156	167	84	51	1.6	2.1

2.3.5. *Vicia dasycarpa* (woolly pod vetch): 16 lines of woolly pod vetch were tested at Tel Hadya only. This species is being improved mainly for high elevation areas where its great frost tolerance is most useful. There were large differences in herbage production, grain yield, straw yield, and harvest index (Table 2.11). Harvest index was again low, and it seems that this species has a problem with seed production, because of poor fertilization, or because it flowers too late at Tel Hadya.

Table 2.10. Biological and grain yields and harvest index of promising lines of V. narbonensis grown at Tel Hadya (TH) and Breda (third year advanced yield trials).

Selection no.	Biological yield (kg/ha)		Grain yield (kg/ha)		Harvest index (%)	
	TH	Breda	TH	Breda	TH	Breda
0067	2020	1011	666	280	33	28
2391	1358	953	565	316	34	33
2392	1063	960	531	354	39	37
2387	1244	1074	512	363	33	34
2388	1196	771	531	288	35	37
2380	1088	1088	651	370	40	34
2390	1653	975	730	273	36	28
2393	2025	1145	977	283	42	25
2383	1979	1367	942	300	40	22
Grand mean	1411	1038	678	357	36	31
SE (±)	135	64	63	22	2.4	2.3

Table 2.11. Herbage yield at 100% flowering, seed, straw yields and harvest index of the best promising lines of V. villosa ssp dasycarpa grown in advanced yield trials at Tel Hadya.

Selection no.	Herbage yield (kg/ha)	Seed yield (kg/ha)	Straw yield (kg/ha)	Harvest index (%)
0683	1803	190	1462	12
2441	2034	182	1547	11
2446	2050	171	1634	10
2455	1816	210	1699	11
2456	1792	112	1559	11
2439	1843	98	1640	6
Grand mean	1704	146	1540	8
SE (±)	192	33	187	1.7

Table 2.12 summarizes the results from the four species grown at both sites, and compares them with lentils. Common chickling equalled and dwarf chickling and Narbon vetch exceeded the biological and grain yields of lentil. The grain yield of dwarf chickling at Breda was of special interest as it was four times that of lentil. In the dry season of 1989/90 these results hold great promise of finding legume crops suitable for the dry areas. It must be emphasized, however, that finding and improving the crops are only part of the development process; uses and markets for these crops will also need to be developed.

Table 2.12. Average of major attributes of four legume species grown at Tel Hadya and Breda in advanced yield trials compared with the average of two promising lines of lentils.

Attributes/ location	Common chick-ling	Dwarf chick-ling	Ochrus chick-ling	Narbon vetch	Lentil
Tel Hadya					
Frost effect[1]	2.0	1.6	4.9	1.5	2.0
Days to maturity	160	154	-	130	152
Grain yield (kg/ha)	320	495	-	720	320
Biological yield (kg/ha)	1450	1700	-	1870	1760
Harvest index (%)	22	29	-	37	15
Breda					
Frost effect	2.7	2.0	-	2.0	2.2
Days to maturity	150	140	-	120	145
Grain yield (kg/ha)	180	350	-	255	90
Biological yield (kg/ha)	990	1230	-	1040	700
Harvest index (%)	17	29	-	25	11

[1] On visual scale where 1= no damage; 5 = nearly all plants killed by frost.

2.4. Grazing trials with subterranean vetch (*Vicia sativa* subsp. *amphicarpa*)

Clipping the aerial stems of subterranean vetch stimulates branching of underground stems, reduces total number of pods and increases the proportion of underground pods. Dry conditions increase the proportion of underground stems.

In 1989/90 an experiment was started in which clipping was replaced by grazing with sheep, and the subterranean vetch was grown in rotation with barley, where it will be allowed to regenerate naturally to give a ley farming system. The underground seed bank will be monitored, the number of seedlings emerging after the barley crop will be counted, and the breakdown of hard seed will be observed.

A randomized block design was used with three replicates. Plot size was 10 x 10 m. The treatments were grazing with 12 ewes per plot on 27th March, 4th April, 5th May, no grazing, and continuous barley. The experiment was sown with 100 kg/ha of underground seed, and a basal dressing of 18 kg/ha of phosphorus was applied before sowing. Four quadrats (50 x 50 cm) were cut from each plot before it was grazed. The number of underground seeds was measured using cores of 10 cm depth with a total surface area of 339 cm^2. Above and below ground pods were threshed and cleaned by hand.

The herbage yield was greatest with no grazing. There was little difference in yield between grazing dates (Table 2.13). Underground seed number and yield was highest at the last grazing, or where there was no grazing, and only in the no grazing treatment did the plants produce seeds above the ground. The seed yields of treatment grazed at or after 4th April were good, both by the standards of other vetches, and by comparison with annual medics.

Table 2.13. Herbage yield (kg/ha), numbers of underground seeds/m^2 and underground seed production (kg/ha) of V. sativa ssp. amphicarpa, grazed on March 2, April 22, May 5, and without grazing.

	Grazing dates				
	March 27	April 22	May 5	No Grazing	SE(±)
Herbage yield (kg/ha)	830	730	860	2020	57
No. of underground seeds/m^2	740	3080	4120	3870	933
Underground seed yield (kg/ha)	210	1000	1380	1390	342
Above ground seed production (kg/ha)	0	0	0	236	-00

The experiment will continue for two more years to measure the yields of barley and the regeneration of subterranean vetch in the year after seed set, and in the following year. The reaction of subterranean vetch to longer periods of continuous grazing is still not known, but it seems likely that this species is more tolerant of grazing than other pasture legumes. To be useful in the ley farming system it will also need high hardseededness, which will also be measured in this experiment. Preliminary results show that by 15th December hardseededness had fallen to 56%, low if the species is to be useful for ley farming (Table 2.14).

Table 2.14. Hard seededness % of V. sativa ssp. amphicarpa.

	Sampling Dates		
	4/11/90	25/11/90	15/12/90
March 1990	100	88	50
April 1990	89	71	53
May 1990	99	68	55
Without grazing	100	77	65

2.5. Screening for resistance to stem and leaf diseases

Screening for resistance to stem and leaf diseases begins in the microplots, and continues through the advanced yield trials. To be sure that our material has durable resistance, we test the most promising genotypes under conditions favourable for the development of the disease.

In 1989/90 14 promising genotypes of Narbon vetch, 16 of woolly pod vetch, 16 of common chickling, 16 of ochrus chickling, and 10 of dwarf chickling were tested with artificial epiphytotic infection of several diseases. These were downy mildew (Peronospera vicia sativa) and powdery mildew (Erisiphe pisi f.sp. sativa) in vetches, and downy mildew (Peronospora trifoliorum) and powdery mildew (Erisiphe martii f.sp. lathyri) in chicklings, Ascochyta leaf spot, stem blight, foot rot (Ascochyta pisi and Phoma medicaginis var. pinodella), and botrytis blight (Botrytis cinerea) in both species. Decreases in grain yield were estimated as described in PFLP's 1988 Annual Report. The different genotypes were evaluated on a scale from 1 (resistant) to 5 (susceptible).

In Narbon vetch selection 67 showed resistance to powdery mildew, Ascochyta leaf spot, and botrytis blight, while selections 2465, 2469, and 2475 were tolerant of the same pathogens. Grain losses in Narbon vetch were 10-40%, 5-30% and 10-30% after infection by the same three diseases. Symptoms of powdery mildew did not appear, probably because of the dry spring.

In woolly pod vetch, selection 2454 was resistant to Ascochyta leaf spot, downy mildew and botrytis blight. Crop losses after infection were 13-20%, 8-13%, and 28-66% respectively. In common chickling, selections 519, 529, 522, 530, 531, and 533 were moderately resistant to Ascochyta leaf spot, downy mildew, and botrytis blight; crop losses ranged from 20-67%, 5-17%, and 10-30%, respectively. In dwarf chickling, selections 536 and 488 were tolerant of the three diseases. Crop losses varied from 24-65%, 4-17%, and 17-36%, respectively.

2.6. Screening for resistance to nematodes

In the dry areas for which the forage legumes are intended, tolerance of infection by root nematodes is probably more important than tolerance of stem and leaf diseases. Surveys show that root-knot nematode (Meloidogyne artiella) and cyst nematode (Heterodera ciceri) attack the roots of food, forage, and pasture legumes. We are therefore searching for tolerance to these diseases in vetches and chicklings.

In 1989/90, 14 promising genotypes of Narbon vetch, 16 of woolly pod vetch, 16 of common chickling, and 10 of dwarf chickling were screened in the field to estimate crop losses, and in glasshouses to estimate intensity of infection and distinguish between nematode species. A heavily infested field considered ideal for screening was used with an average of 5130/kg soil of second-stage juveniles of root knot nematode, and 2801/kg soil of cyst nematode. Crop losses, compared with carbofuran treatment, ranged from 18-54%, 3-14%, 35-93%, and 32-77% for Narbon vetch, woolly pod vetch, common chickling, and dwarf chickling, respectively.

In the glasshouse, 20 second stage larvae/g soil of root-knot nematode, and 20 eggs/g soil of cyst nematode were added to soil in large earthen ware pots. Five plants of each species per pot were sown, and there were six replicates. The plants were harvested at the flowering stage, the roots carefully washed, and the density of nematodes on the roots was determined. Nematodes were extracted and counted as the number of nematodes per g of roots.

None of the Narbon vetches were resistant to both nematodes, but selections 67, 2466, 2467, and 2476 were moderately susceptible to both nematodes. In woolly pod vetch, selections 683 and 2439 were tolerant to both nematodes. In common chickling selections 504, 505, 527, 528, and 529 were tolerant of both nematodes, while in dwarf chickling, selection 356 was resistant. In ochrus chickling, selections 544, 545, and 549 were tolerant of both nematodes.

Although Narbon vetch is susceptible to the nematodes, grain losses are smaller than might be expected. Symptoms of nematode infection are expressed most strongly in late spring, when the infected roots are unable to absorb sufficient moisture. Narbon vetch flowers early and so avoids the worst symptoms. - **A. Abdel Moneim**

3. Biological Nitrogen Fixation and Pasture Legume

3.1. Results for 1989/1990 Season

3.1.1. Cold-resistant and early nodulating strain BZI on annual species of medics

One of the constraints to nitrogen fixation by pasture legumes is the inhibition of nodulation caused by low temperatures in the early stages of growth of medic seedlings. A seedling being able to utilize nitrogen via symbiosis has a nutritional and competitive advantage over non-nodulated plants. The effect of cold temperatures on nodulation is a problem of agricultural significance in some Mediterranean countries.

Field experiments were conducted at Le Coulet and St. Bauzille-de-Putois (near Montpellier) on clay soils with 8.6 pH. Local and introduced ecotypes of M. rigidula, M. polymorpha and M. truncatula were included with the aim to identify strains of rhizobia able to induce early nodulation after germination under cold conditions. Results indicated that early nodulating R. meliloti strain BZI performed significantly better ($P \geq 0.05$)/($P \geq 5\%$) in fixing nitrogen and producing herbage than all other local and introduced strains of rhizobia tested in these trials. Results indicated that M. rigidula selection 716 responded to inoculation when inoculated with ICARDA strains at both sites.

The identification of BZI as a naturally occurring strain of R. meliloti able to induce early and abundant effective nodulation in M. rigidula and other medics at low temperatures has been considered a major discovery by researchers of INRA Montpellier. In fact, this strain has already been patented for exclusive use by INRA-Montpellier in France. Antibiotic-resistant mutants of streptomycin, spectinomycin and rifampicin as markers for further ecological studies have been also developed in France by Drs. J.C. Cleyet Marel and M. Obaton.

To test the same hypothesis in a different environment, we decided to initiate field and greenhouse experimentation with strain BZI in Tel Hadya (Syria). The field experiment consisted of a split plot design having strains of rhizobia as main plots and M. rigidula sel 716 and M. rigidula sel 2119/1902 as subplots with three replications. The original strain BZI plus two substrains, one resistant to streptomycin and the other to spectinomycin, were used to monitor nodule occupancy. Other strains tested were: ICARDA M53 and M15, both with and without resistance to streptomycin. As the Tel Hadya soil contained an effective population of R. meliloti, strain BZI was found to be a poor competitor for nodule formation with local medic rhizobia. Forty-eight percent of the nodules were formed by strain BZI and 52% by the native soil population. In addition, there were no statistical differences at the 5% level for earliness of nodulation and number of nodules. Similarly, herbage yields showed no differences when inoculated with BZI and other strains of R. meliloti as shown in Table 3.1.

The greenhouse experiment consisted of an RCB in which both M. rigidula selections were tested in pots containing soil from the field experiment. The inoculation treatment consisted of the same strains of rhizobia. The forms of inoculation included both the normal peat method and the lyophilized form of inoculation. As in the field experiment, ICARDA M3 strain outperformed BZI when assessed by nodule number and herbage production. Perhaps the hypothesis proposed by the French team might be correct if there are severe cold conditions after seed germination. It is also likely that behavior of medic rhizobial strains may also be affected in conditions of low temperature in semi-arid regions, a matter that requires further experimentation. **- J.C. Cleyet-Marel, M. Obaton, G. Gintzburger and Luis Materon**

Table 3.1. Herbage yields of two *M. rigidula* selections when inoculated with a variety of rhizobial strains including BZI.

M. rigidula selection	Treatment	Herbage yield (t DM/ha)
716	BZI	5.54
2119/1902	BZI	4.92
716	BZI strep resistant	5.04
2119/1902	BZI strep resistant	5.44
716	BZI spect resistant	6.17
2119/1902	BZI spect resistant	4.84
716	ICARDA M53 strep resistant	5.15
2119/1902	ICARDA M53 strep resistant	5.50
716	ICARDA M53	5.43
2119/1902	ICARDA M53	4.59
716	ICARDA M15 strep resistant	5.33
2119/1902	ICARDA M15 strep resistant	4.78
716	ICARDA M15	4.65
2119/1902	ICARDA M15	3.57
716	Uninoculated + 90 kg N/ha	5.89
2119/1902	Uninoculated + 90 kg N/ha	4.21
716	Uninoculated	5.19
2119/1902	Uninoculated	3.56
Std error of the difference between two selection means at the same level o f strain treatment		0.965
LSD (5%)		2.027
Std error of the difference between two treatment means for the same selection mean or for different levels of the selections		0.8
LSD (5%)		1.680

3.1.2. Genetic diversity of some French and West Asian medic strains of *Rhizobium meliloti*

In vitro experiments conducted in Montpellier revealed that two French selections of *M. rigidula* (Combaillaux and St Bauzille) inoculated with indigenous rhizobial strains produced 3.5 times more herbage than *M. rigidula* sel 716 inoculated with the same strains.

However, M. rigidula sel. 716 had better nodulation and produced more herbage than the French medic nodulated by local rhizobia. Strain ICARDA M29 produced 5 times more herbage in M. rigidula sel. 716 than any other strain, including those isolated in France.

It was also found that isolates of R. meliloti from M. orbicularis, M. minima, M. truncatula, M. polymorpha, M. sativa and M. rigidula nodulated very poorly when associated with M. rigidula sel 716. Plants inoculated with these isolates produced approximately 4.5 times less herbage than others inoculated with ICARDA M29. On the other hand, the French selection of M. rigidula was well nodulated by isolates of rhizobia from all the above species, which produced similar herbage yields. All these isolates outperformed ICARDA M29 on the Combaillaux medic selection. These results clearly indicate the complexities of the close interaction between the environment, the host plant and its rhizobial partner and demonstrates their coevolution.

To study the genetic characteristics of the ICARDA and French strains of rhizobia their cultural, serological and chromosomal characteristics were analyzed. Plasmid profiles indicated the presence of a megaplasmid characteristic for all the strains of R. meliloti having a molecular weight higher than 300 Md. Plasmids of the French rhizobia had molecular weights of 300, 160, 95 and 70 Md. ICARDA M29 and CC169 strains revealed plasmids of 90 and 99 Md, respectively, in addition to the common megaplasmid of 300 Md. - **J.C. Cleyet Marel, P. Bourgeais and L.A. Materon**

3.1.3. International inoculation network experiments

Because each country of the region has different environmental and soil microbial characteristics it is necessary to conduct experiments on host/Rhizobium relationships with cooperators from national institutions. Without such research the recommendations emanating from Tel Hadya are likely to be misleading when applied, for example in Jordan. International networking increases awareness in respective countries on the need to solve problems related to inoculation and nitrogen fixation and increases the demand for training. The network also enables ICARDA to evaluate its rhizobial strains in different environments and compared them with the indigenous populations.

Table 3.2 lists the experiments conducted by members of the network in 1989-90. The research was targeted to annual medics and their rhizobia.

Table 3.2. International network for inoculation of pasture and forage legumes: activities during 1989-90 (all on medics).

Collaborative Institution	Country	No. of sites
Ministry of Agriculture	Jordan	1
Ministry of Agriculture	Syria	4
Ministry of Agriculture	Iraq	1
Alfateh University	Libya	1
Ministry of Agriculture	Iran	1
Ministry of Agriculture	Algeria	2
University of Cukurova	Turkey	1
University Moulay Ismail	Morocco	3
Agric. Res. Institute	Cyprus	1
University of Granada	Spain	1
University of Thessaloniki	Greece	1
INRA Montpellier	France	2
Ministry of Agriculture	Chile	1
CSIRO/Canberra	Australia	1

Jordan. A series of experiments were conducted in cooperation with the National Center for Agricultural Research and Technology Transfer (NCARTT) at Ramtha Research Station. The experiments aimed at evaluating 18 strains of R. meliloti for symbiotic performance. Investigations on inoculation techniques involving coating and inoculant adhesives were also conducted at Ramtha.

Strain selection. As reported in the previous season, results indicated that M. rigidula sel 716, M. rotata sel 2123, M. polymorpha sel 1035 and M. truncatula cv Jemalong showed marked preferences towards those strains which were more specific than others. The highlights of these experiments are: M. rigidula responded to inoculation with strains ICARDA M54, M254 and M460 producing 3330, 2850 and 4300 kg of dry herbage per hectare. Uninoculated yield was 1990 kg/ha and with 90 kg N/ha the yield was 3,080 kg dry herbage/ha. This is a clear indication of the savings accrued to fixation by the legume compared with nitrogen fertilization. Significant interactions between the hosts and the strains were evident. Some strains were highly superior in a particular host. Yields of dry herbage ranged from 770 to 3920 kg/ha for all inoculated species, excluding M. rigidula.

Based on previous investigations conducted during three years the following strains of Rhizobium meliloti can be recommended for Jordan: for M. rigidula strains ICARDA M53, M254 and M460; for M. rotata strains ICARDA M15, M60 and M417; for M. truncatula strains ICARDA M15, M32, M53, M60, M178, M254, M367, M404 and M417; and for M. polymorpha strains ICARDA M15, M32, M53, M60, M254, M367 and M417. In all cases, these strains, when associated with the respective specific host, produced significant increases ($P \geq 0.05$) in dry herbage compared with those of the native medic rhizobial populations. Some of these strains performed similarly well under the moisture stress conditions which prevailed in the previous seasons.

Inoculation techniques. If the peat inoculant is to adhere satisfactorily to the seed, the slurry must contain an adhesive solution. This ensures that the material containing the bacteria will be kept together with the seed. Some of the adhesives have been reported to sustain rhizobia thus decreasing mortality rates and extending viability. Materials with certain types of carbohydrates have proved convenient for this purpose.

Some experiments were conducted in Jordan at Ramtha Experiment Station in which these inoculation techniques were evaluated. The adhesives used were gum cellulose, polyvinylpyrrolidone (PVP), gum arabic and water on four medic species. Number of nodules was significantly increased in M. rotata when the inoculant was treated with a solution of 20% gum arabic: an average of 64 nodules per inoculated plant versus 4 nodules when the plant was not inoculated. Dry matter yields varied according to the host, as each host was inoculated with a specific strain of Rhizobium meliloti. Gum arabic, molasses and gum cellulose were the best adhesives for the inoculants when assessed as herbage yield of medic. Inoculated seed produced more than double the quantity of dry herbage yield when measured at seeding stage when compared with the uninoculated treatment.

After the seed has been inoculated with the slurry of peat and adhesive solution, it is usually recommended that a coating material be applied. Materials such as ground rock phosphate or calcium carbonate (lime) may increase viability of rhizobia by protecting them against adverse environmental factors such as desiccation. A trial was conducted at Ramtha Experiment Station in which seed inoculated with ICARDA M3 was treated with calcium carbonate and rock phosphate. The results indicated no differences due to coating. As the hypothesis that application of a coating material gave extra protection was statistically rejected in the experiment, we believe the technique needs further investigation, as other factors may have been responsible for the unexpected results - **NCARTT and L. Materon**

Cyprus. Special interest has been shown by the Cyprus Ministry of Agriculture in increasing herbage yields by inoculating medic seed with specific strains of rhizobia. Experiments conducted last season showed significant increases in herbage yields in M. rotata, M. truncatula, M. polymorpha and M. rigidula when inoculated with superior strains of R. meliloti (PFLP Annual Report 1989, p 64). Similar experiments were carried out in a different location in Cyprus. The results indicated similar trends in herbage increases and a high proportion of nodules formed by the inoculant strain. Pure cultures of inoculant strains for the above medic hosts have been released to the Cypriot National Program.

Turkey. The effect of the pesticide aldicarb (Temik) and carbofuran on survival of pasture rhizobia is currently being evaluated using soils of central southern Turkey. Currently an in vitro technique is being developed utilizing various quantities of aldicarb in the rooting medium of Medicago noeana and M. rigidula and the populations of medic rhizobia tested using the most probable number technique (MPN).

A greenhouse experiment conducted at Cukurova University examined doses of the pesticides corresponding to the recommended application rates (1.62 kg aldicarb/ha and 1.5 kg carbofuran/ha), half of this rate and no application. Inoculation was done by giving 1 ml of a liquid suspension of Rhizobium meliloti strains ICARDA M192 and 197 to seedlings of M. noeana and M. rigidula growing in Jiffy pots. The seedlings were raised from surface sterilized seed. Plants were harvested after five weeks of growth. Results indicated that both chemicals markedly affected the symbiotic system ($P \geq 0.01$) regardless of the medic host. As expected, there were significant differences in herbage yield and root biomass ($P \geq 0.05$) in the host by inoculant interaction. Similarly, the numbers of nodules were affected by the recommended doses of both pesticides. The effects merit further investigation. - **M. Engin and L. Materon**

Morocco. Increases in herbage yield of M. rigidula, M. polymorpha and M. rigidula were detected in two localities around the city of Meknes and under glasshouse conditions. The second year results were similar to those reported previously (Annual Report 1989 p 65). Significant increases of between 230 and 310% resulted from using strains ICARDA M29, M38, CC169 and W118. In contrast to the previous year there was no response to inoculation with strains U45 and WSM244. Efforts are being made to release the tested rhizobial inoculants as pure cultures to agricultural institutes in Morocco that are currently developing inoculant production facilities.

Fractional distribution of biologically fixed nitrogen by annual Medicago species to the following wheat crop is a major interest in Morocco. Miss Nadia Lahrach, a graduate student, has been actively involved in field and glasshouse experimentation on this subject since January 1990. - **M. Ismail, N. Lahrach and L. Materon**

3.1.4. Improvement of the energetic efficiency of medic rhizobia (in collaboration with Polytechnical University, Madrid, Spain and INRA, Montpellier, France)

In the process of nitrogen fixation, hydrogen is lost as a gas diffusing out of the nodules of medic plants. However, some other groups of rhizobia, which are able to nodulate legume plants other than medics, recycle hydrogen by means of an enzymatic system. The enzyme involved is called hydrogenase. If R. meliloti were able to recycle its lost protons (H^+), the nitrogen - fixing process in the Medicago genus would be more efficient energetically.

Because medic rhizobia do not possess the genes coding for hydrogenase, we are attempting to incorporate the hydrogenase gene from R. leguminosarum into the genome of R. meliloti using molecular biology techniques which have been developed recently. The strains being engineered are compatible with some of the medic species of interest to ICARDA and national programs.

The objective is to transfer the gene P Sym-hup, which codes for nitrogen fixation and hydrogen uptake, located in a portion of a plasmid carried by R. leguminosarum strain 128C53 into the genome of R. meliloti strains ICARDA M29 and M34 (Spanish cooperator) and ICARDA M15, M24 and M138 (French cooperator). The plasmids have been marked by the transposon system (Tn-mob) and transferred by bacterial conjugation into the receptor rhizobial strains. The organisms so produced are still being tested for genetic stability, possible alterations due to the presence of the double gene coding for nitrogen fixation and hydrogen recycling. The effect of oxygen concentration and its role in accepting electrons in the presence hydrogenase systems is now under study by Dr. Drevon in France. Once these parameters are defined and the genetically engineered rhizobia recommended for release, we will evaluate their symbiotic performance in association with the annual medics of interest to the Program.

ICARDA is aware that there are reservations about the release of genetically engineered micro-organisms into the environment. Rhizobia are nonpathogenic and do not represent any risk whatsoever to the environment. ICARDA will respect the views of organizations and countries and only proceed with the release of genetically engineered strains when it is considered safe. - **L. Ruiz-Argüeso, J. Drevon and L.A. Materon**

3.1.5. Freeze-dried oil-based inoculants (in collaboration with Boyce Thompson Institute at the University of Cornell, USA)

A joint approach is being taken with the Boyce Thompson Institute for the improvement of viability of seed-applied rhizobia on medic seed under dry conditions. Pre-inoculation of seed has not been widely adopted because desiccation often results in low bacterial counts. Recent reports of a new type of inoculant suggest an alternative to the pre-inoculation technique. Inoculants prepared by suspending lyophilized rhizobia in oil have been found to maintain cell viability on inoculated seed (Kremer and Peterson, 1982; 1983). The oil-based inoculant was found to be superior to a standard peat-based inoculant particularly under hot, dry conditions, thus making it attractive as a pre-inoculation strategy.

For developing countries, oil-based inoculants have certain advantages over peat-based types. Oils are generally freely available and inexpensive, and production technology often already exists within the pharmaceutical industry. Freeze-dried inoculants have the advantage that they can be applied at higher rates (cells per seed) than peat-based inoculants.

Here we report preliminary aspects of joint research conducted last year with the aim of developing basic knowledge of this technology for the ICARDA region.

We have reported previously (ICARDA Annual Report, 1988) that when lyophilized medic rhizobia were suspended in Syrian olive oil and in paraffin oil, a steady decline in numbers was observed after the fourth week as shown in Table 3.3. This was prevented by adding finely powdered charcoal as coating material.

Lyophilization or freeze-drying of rhizobial cells also ensures long viability and lack of genetic variability during long -term storage. Research is currently being conducted at ICARDA on the most suitable technique to store rhizobial cultures in a lyophilized form in ampoules under vacuum and on the reconstitution of the culture.

Table 3.3. Viability of R. meliloti strain ICARDA M15 from oil-based inoculants on medic seed as affected by time and type of suspending oil when stored at 26°C. In parentheses, data from inoculated seed treated in addition with finely powdered charcoal.

Week	Log_{10} number of rhizobia per seed			
	Olive oil		Paraffin oil	
0	6.62	(6.35)	6.30	(6.52)
1	5.78	(6.30)	5.67	(6.49)
2	5.49	(6.21)	5.33	(6.40)
3	-	(6.25)	-	(6.43)
4	5.15	(6.11)	4.88	(6.24)
5	-	(6.15)	-	(6.05)

Studies conducted at ICARDA under greenhouse conditions using seed inoculated with lyophilized bacteria suspended in oil resulted in similar nodulation of the plants inoculated with normal peat inoculants. Emphasis will be given to studies in which seed inoculated with lyophilized bacteria is exposed to moisture stress and to conditions of bacterial competition for nodulation. Enumeration of the system is conducted by the most probable number technique.

3.1.6. Nutrition studies on the medics of nodulation

In some circumstances the particular strain of Rhizobium suitable for nodulating a medic host may vary, depending on the environment (Materon and Cocks, 1987). These interactions between the environment and the Rhizobium strain make the task of ensuring adequate nodulation of medics extremely complex. The soil environment is one component of the total environment which is likely to have a large influence on these interactions and is an area which needs definition.

Nitrogen and phosphorus are important factors of the soil environment which will effect the development of the N-fixing symbiosis (Pate, 1977; Israel, 1987). The symbiosis is generally inhibited by nitrogen but nodulation may be promoted under some conditions. Phosphorus is specifically involved in nodule initiation, growth and function (Israel, 1987). So the efficiency with which medics take up P may therefore influence the effectiveness of the symbiosis.

Experiments were designed to determine which of the medics species regarded as potentially suitable for pastures in the west Asian north African regions are most sensitive to applied nitrogen in terms of nodulation. Experiments were also designed to determine whether these nodulated medics have a differential ability to fix nitrogen at low external phosphorus concentrations.

3.1.6.1. Effect of nitrate on the nodulation of medics

Greenhouse experiment. Four rates of nitrate (0, 1, 6, 16 mM NO_3^-) were applied to six species of Medicago (M. noeana IFMA2351, M. orbicularis IFMA3313, M. polymorpha IFMA1172, M. rigidula IFMA811, M. rotata IFMA2600, M. truncatula cv. Jemalong) in combination with four strains of Rhizobium meliloti (ICARDA M15, ICARDA M176, ICARDA M201, ICARDA M28). Plants were grown in Modified Gibson tubes (Gibson, 1987) where the agar slope in Gibson's description was replaced by vermiculite that filled the entire tube.

M. noeana and M. orbicularis were generally poorly nodulated at all nitrate levels, so, for simplicity only, results for M. polymorpha, M. rotata, and M. truncatula are presented here. The effect of nitrate on the number and appearance of nodules depended greatly on the rhizobial strain and medic species (Figure 3.1). Nitrate tended to increase or have no effect on the number of

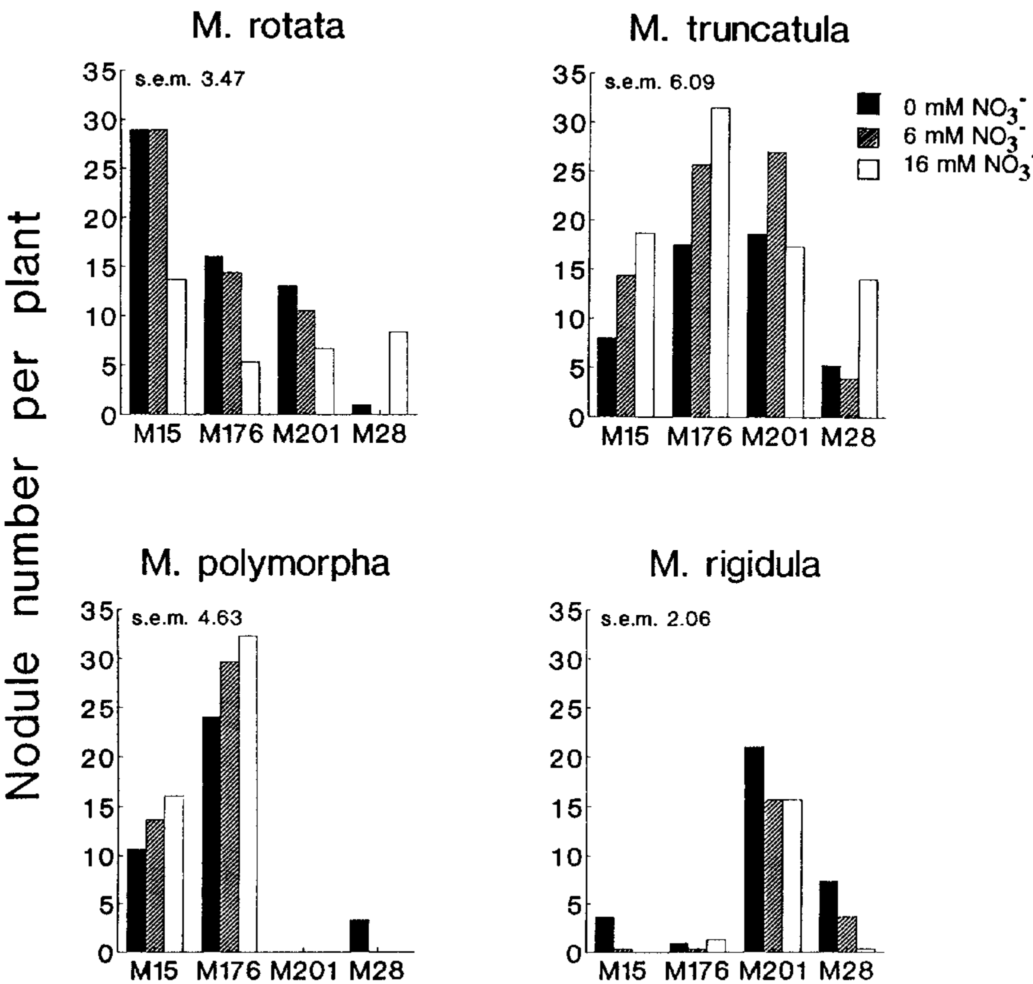

Figure 3.1. The effect of nitrate application on the dry weight of shoots of four species of _Medicago_ inoculated with four strains of _Rhizobium_ _meliloti_.

nodules formed by _M_. _polymorpha_ and _M_. _truncatula_ but decreased the number formed by _M_. _rotata_ or _M_. _rigidula_. _Medicago_ _rotata_ was most severely affected by nitrate with nodule number decreasing by over 50% by the addition of 16 mM nitrate with strains M15, M176 and M201. Important differences occurred between strains. For example, in contrast to the general trend for M. rotata, nitrate increased the number of nodules formed by M28. Also 16 mM nitrate almost completely eliminated nodules formed on M. rigidula by M28, whereas it reduced the number of nodules formed on this species by M201 by less than 30%.

Results from this experiment clearly indicated that the response of nodulation to nitrogen of medics indigenous to west Asia and north Africa will depend on the particular combination of host species and Rhizobium strain present. Furthermore, widely differing conclusions about the effectivity of a particular strain of Rhizobium will occur if assessment is based on nodule number and appearance at different nitrogen levels. For example, the number of nodules formed on M. rotata by M15 and M28 was similar when 16 mM nitrate was applied, but the number was very different when no nitrate was applied; thus, very different conclusions about their effectiveness could occur.

The experiment also gave an indication of the likely effects of soil nitrogen on the nodulation of medics in pastures; however, caution is necessary because of the artificial conditions under which the plants were grown and the fact that nitrogen fixation or nodule weight were not assessed. Nevertheless, results in this experiment were supported by subsequent experiments which gave a better indication of how these medics are likely to respond when grown under field conditions.

Field experiment. This experiment was conducted at 2 locations - Tel Hadya (Syria) and Ramtha (Jordan). Treatments were a combination of 4 species (M. polymorpha IFMA1172, M. rigidula IFMA811, M. rotata

IFMA2600, M. truncatula cv. Jemalong), 2 nitrogen rates (equivalent to 0 and 60 (Tel Hadya) or 90 (Ramtha) kg urea/ha) and 4 phosphorus rates (equivalent to 0, 40, 80, 160 kg triple superphosphate/ha). Plants were all inoculated by the same strain of R. meliloti. There was no response to phosphorus at either location so only the nitrogen results are discussed here.

The experiment confirmed results from the greenhouse study. Species differed in their response to nitrate with nodulation of M. rotata being more sensitive to urea application than the other species (Table 3.4). The number of nodules formed by M. rotata decreased by 20-30% with urea application, while there was no effect on the other species.

It appears therefore that M. rotata and possibly M. rigidula are more sensitive to N, in terms of nodule formation, than either M. truncatula or M. polymorpha. Further work is continuing to confirm these differences.

Table 3.4. Effect of nitrogen on the number of nodules formed by medics on fields in Syria and Jordan.

Species	Syria		Jordan	
	N0	N90	N0	N90
M. polymorpha	15	14	13	14
M. rigidula	17	18	3	2
M. rotata	28	23	21	15
M. truncatula	17	17	11	8

s.e.m. Syria 1.4
Jordan 1.1

3.1.6.2. Effect of phosphorus on the nitrogen fixation of medics

The effect of 4 phosphorus rates (0, 20, 60, 180 mg P/kg soil, applied as KH_2PO_4) on the growth and nodulation of 3 medic species (M. polymorpha IFMA1172, M. rigidula IFMA2351, M. rotata IFMA2600) inoculated with 2 strains of R. meliloti (ICARDA M3, streptomycin resistant; ICARDA M29, kanamycin resistant) was determined in a pot experiment in the greenhouse. M. rigidula and M. rotata had an additional treatment of no inoculation and thus were nodulated by the rhizobia indigenous in the soil.

All species responded strongly to phosphorus. The response for each species, however, varied depending on the particular strain of Rhizobium by which it was nodulated. The most important differences were seen between the strains nodulating M. rotata.

Nodulation of M. rotata by indigenous Rhizobium (IR) produced maximum dry weight at a lower rate of phosphorus application than when it was nodulated by M29 or M3. These differences were also reflected in the N concentrations in the shoots; plants nodulated by IR reached their maximum N concentration at a lower P rate than plants nodulated by M29 or M3. Maximum growth and N concentration of shoots of M. rotata were the same regardless of the strain of rhizobia forming the nodules. Differences therefore could not be explained by differential effectiveness of the rhizobial strains with the host.

The response of nodule dry weight and number to phosphorus was the same for each species and did not differ among strains. All species achieved 70-80% of maximum dry weight or number of nodules at 60 mg phosphorus application.

Results of this work have potentially important implications for pastures in west Asia and north Africa. It appears that maximum growth and N fixation of medics in some situations may be limited by their ability to fix N with some rhizobia at low soil P levels. It follows therefore that it may be possible to select strains of R. meliloti which are more efficient at fixing N at these levels. Cassman et al. (1981) showed that it was possible to select strains of R. japonicum which are tolerant to low P levels. At present all preliminary rhizobial strain selection for medics at ICARDA is conducted at very high P levels. This may inadvertently select for strains that are poor at fixing N at low P levels. Much work, however, is still required. - **P. White and L. Materon**

3.1.7. Projects on non-symbiotic nitrogen fixation

It has been reported that the bacterium Azospirillum brasiliense fixes atmospheric nitrogen in association with the roots of several crops including cereals. Some researchers conclude that the plant growth responses to A. brasiliense may not be entirely to nitrogen fixation activity. Associations of A. brasiliense with cereal roots may increase permeability of the host roots to N, P and K ions, alter plant root growth due to bacterially produced growth-regulating substances, and alter root bacterial enzymatic activities. Plant growth regulators produced by A. brasiliense include auxins, gibberellin-like substances, cytokinins and other unidentified substances.

Another bacterium reputed to have associative nitrogen - fixing abilities is the yet unidentified Bacillus strain C-11-25. It has been shown that this bacterium supplied more nitrogen to wheat plants under temperate conditions than A. brasiliense, and that the amount of associative nitrogen - fixation was dependent on the host plant genome. It has not yet been determined whether the plant growth-altering activities of associative nitrogen fixing bacteria are also affected by the host plant genome. Previous research at ICARDA has indicated that genotypes of barley increased biomass in the presence of applied Azospirillum and phosphorus fertilization (ICARDA Annual Report, 1988-89).

A pot experiment was conducted to determine whether method of inoculation early nitrogen application affects non-symbiotic nitrogen fixation by rhizosphere microorganisms on barley and wheat in a soil low in available nitrogen. The cereals consisted of barley (cv Rihane 03), durum wheat (cv Cham-1) and bread wheat (cv Nesser). The microorganisms were obtained from Canadian and Italian researchers and designated as Azospirillum brasiliense 555, cd ATCC and 39. Three inoculation methods were compared: liquid inoculation (10 ml/seed), liquid inoculum mixed with sterile peat (25 ml/peat bag) to inoculate at the rate of 1 g per seed, 500 ml gum arabic mixed with a peat bag of inoculum and sprinkled on the seed bed, and no inoculation with and without nitrogen fertilizer. Nitrogen fertilization at the rate of 100 kg N/ha was split into two applications. The experiment also included the option of determining whether or not starter nitrogen at a rate of 20 kg/ha affected the performance of the inoculation treatments. The experimental design consisted of an RCB with three replicates. The weight of the soil in each pot was 3 kg. Eight seeds were planted per pot. The temperature in the plastic-house was 20-28°C. Plants were evaluated at different stages of growth, for appearance, root and shoot length, dry mass of shoots and roots, nitrogen content of roots and shoots.

For all the above parameters, no significant differences were detected ($P < 0.05$) between the means for the different inoculation methods within cultivars and between cereal treatments. This suggested that no increases in biomass and plant length were apparent in cereals planted in Tel Hadya soils when associated with non-symbiotic nitrogen - fixing microorganisms. The question of specificity and/or adaptability of the imported sources of inoculum remains to be investigated.

Applying a low amount of nitrogen with the intention of increasing the chances of nitrogen fixation only confirmed the response of the plants to nitrogen. Plants treated with starter nitrogen produced more shoot and root biomass regardless of the type of bacterial treatment applied at planting (Table 3.5).

Studies on non-symbiotic nitrogen - fixing bacteria and their effect on the growth of cereals are, at this stage, of low priority in the Program. Interest arose as virtually no research on this topic has been conducted in the ICARDA region. We will attempt to continue elucidating the factors affecting non-symbiotic nitrogen fixation by Azospirillum in cereals to establish the relevance of these systems in semi-dry areas. - **M. Zaklouta, L.A. Materon, G. Ortiz-Ferrara and M. Nachit**

Table 3.5. Effect of starter nitrogen on biomass production on barley and wheat inoculated with Azospirillum brasiliense.

Strain	Rihane 03		Cham 1		Nesser	
	N^+	N^-	N^+	N^-	N^+	N^-
Shoot dry mass (mg)						
AZO 555	518	356	463	326	420	305
AZO 39	520	280	509	350	485	333
AZO cd	564	325	414	479	465	251
Uninoc.	-	289	-	371	-	310
LSD (5%)[1] 71.5						
Root dry mass (mg)						
AZO 555	492	333	449	244	336	289
AZO 39	440	289	429	359	395	298
AZO cd	596	363	392	420	511	272
Uninoc.	-	275	-	289	-	274
LSD (5%)[1]	98					

[1]LSD for comparison of means excluding the uninoculated controls.

3.1.8. Laboratory activities

Rhizobial inoculants have been produced in the laboratory by means of fermentors utilizing gamma - irradiated peat imported from Australia. Quality of the inoculant is maintained by counting the number of rhizobia per gram of peat. The standard set is 10^9 rhizobia per gram. In 1989/90 the laboratory distributed 462 inoculant bags free of charge to cooperators throughout the region, mostly from countries of the Mediterranean basin (Table 3.6).

Table 3.6. International requests for peat-based inoculants for pasture and feed legumes in 1989/90.

Type of legume	Amount of seed inoculated	No. of bags of inoculant	Country[2]
Medics	595.0	170	Algeria
Lathyrus	24.0	8	Cyprus
Vetches	24.0	8	Cyprus
Medics	21.0	6	Cyprus
Vetches	3.0	1	Yemen
Medics	7.0	2	Yemen
Medics	17.5	5	Iran
Medics	7.0	2	Iraq
Medics	402.5	115	Jordan
Medics	35.0	10	Morocco
Medics	24.5	7	Turkey
Medics	420.0	120	Syria
Medics	14.0	4	France
Medics	14.0	4	Spain

[1] Each bag of peat-based inoculant weighs 90 g and inoculates approximately 3.5 kg of medic seed or 3.0 kg of the other species listed regardless of the type of bacterial inoculum.
[2] Includes cooperative projects between ICARDA and Ministries of Agriculture.

3.2. Results for 1990/1991 Season

3.2.1. The symbiotic response of a wide range of species of annual medics to strains of *Rhizobium meliloti*

Past research has concentrated on investigating the response of a selected number of species of annual medics to strains of *Rhizobium meliloti*. These medics (*M. rigidula*, *M. noeana*, *M. truncatula*, *M. polymorpha*, *M. rotata* and *M. orbicularis*) represent a range of potential economically important species for ley farming systems in the Mediterranean region. A group of elite strains of rhizobia have been identified, tested and recommended as effective inoculants for these particular legumes. In view of the marked strain by host interaction usually present in our studies, it was necessary to expand research efforts to other species of annual medics occurring naturally in the region.

The medic species, obtained from the Genetic Resources Unit, were: M. blancheana, M. minima, M. aculeata, M. scutellata, M. coronata, M. radiata, M. intertexta, M. rigidula, M. polymorpha and M. orbicularis. The source of inoculum consisted of R. meliloti strains ICARDA M15, M29, M53, M194, M197, M235, M276 and M277. Uninoculated controls with and without nitrogen were also included. The combinations of treatments were arranged as a completely ramdomized set of tubes in racks containing 100 tubes. Racks with tubes were changed in position on a daily basis. Four replications for each host x treatment combination were included.

The experiment was conducted in a plastic house using modified Gibson tubes. The sterile in vitro system contained vermiculite and a mineral solution lacking nitrogen. Seedlings were raised from disinfected seed and transferred aseptically to the tubes. Inoculation was then performed using 1 ml of a bacterial suspension.

The parameters evaluated during the growth cycle were visual score of shoots at the 14th and 28th day after inoculation, number of nodules, quality of nodules, and shoot biomass at harvest. Plants were grown for 28 days at an average temperature range of 15-25°C.

The in vitro system allowed us to detect differences among strains in their ability to nodulate medic species. The inclusion of the uninoculated control containing 70 ppm of nitrogen verified that plants responded normally to all the physiological and environmental factors to which they were exposed during the growth period. In contrast, plants of the uninoculated controls with no mineral nitrogen showed typical symptoms of nitrogen deficiency, stunted plants with yellowish foliage and purple stems. No nodulation occurred on the roots of the uninoculated control plants.

Table 3.7 shows consistent plant response to rhizobial strains as indicated by correlation coefficients. Absolute values higher than 0.71 and 0.83 indicated significant correlations at the level of 5 and 1%, respectively. On this basis, there were strong associations between medic species in response to inoculation: the symbiotic behavior of M. polymorpha with either M. intertexta, M. blancheana or M. aculeata or among themselves, was very similar and showed no evidence of strain-specific associations. The pairs M. rigidula and M. coronata, and M. orbicularis and M. minima exhibited the same consistency of symbiotic response.

In general, nitrogen fixation and nodulation of most of the species responded differently to the rhizobial strains. The weak and negative correlations (Table 3.7) indicated that these medic species required specific strains of R. meliloti in order to produce effective nodules and fix sufficient nitrogen. Results on M. truncatula, M. rigidula and M. polymorpha confirmed previous findings, which showed the necessity to use highly specific strains. It is noteworthy, however, that we have already identified superior strains for these particular species.

As with some other temperate legume genera, medics display a high specificity for their rhizobia. Their symbiotic habit ranges from promiscuous to high specificity depending on the type of indigenous soil rhizobia. Table 3.8 shows the effect of strain of rhizobia on the herbage biomass with strong strain-specific interactions between rhizobial strains and some medics.

Results strongly indicate that there is potential to select better strains of rhizobia for all medics. In most cases, herbage yields of uninoculated plants were not significantly different from those of the inoculated treatments. Superior strains were detected,

Table 3.7. Correlation coefficients for the relationships between the symbiotic response of 11 annual medic species and 8 strains of Rhizobium meliloti (In vitro experiments).

	min	rig	cor	pol	rad	int	scu	tru	bla	acu
orb	-0.74	0.10	0.02	-0.28	-0.17	-0.16	0.005	0.49	-0.19	-0.44
min		-0.01	-0.13	-0.08	-0.59	-0.06	-0.17	0.58	-0.33	-0.17
rig			0.83	-0.09	0.65	-0.06	-0.51	-0.25	-0.04	-0.05
cor				-0.23	0.64	-0.22	-0.51	-0.44	-0.05	-0.10
pol					-0.30	0.98	0.01	0.02	0.87	0.91
rad						-0.28	-0.40	-0.36	-0.01	-0.34
int							0.11	0.04	0.91	0.89
scu								-0.22	0.14	0.20
tru									-0.17	-0.25
bla										0.79

d.f. = 6; r = 0.71 (P = 0.05); r = 0.83; (P = 0.01)
orb = M. orbicularis, min = M. minima, rig = M. rigidula, cor = M. coronata, pol = M. polymorpha, rad = M. radiata, int = M. intertexta, scu = M. scutellata, tru = M. truncatula, bla = M. blancheana, and acu = M. aculeata

Table 3.8. Effect on foliage dry weight (mg/plant) of inoculating 11 species of annual medics with 8 strains of Rhizobium meliloti.

Strain	acu	bla	cor	int	min	pol	rig	orb	rad	scu	tru
M15	23	20	24	29	5	11	10	10	9	173	10
M29	21	16	23	41	6	17	11	10	9	63	16
M53	57	55	22	118	5	42	10	11	7	106	13
M194	16	29	24	40	6	15	7	15	7	17	14
M197	26	27	55	42	6	16	15	12	14	40	11
M235	14	21	26	47	10	15	12	20	7	96	15
M276	22	18	26	38	8	17	10	12	7	42	13
M277	8	28	32	36	4	14	12	13	17	48	13
NIL + N	-	125	98	133	26	70	50	35	55	112	85
NIL	7	14	12	24	5	14	9	11	10	37	10
LSD	10.7	13.9	10.2	16.6	3.8	9.6	7.7	6.9	5.4	87.9	8.7

LSD values only for corresponding column at $P \geq 0.05$.
acu = M. aculeata, bla = M. blancheana, cor = M. coronata, int = M. intertexta, min = M. minima, pol = M. polymorpha, rig = M. rigidula, orb = M. orbicularis, rad = M. radiata, scu = M. scutellata, tru = M. truncatula.

however, which resulted in plant growth 4 to 5 times greater than the uninoculated control plants. Strain M15, M53 and M194 produced good quality nodulation and nitrogen fixation in M. scutellata. In addition, strain M53 had a broader spectrum of promiscuity compared with other strains. M53 was superior in fixing nitrogen in association with M. intertexta and was effective with M. aculeata, M. blancheana and M. polymorpha. All species responded to inoculation with at least one of the strains, with the exception of M. radiata, M. orbicularis, M. truncatula and M. rigidula. These investigations revealed that most of the medic species tested in the region need specific rhizobia in order to fix nitrogen. Once effective rhizobia are identified and prove satisfactory under field conditions, they would be suitable inoculants for their respective hosts in situations where inoculation is deemed necessary. More studies will be conducted in the coming season with additional accessions and species of annual medics. - **L.A. Materon and J. Valkoun**

3.2.2. Collection of rhizobia for pasture and feed legumes

The Program aims to establish an international collection of Rhizobium meliloti for annual Medicago, R. trifolii for trifoliums (clovers), and R. leguminosarum for feed legumes (Lathyrus, Vicia, Astragalus) and other indigenous legume species. The objectives of the collection are to:

- have a bank of effective strains suitable for legumes with economic potential for the region;
- promote and encourage research in strain selection in WANA, and
- preserve the microbial resources in the region.

Most of the strains are collected from nodules and soils of the region during winter or spring. Dilutions from a particular soil sample collected from a specific area are used to inoculated legume seedlings. Rhizobia are then isolated from the nodules and preserved in a lyophilized (freeze-dried) state to minimize genetic variation and prolong storage life. Purified strains of rhizobia for pasture and feed legumes are available upon request to scientists of national programs and elsewhere.

At present, the rhizobial collection consists of 685 purified strains of effective rhizobia for pasture and feed legumes. Most of the strains consist of R. meliloti with 466 strains for annual medics, 58 for medics adapted to acid soils (most from Morocco) and 22 medic strains obtained from foreign collections. The second group holds a collection of clover rhizobia (R. trifolii) with 128 strains collected in the region. In addition, the rhizobial collection for feed legumes is made up of 28 strains for Lathyrus (vetches), and the remainder for Pisum, Astragalus, Hymenocarpus and Scorpiorus.

Cultures of spontaneous antibiotic-resistant mutants of 35 strains of medic rhizobia are also included in the collection. The collection is continually expanding with the assistance of cooperators from national institutions, including IBPGR, MIRCENs, and ICARDA's Genetic Resources Unit.

Our laboratory also produces peat-based inoculants utilizing gamma - irradiated peat imported from Australia. Quality of the inoculant is monitored by counting the number of rhizobia/g peat. The standard set is 10^9 rhizobia/g of peat. In 1990-91 the laboratory distributed a record number of bags to cooperators throughout the region, mostly from countries of the Mediterranean basin (Table 3.9). Each bag weighs 90 g and inoculates approximately 3.5 kg of medic seed (R. meliloti) and 3.0 kg of vetch seed (R. leguminosarum). - **L.A. Materon and M. Zaklouta**

Table 3.9. International requests for peat-based inoculants for pasture and feed legumes in 1990-91.

Type of legume	Amount of seed inoculated (kg)	No. of bags of inoculant	Country*
Medics	298	85	Algeria
Medics	2488	711	Jordan
Medics	31	9	Iraq
Medics	17	5	Iran
Vetches	300	10	Jordan
Medics	882	252	Syria
Medics	56	16	Turkey
Medics	80	23	Morocco

*Includes cooperative projects between ICARDA and Ministries of Agriculture.

3.2.3. Symbiotic performance of lyophilized (freeze-dried) rhizobia under field conditions

Lyophilization or freeze-drying of rhizobial cells ensures long viability and lack of genetic variation during long-term storage. Joint research with cooperators at the Boyce Thompson Institute at Cornell University has indicated that lyophilized rhizobia, reconstituted and suspended in vegetable oil, are able to survive on seeds under adverse environmental conditions. Oil-based inoculants with lyophilized rhizobia have the advantage that they can be applied at higher rates (cells per seed) than peat-based inoculants. This is especially important for small-seeded legumes and where populations of ineffective rhizobia are large. Mortality of rhizobia by desiccation is common with the small seeds of Medicago, which have to be sown at a shallow depth. Alternative inoculation techniques are currently being explored to solve the problem of the rapid decline in the population of rhizobia applied on seeds.

Oil-based and peat-based inoculation were compared on seed of M. rotata sel 2123, M. rigidula sel 716, M. polymorpha sel 1035 and

M. truncatula cv Jemalong using the ICARDA M15, M29, M53 strains of R. meliloti.

The strains of rhizobia were freeze-dried and kept in vacuum in glass ampoules. Prior to planting the ampoules were cracked open and their contents reconstituted using vegetable oil. The suspension was then mixed thoroughly in a vortex apparatus for 4 minutes. Water was not used to reconstitute the freeze - dried material as it is known to be lethal to dehydrated bacteria. An aliquot of 0.2 ml of this suspension was used to inoculate 6-g batches of medic seed. Then finely powdered charcoal was used to coat the freshly inoculated seed. The other method of inoculation consisted of the traditional slurry paste made of finely ground peat inoculant and a sticker (25% solution of beet molasses) applied onto the seed and then coated with calcium carbonate.

The layout of the experiment was a split plot design having main plots as inoculation treatments and medic species as subplots with three replicates. Having inoculation treatments as main plots minimizes the chances of cross contamination. The size of plots was 2.5 m^2 with alleyways of 1 m between subplots and 2 m between main plots. There were 96 plots. At planting the soil contained 14.9% water and a low population of indigenous medic rhizobia (less than 500 rhizobia per g of soil). The soil contained 18 ppm P and was not fertilized with superphosphate. Carbofuran was applied at a rate of 30 kg/ha to prevent attack of Sitona weevil on the roots and nodules of the medics. Seed was sown on 6 December 1990.

Statistical analysis indicated some significant differences in herbage yields; all medics tested had nodules from peat and lyophilization treatments, except M. rigidula (Table 3.10).

The effect on herbage yield of the lyophilized rhizobial inoculant was significant in M. truncatula and M. polymorpha compared with yields from peat-based inoculation treatments.

Table 3.10. Herbage yields of medics as affected by methods of seed inoculation. Data from first harvest (April 17, 1991).

Inoculation treatment	Herbage yields (t/ha) M. rigidula	M. rotata	M. truncatula	M. polymorpha
M15/Peat	2.02	2.75	1.64	1.68
M15/Lyo	1.95	1.71	1.15	2.24
M29/Peat	1.78	1.48	0.61	0.88
M29/Lyo	1.62	2.17	1.69	1.28
M53/Peat	1.95	1.71	0.64	1.14
M53/Lyo	2.15	2.21	1.34	1.91
UC +N	3.11	3.15	1.96	2.21
UC -N	2.40	2.27	0.93	1.08

[a] LSD to compare herbage means within an inoculation level = 0.616
[b] LSD to compare same herbage means of same or different species between inoculation levels = 0.781.

Inoculation of M. truncatula with lyophilized strains M29 and M53 increased herbage yields by 260% and 210% respectively, compared with peat inoculation. Similarly, M. polymorpha inoculated with lyohilized M53 resulted in a yield increase of 170% compared with peat inoculation. Orthogonal comparisons also indicated that these contrasts were significant at the 5% level of probability. Inoculation method had no effect on the yields of M. rigidula and M. rotata. The question of comparing, and improving, the oil-based (lyophilized rhizobia) method with normal peat-based inoculation technique merits further research, which should include closer examination of the fate of seed-applied rhizobia. - **L.A. Materon**

3.2.4. Effect of environment on the rhizobial relationships with medics in Salamieh, Syria

It was reported previously that the symbiotic association between annual medics and their rhizobial partner is affected by the environment in which they grow. Most of the large-scale experimentation by ICARDA on this topic has been conducted at Tel

Hadya (Syria) and Ramtha Experimental Station (Jordan). Some observations of host x strain x environmental interactions and of lack of effective nodulation have also been recorded by our cooperators throughout the region. An experiment with 4 strains of Rhizobium meliloti (ICARDA M15, M29, M53 and BZI) and 3 species of medicagos, M. polymorpha sel 1035, M. rotata sel 2123 and M. rigidula sel 716, was designed at the request of the Syrian Ministry of Agriculture and carried out at the Agricultural Experiment Station located in Salamieh. The four strains are resistant to 100 μg streptomycin and effective on the above medic species. Salamieh is situated in slightly drier zone than Tel Hadya, with a mean precipitation of 285 mm.

The Olsen P value for the soil prior to planting was 9.2 ppm and based on this information phosphorus was applied at a rate of 9 kg P_2O_5/ha. Carbofuran (30 kg/ha) was applied to prevent Sitona weevil attack. The layout of the trial consisted of a split plot design having main plots as rhizobial strains and medic species as subplots. The plot size was 3.25 x 0.75 m with alleyways of 1 m.

The seed was inoculated with a slurry made of peat inoculant and a solution of molasses (25% vol/vol). Seed was coated by covering the freshly inoculated seed with a layer of fine powdered calcium carbonate. The seed at this stage contained 4.3×10^4 rhizobia. Seeds from the uninoculated controls with and without mineral nitrogen were planted first to prevent any cross contamination. The experiment was planted on November 11, 1990. The soil moisture concentration was 15.7% and the accumulated rainfall was 40 mm at planting. In addition, counts on the soil medic rhizobial population revealed a density of less than a thousand rhizobia per gram of soil in December. Thereafter the population increased to up to 7×10^3 rhizobia per gram of soil.

The station was visited regularly to check for number and distribution of nodules and record plant vigor. Nitrogen (30 kg N/ha) in the form of urea was applied 3 times during the growing season. Herbage was harvested on April 23 and May 14, 1991. The samples were transported to Tel Hadya for drying and processing.

The positive response of the three medic species to the indigenous strains present in the soil indicated that there is no need to inoculate these medics at Salamieh (Table 3.11). Cultures of these bacteria were isolated for further incorporation into our strain selection program. - **L.A. Materon, R. Kassem and M. Zaklouta**

Table 3.11. Herbage yields (t/ha) of medics with different inoculation treatments at 2 harvest dates.

Inoculation Treatment	Harvested (23-4-91) rig	rot	pol	Harvested (14-5-91) rig	rot	pol
M3	1.29	1.20	0.94	3.92	4.20	1.30
M15	1.11	1.16	0.77	5.17	3.42	1.53
M29	0.98	1.11	0.72	3.33	3.74	2.00
M53	1.27	1.33	0.95	3.12	3.08	1.65
BZI	1.25	1.49	1.26	3.94	3.15	1.48
UC +N	1.58	1.87	0.80	4.06	3.57	1.59
UC -N	1.23	2.05	1.06	3.77	4.52	2.23

rig = M. rigidula, rot = M. rotata, pol = M. polymorpha.
LSD to compare means of species within the same level of the inoculation treatment = 0.603 (first harvest) and 1.387 (second harvest).
LSD to compare means for the same or different levels of medic species within or across inoculation treatments = 0.703 (first harvest) and 1.575 (second harvest).

3.2.5. Rhizobial requirement of clovers in marginal lands

Past investigations using indigenous species of Trifolium spp. have shown variation in nitrogen fixation and nodulation response. Parasitic or ineffective nodulation was accompanied by low herbage yield and plants showed the typical symptoms of nitrogen deficiency. Clovers are important pasture legumes in marginal lands in the WANA region. We have initiated further research to elucidate whether the main species of clovers found in the region require inoculation, and if so, select the appropriate rhizobia for use in peat-base inoculants.

An experiment was carried out to evaluate the indigenous populations of Rhizobium trifolii and determine the degree of symbiotic association with various Trifolium species. Soil samples were collected at Tel Hadya from areas receiving nil and low phosphorus (25 kg P_2O_5/ha/year) fertilization in Project ML2 on field C2 (soils 1 & 2) and from 2 areas in field A24, which received 40 kg P_2O_5/ha/year (soils 3 & 4). Soil sampling was done at random at depths ranging between 10 and 20 cm. The samples were sieved carefully and sieves disinfected between samples to prevent cross contamination by indigenous rhizobia.

Seed of T. purpureum, T. resupinatum, T. lappaceum, T. speciosum, T. campestre, T. stellatum and T. tomentosum were mechanically scarified, disinfected and germinated on water agar plates. The plates were kept inverted to provide straight roots. Seedlings were then aseptically transferred to Gibson tubes. The tubes contained a rooting medium consisting of vermiculite and a nitrogen-free mineral solution. Dilutions of soil were prepared (10 g per 90 ml of water) as a source of inoculum. The soil suspensions were vigorously agitated in a reciprocating shaker for a period of 20 minutes. Plants were then inoculated with 1 ml of this suspension on the assumption that indigenous soil R. trifolii (clover rhizobia) produce nodules in the roots of the clover seedlings. Uninoculated controls with and without mineral nitrogen (70 μg N per liter of water=70 ppm N) were also included. Strains of R. trifolii ICARDA T5 and T49 were used as culture-source controls for comparative purposes. Strain T5 was isolated from a T. campestre plant growing in Tel Hadya (field C5) and T49 isolated in Morocco from a functional nodule of T. hybridum.

The experiment consisted of a completely randomized design. Wooden racks containing 100 tubes were periodically changed in position in the plastic house. There were six replications for each clover host by inoculation treatment. Plants were harvested 28 days after inoculation and shoot dry mass and number of nodules were recorded. Overall plant response on a scale from 0 to 5 and nodule appearance were measured according to a qualitative scale.

Results indicated considerable variation in response to inoculation regardless of whether the fields were amended with phosphorus or not. The significant responses in shoot yield due to inoculation were a function of the type of symbiotic association (Table 3.12). It was found that plant growth was, in general, much

Table 3.12. Shoot biomass production (mg/plant) of seven indigenous clover species in response to inoculation with four sources of Rhizobium trifolii.

Treatment	Species[1]						
	pur	res	lap	spe	cam	ste	tom
Soil 1	11.0	9.3	6.1	4.2	4.0	8.6	8.2
Soil 2	6.4	7.7	6.4	6.3	3.8	7.7	9.7
Soil 3	4.1	4.3	4.1	3.8	3.0	9.0	3.9
Soil 4	4.1	3.6	4.6	3.3	3.6	7.2	3.6
Strain T5	9.4	3.3	4.2	2.7	3.2	9.5	5.2
Strain T49	6.1	1.6	3.9	3.3	2.9	8.1	3.3
UC +N	17.8	15.5	10.5	6.3	5.3	17.5	16.4
UC -N	5.0	3.8	4.1	2.6	2.6	8.1	3.7
SEM	1.9	1.0	0.8	0.6	0.6	1.4	1.2

[1] pur = T. purpureum, res = T. resupinatum, lap = T. lappaceum, spe = T. speciosum, cam = T. campestre, ste = T. stellatum, tom = T. tomentosum

greater in response to mineral nitrogen than in response to the inoculations with the 4 soils and the 2 rhizobia. This highlights the need to select superior strains of R. trifolii able to match the responses of mineral nitrogen.

Shoot biomass (Table 3.12) of T. purpureum, T. resupinatum, T. lappaceum, T. speciosum and T. tomentosum inoculated with soils 1 and 2 were statistically superior to those inoculated with soils 3 and 4 and the suspensions of rhizobial strains T5 and T49. This reflects the presence of functional, effective nodules (Table 3.13). In contrast, T. campestre and T. stellatum were ineffectively nodulated by the indigenous rhizobia in the soils but responded to inoculation with rhizobia of strains T5 and T49. All plants which were inoculated with soil suspensions of field A24 (soils 3 and 4) were chlorotic and were similar to those of the uninoculated control. Examination revealed the absence of nodulation.

Table 3.13. Number and effectiveness (in parenthesis) of nodules of clover species inoculated with indigenous and introduced Rhizobium trifolii.

Treatment	Species[a]						
	pur	res	lap	spe	cam	ste	tom
Soil 1	3(E)[b]	4(E)	3(E)	4(PE)	4(I)	1(I)	4(E)
Soil 2	0	5(E)	7(E)	8(E)	4(I)	0	4(PE)
Soil 3	0	0	0	0	0	0	0
Soil 4	0	0	0	0	0	0	0
Strain T5	4(E)	0	0	4(I)	6	6(E)	4(I)
Strain T49	4(I)	0	0	5(E)	0	9(E)	1(I)
SEM	0.7	1.0	1.1	1.6	1.6	0.8	1.4

[a] pur = T. purpureum, res = T. resupinatum, leap = T. lappaceum, spe = T. speciosum, cam = T. campestre, ste = T. stellatum, tom = T. tomentosum

[b] E = effective, PE = partially effective and I = ineffective nodulation.

The indigenous rhizobial population of soils 1 and 2 nodulated T. purpureum, T. resupinatum, T. lappaceum, T. speciosum and T. tomentosum. Although nodulation was functional and the plants fixed nitrogen, shoot biomass was lower ($P \geq 0.05$) than that produced when the plants were treated with mineral nitrogen. This again clearly indicates the need to search for superior strains of Rhizobium trifolii.

The behavior of the plants inoculated with strains ICARDA T5 and T49 deserved some discussion as they showed selective responses by clovers to rhizobia. T. tomentosum was incompatible with both strains and nodulation was ineffective. Both strains produced no nodules in T. lappaceum and T. resupinatum. T. speciosum and T. campestre had contrasting responses: T5 produced ineffective nodules in T. speciosum and effective ones in T. campestre, whereas TA9 strain produced effective nodules in T. speciosum and no nodulation in T. campestre (Table 3.13). - **L.A. Materon and A. Osman**

3.2.6. Studies on dynamics of populations of medic rhizobia

Many factors affect the viability of rhizobia applied on seed once they are in soil. Temperature and desiccation are known to drastically reduce their numbers. Seeds of annual medics are small (2-4 mm) and must be planted at 2 to 3 cm to allow them to germinate, which poses a problem for the rhizobia, as the soil temperature is higher at this depth. We have investigated techniques of inoculation that will extend the survival of rhizobia applied on seed. Although there should ideally be between one and ten thousand rhizobia per seed, adverse conditions at or after planting may reduce these numbers to less than one hundred per seed.

Experiments were initiated to further quantify this problem. One of the difficulties is that the methods of counting bacteria retrieved from the soil involve the use of the most probable number technique (MPN). The technique requires growing plants raised from disinfected seed to estimate numbers of rhizobia by the presence and absence of nodules at a certain level of a dilution series. We are trying to develop a technique that will allow direct counts of rhizobia and exclude, by the use of selective media, the many microbial contaminants that commonly appear on agar plates. In this preliminary attempt, we found that the yeast mannitol agar medium (YMA) supplemented with 30 ppm of congo red and an antibiotic was sufficient to exclude many microorganisms and made counts of rhizobia easier.

Seeds of Medicago polymorpha and M. scutellata were inoculated with antibiotic - resistant mutants of Rhizobium meliloti strain ICARDA M15 and planted in Jiffy pots (8 x 7.5 cm) containing soil. Seeds of M. polymorpha and M. scutellata had average lengths of 3 mm and 4 mm respectively. The Jiffy pots were buried in the soil, simulating a block of soil, and their surfaces were at the same level as the field. The pots were then removed and taken to the laboratory where seeds were located with the minimum of disturbance using a forceps. Pot units were taken after 0, 2, 3, 4, 7 and 13 days after planting. Temperatures were low and the soil had a low moisture content during this period of sampling. The test was done with seed that did not germinate. Ten seeds per treatment were put into a test tube containing 10 ml of water. The seeds were shaken in a vortex for 3 minutes to dissolve the inoculant coat and uniformly suspend the bacteria in the water. Ten-fold dilutions were prepared and aliquots of 0.1 ml from dilution levels up to 10^4 were uniformly spread on the surface of duplicate YMA plates. The plates were incubated at 26°C for 3 days and then removed for counting.

Results from this preliminary study (Table 3.14) indicated that the numbers of rhizobia applied on seed were not significantly different from numbers at day 0. An average of 100,000 viable

Table 3.14. Numbers ($\log_{10}$/seed) of K. meliloti (strain ICARDA M15) on surviving on seed of Medicago placed in soil (Counts were performed on seed that had not germinated).

Days after inoculation	M. polymorpha	M. scutellata
0	5.00	5.10
2	5.00	5.29
3	5.18	5.63
4	4.84	5.42
7	5.26	5.16
13	5.18	5.32
LSD (5%)	0.25	0.22

rhizobia per seed is considered a high number and maintaining this level of population on seed for two weeks is a desirable situation. Strain ICARDA M15 produces good nodulation and is persistent under field conditions. Verification of the techniques used in these assays is currently under investigation to find the factors affecting the counting procedures. - **L.A. Materon and M. Zaklouta**

3.2.7. Response of medics to phosphorus fertilization and rhizobial inoculation.

The aim of this investigation was to determine if variability exists in the symbiotic efficiency of combinations of different medic species and Rhizobium at various concentrations of phosphorus. The experiment was conducted at Tel Hadya (Syria) in field A6. The concentration of available phosphorus was low (2.7 ppm, Olsen P). We assumed, therefore, that the site was suitable for this kind of experiment.

The experiment consisted of a split-split plot design with 4 strains of rhizobia as main plots, 3 species as subplots and 3 phosphorus levels as sub-subplots with three replications. The Rhizobium meliloti strains were ICARDA M15, M29, M53 and BZI. All the strains were spontaneous antibiotic - resistant mutants to streptomycin and this property was used to determine nodule occupancy. The medic species were M. rigidula sel 716, M. rotata sel 2123 and M. polymorpha sel 1035. The levels of phosphorous fertilization were 0, 18, and 60 kg P_2O_5/ha. Uninoculated controls with and without mineral nitrogen were also included. Nitrogen in the form of urea was applied in three doses at the total rate of 90 kg N/ha. Carbofuran was incorporated into the soil at the rate of 30 kg/ha to prevent any possible attack of Sitona weevil.

The area of the plots was 2.1 m^2. The alleyways were 2 m wide between main plots and 1 m for all other plots. The seed was inoculated using a slurry of peat inoculant and a solution of 25% gum arabic as a sticker. The inoculants had an average number of rhizobia of 3.45×10^9. The experiment was planted on 12 December 1990. On this date the soil contained 13.7% moisture and the accumulated rainfall was 40.7 mm. The number of medic rhizobia per gram of soil was 2.3×10^3 as determined by the most probable number technique (MPN).

Herbage dry weights were determined on 18 April 1991 and 12 May 1991 by harvesting all plants growing inside an area of 1 m^2. The herbage was collected and oven - dried for 2 days at 72°C. Other measurements included nodule distribution, nodule numbers, plant vigor and measuring the relative occupancy of rhizobial strains in nodules.

Although the concentration of phosphorus in the soil was very low (2.7 ppm) statistical analysis showed no significant differences for main factors except for inoculation treatments ($P \geq 0.05$). All interactions between the three main factors were also non significant ($P \geq 0.05$). Table 3.15 shows the herbage means for the first harvest, when plants were actively fixing nitrogen.

Due to importance of phosphorus fertilization in legumes, particularly, in soils of low concentration, the experiment will be repeated in the coming season in a similar field. - **L.A. Materon**

Table 3.15. Response of medics to inoculation and phosphorus fertilization.

Medic species	P level	Inoculation treatment M15	M29	M53	BZI	UC +N	UC -N
				herbage (t/ha)			
M. rigidula							
	0	1.02	2.53	1.46	1.84	2.19	2.06
	18	1.79	1.63	3.92	1.79	2.49	1.68
	60	1.21	1/54	1/26	2.32	1.98	2.17
M. rotata							
	0	1.14	1.96	1.73	1.72	2.82	2.05
	18	1.38	1.36	1.33	1.68	1.71	2.13
	60	1.46	1.88	1.46	1.74	2.37	2.93
M. polymorpha							
	0	1.09	2.42	1.45	1.66	2.94	2.24
	18	2.00	2.05	1.81	1.63	2.18	2.67
	60	1.84	1.71	1.91	2.01	1.84	2.15

LSD (5%) to compare two P levels at the same level of species: 0.441
LSD (5%) to compare two P levels at the same level of strain: 0.586
LSD (5%) to compare two inoculation treatments at the same level of P: 0.658
LSD (5%) to compare two levels of inoculation treatments at the same level of species: 0.691
LSD (5%) to compare two levels of inoculation treatments: 0.432

3.2.8. Inoculation network experiments

Following the recommendations of a workshop organized by ICARDA/UNDP on biological nitrogen fixation in 1986 (Beck and Materon, 1988) closer links have already been established among cooperators in west Asia and north Africa. Because each country of the region has different environmental and soil microbial characteristics it is necessary to conduct a series of experiments with regional cooperators from national institutions. Without such research, the recommendations emanating from Tel Hadya are likely to be misleading when applied elsewhere.

Table 3.16 lists the institutions participating in the network in 1990/91. Most of the research was targeted to annual medics and their rhizobia. Some of the highlights of the results reported by members of the network are presented here.

Table 3.16. International network for inoculation of pasture and feed legumes: activities during 1990/91.

Collaborative institution	Country	Number of sites
Ministry of Agriculture	Algeria	2
Ministry of Agriculture	Iraq	1
Ministry of Agriculture	Iran	2
University of Moulay Ismail	Morocco	4
Ministry of Agriculture	Syria	3
Agric. Res. Institute	Cyprus	1
University of Cukurova	Turkey	2
INRA Montpellier	France	2
Agricultural University	Greece	1
El Zaidin Agric. Exp. Stn.	Spain	1
University of Granada	Spain	1
University of Pennsylvania	USA	1
CSIRO (Canberra)	Australia	1
Ministry of Agriculture	Chile	2

3.2.9. Research with cooperators within ICARDA region

Cyprus. Four species of medics (M. rigidula, M. polymorpha, M. rotata and M. truncatula) and five strains of R. meliloti (ICARDA M3, M15, M29, M53, and M254) were tested at an experiment station in Nicosia. The objective was to determine responses to inoculation as well as host-strain interactions under Cypriot conditions. Reports indicated that there were no significant differences among strains within each of the medic species tested. Again, the observation that the herbage yields of Australian cultivars of M. truncatula and M. polymorpha inoculated with rhizobia were not different to those of the uninoculated controls indicated that the indigenous strains of rhizobia are effective. Both M. rigidula and M. rotata were responsive to inoculation as their herbage yields were statistically superior to those obtained with the uninoculated controls. Some strains isolated from various Cypriot soils were also tested for effectiveness. - **I. Papastylianou and L.A. Materon**

Turkey. The objective of the experiments in Cukurova University in Adana is to determine whether or not residual aldicarb (Temik) affects the numbers of indigenous R. meliloti. Counts of soil were made using M. polymorpha and M. noeana as trap species for the most probable number technique (MPN). Preliminary investigations indicated that in areas where the pesticide has been previously applied the number of medic rhizobia is 1.2 log lower than that found in adjacent areas where the herbicide was not applied. The average numbers of medic rhizobia in untreated areas reached approximately 4 x 10^4 per g soil. - **M. Engin and L.A. Materon**

Morocco. Experimentation with annual medics continues at the University of Moulay Ismail where the project involves graduate students who prepare inoculants and carry out experiments on the University farm and in glasshouses. Yields of M. murex, M. scutellata and M. truncatula increased by 150-270% by inoculation. Strains M15, M28, M29, M34, WSM244 and CC169 have been extensively tested.

The cooperator is now producing inoculants in a recently acquired fermentor of 120 - liter capacity. The concentration of the inoculant reaches an average of 1.23 x 10^9 rhizobia per gram of peat.

Fractional distribution of biologically fixed nitrogen by annual Medicago species to the following wheat crop is of major interest in Morocco. A postgraduate student spent 6 months training on aspects of ^{15}N experimentation in our laboratory. Current experiments in Morocco aim to measure the direct transfer of nitrogen to the soil and its effect on the subsequent cereal crop using isotopic dilution techniques. Results will be reported next year as samples for ^{15}N analysis by mass spectrophotometer are not complete yet. - **M. Ismaili, Nadia Lahrach and L.A. Materon**

3.2.10. Specificity of medics at the level of ecotypes

A field experiment was conducted at Tel Hadya (field A1) to test the hypothesis that Rhizobium meliloti shows a high host specificity down to the ecotype level. The aim of the experiment was to record preliminary information on the ability of different ecotypes to fix nitrogen when nodulated by various strains of medic rhizobia including the indigenous ones. The medic ecotypes tested were Medicago polymorpha selections 1035, 1036, Tah and Australian cultivar Circle Valley (CV), and M. rotata selections 1943, 2119, 2123 and 2532. The seeds were inoculated with each of Rhizobium meliloti strains ICARDA M15, M29, M38, M53, M254 and M295. Controls included uninoculated treatments with and without mineral nitrogen, at the rate of 90 kg N/ha applied as urea split in 3 applications.

The experiment was designed as a split-plot layout having inoculation treatments as main plots, thus minimizing the risk of contamination, and medic ecotypes as subplots. There were three replicates. The plots had an area of 2.1 m^2 with alleyways of 1 between subplots and of 2 m between main plots. The medics were sown on 7 December 1990. The soil moisture content at planting was 14.9% with accumulated rainfall of 40.7 mm. Field A1 had 18 ppm P and was not amended with phosphorus fertilizer.

Herbage cuts were taken on 19 April and 10 May 1991 and dry weight determined. The response to inoculation was based on plant growth prior to flowering when nitrogen fixation is at its peak. The second measurement corresponded to the pod fill stage of the plants.

Table 3.17 shows herbage yields collected in the period when nitrogen fixation was high. There were native populations of medic rhizobia in the soil, which fully nodulated the plants growing in the uninoculated control plots, but the herbage production of these plants was sometimes lower than that of the inoculated plants of both M. polymorpha and M. rotata. In addition, yields from the uninoculated controls fertilized with nitrogen were not significantly different from the best strain x ecotype combinations. Some ecotypes responded positively to inoculation but the response varied between strains. For example, ecotype 1943 of M. rotata produced the highest herbage yield when nodulated by strains M254, M15 and M295. In contrast, M29 produced the highest yield with ecotype 2119. Similar responses occurred with all ecotypes. This symbiotic behavior corroborates our previous findings that medics are responsive to inoculation and that selection of rhizobial strains is necessary.

Specificity at the level of ecotypes was detected. Comparing the means within each row of Table 3.10, shows that significant yield variations ($P \geq 0.05$) due to strain can easily be identified. For instance, the ecotypes of M. rotata behaved differently when exposed to strain M29. Ecotype 2119 produced 3 times more herbage than ecotype 2532, and 1.5 times more than ecotype 2123 when inoculated with strain M29 ($P \geq 0.05$). The experiment clearly shows that ecotypes do not respond equally to nodulation and nitrogen fixation when inoculated with a given strain. This must be considered when introducing ecotypes into a region where other ecotypes or varieties of the same species have been previously grown successfully. More experimentation will be conducted using more

Table 3.17. Herbage yields (t/ha) of medic ecotypes inoculated with several strains of *Rhizobium meliloti*. Harvested on 19 April 1991.

Strain	Selections of *M. polymorpha*				Selections of *M. rotata*			
	1035	1036	Tah	CV	1943	2119	2123	2532
M15	2.82	1.62	2.40	2.82	2.22	2.63	2.71	1.73
M29	1.44	0.99	2.14	1.33	1.42	2.65	1.82	0.89
M38	1.51	0.90	1.72	1.51	1.61	1.91	1.59	1.48
M53	1.87	1.66	1.98	2.07	1.86	2.42	1.98	1.65
M254	2.59	2.34	2.17	3.22	2.60	2.46	3.07	1.87
M295	2.28	2.17	1.66	2.85	2.05	2.45	2.38	2.00
UC +N	2.80	2.71	2.36	3.64	2.86	3.22	2.38	3.21
UC -N	1.45	1.16	1.71	1.17	1.18	1.80	1.39	1.26

LSD to compare herbage yields of ecotypes within an inoculation level = 0.699.
LSD to compare herbage yields of same or different ecotypes between inoculation levels = 0.719.

species of medics and their ecotypes to verify the theory. In addition, in vitro experiments have been started. - **L.A. Materon**

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4. Rotations of Annual Pasture, Forage and Food Legumes with Cereals

Pasture, feed and food legume species can help to stabilize Mediterranean dryland farming systems located in 250-350 mm rainfall zones. Farmers are using less fallow, plowing more marginal land and growing fewer legumes than in the past (Jones 1990). Researchers are keen to replace the fallow, but to do so by encouraging reintroduction of pasture, feed and food legumes; primarily in 300-350 mm rainfall zones, where in most years they can demonstrate benefits of cereal/legume rotations (Jones, 1989; 1990).

The objective of long-term trials has been to establish base line production data for comparison of alternative cropping systems under Syrian conditions. Data are accumulating which permits examination of long-term treatment effects. This chapter highlights some of these long-term results from two-course rotation experiments.

4.1. Fallow Replacement Using Lentil and Vetch in Northwest Syria (Preschedule L13)

In 1986 an experiment was initiated to study the performance of annual Medicago spp. in rotation with wheat. The objective was to compare the biological yields and economic benefits from several two-phase, wheat-based rotations. Several common crops (lentil, vetch and watermelon) and fallow were included in the rotations for comparison with a pasture legume system (medic) using stocking rate treatments of 4, 7 or 10 ewes/ha. Details of the methods used to conduct the trial are presented in PFLP's Annual Reports for 1987 (pp. 43-62), 1988 (pp. 74-88) and 1989 (pp. 74-80).

Due to the complexity of comparing pasture, which has to be transformed to salable products through animals, with food and feed legume production, this chapter only discusses the lentil/wheat, vetch/wheat, and clean fallow/wheat rotations. The economic analysis of all the rotations is discussed in section 4.6.

4.1.1. Methods

A randomized complete block design was used; three replicates of 'Cham-2' bread wheat rotated with vetch, lentil and fallow. Both phases of each treatment were present each year. The entire experimental area received 60 kg/ha P_2O_5 at the start of the experiment. Wheat, lentil (ILL 4401 (Syrian Local Small)) and vetch (Vicia sativa) were planted with a seed drill at 120, 80, and 100 kg/ha, respectively. Wheat is usually fertilized in both the autumn and spring but in dry years the spring application is not applied; therefore, the rates vary between 45 and 90 N kg/ha.

Broadleaf weeds in wheat plots are controlled with bromoxynil herbicide (Brominal+MCBA); mixed and sprayed at 2 L active ingredient (AI)/400 L H_2O/ha. Fusilade 25 EC-W (Fluazifop-Butyl) is sprayed at 2 L AI/400 L H_2O/ha in vetch and lentil plots to control cereal volunteers. Fallow plots are cultivated whenever necessary to destroy weeds the objective being to conserve water.

Cereal plots are sampled by clipping plants at ground level to estimate grain and straw yields from quadrats and then the fields are combine harvested. Vetch and lentil are sampled at full maturity to estimate seed and straw yields then hand-harvested.

Throughout the course of the experiment, prices in the local market were monitored and those pertinent to this report (Table 4.1) have been deflated to a 1990 basis using wholesale price indices.

4.1.2. Locality and Climate

ICARDA's headquarters at Tel Hadya is located 30 km southwest of Aleppo, Syria in Agricultural Stability Zone 2, a primary wheat-growing region of Syria. The site has heavy calcareous Luvisol soils

(Terra Rossa) with montmorillonitic clays as the main clay minerals. The soils are poor in organic matter (1.0%); have an average pH=8.0 and are low in phosphorus, averaging 5 mg/kg available P at a soil depth of 0-20 cm.

Table 4.1. Commodity prices in the Aleppo area of Syria from 1986 to 1991 deflated to a 1990 price basis.

	Prices in Syrian Lira per kilogram						
Item	1986	1987	1988	1989	1990	1991	Mean
Wheat grain	5.61	5.99	7.29	9.13	9.50	8.88	7.73
Wheat straw	1.35	1.19	1.59	3.43	3.00	1.78	2.22
Vetch hay	2.92	4.39	2.92	6.96	6.60	4.80	4.77
Vetch grain	7.85	8.77	9.28	10.30	11.00	8.44	9.27
Vetch straw	2.47	3.66	2.39	5.82	5.50	4.00	3.97
Lentil grain	8.52	9.06	10.60	10.30	12.50	12.40	10.50
Lentil straw	2.24	3.36	2.12	5.71	5.00	3.11	3.59

The climate is Mediterranean with an annual rainfall of 330 mm (Fig. 4.1). Marked differences in rainfall totals and distribution provided an examination of treatment effects under a range of conditions. For example, 1985/86 and 1986/87 were below average but fairly normal, 1987-88 was the wettest season in NW Syria since 1940-41, while 1988/89 and 1989/90 were drought years when grazing of barley and wheat fields was widespread in Syria. The 1990/91 growing season was a below-average rainfall year; however, the distribution was quite good which led to reasonable crop yields.

4.1.3. Crop Yields 1986-1991

No significant treatment effects were detected in the establishment year; thereafter, wheat after fallow produced more wheat grain and straw than wheat after lentil and wheat after vetch treatments (Fig. 4.2).

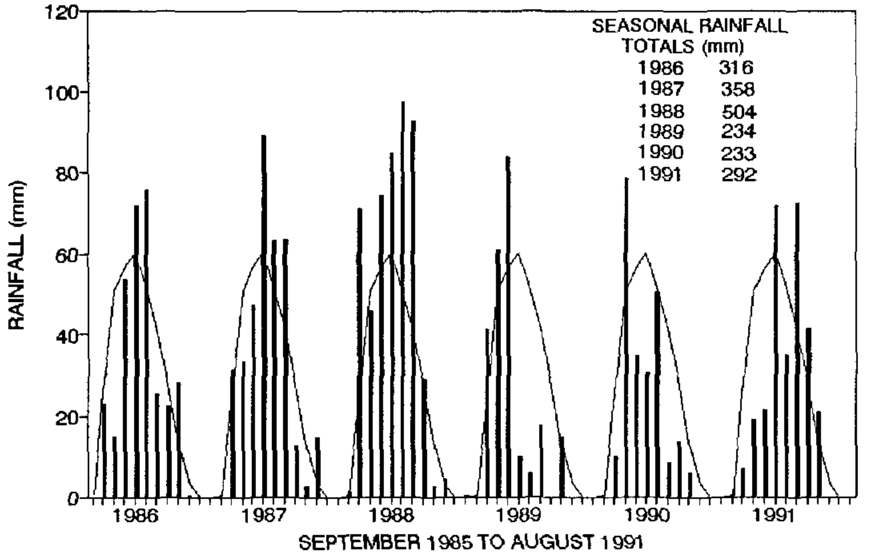


Fig. 4.1. Monthly rainfall data for Tel Hadya, NW Syria from September 1985 to August 1991.

Averaged across seasons, wheat following vetch and lentil gave 25 and 30% less grain, and 24 and 36% less straw, respectively, than wheat after fallow. Wheat yields were similar following a vetch or lentil crop; however, straw yields were higher following vetch compared with lentil in all but the driest years. Given that a clean fallow gives no yield in the fallow phase we will later present biological yields taking both halves of the rotations into account.

Each year nitrogen fertilizer is applied to half of each wheat plot. It stimulates both wheat straw and grain yields in wet years but has little advantage when the weather is dry; particularly so for grain yields as drought conditions can severely impair the

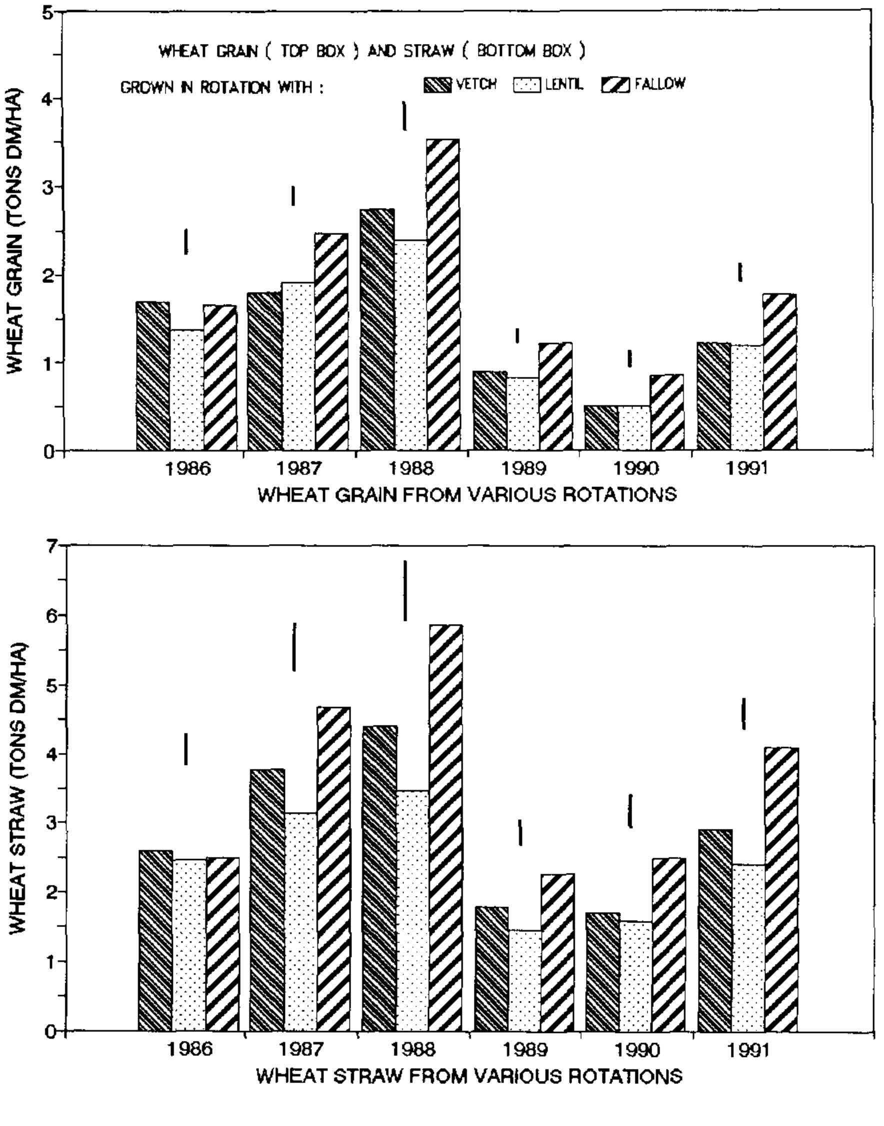


Fig. 4.2. Wheat grain (top) and straw (bottom) yields in northwest Syria following lentil, vetch or fallow. Error bars represent ± 1 S.E. of the mean for the three treatments within each year.

reproductive phase of growth. Wheat grain and straw on plots following fallow, lentil and vetch responded to nitrogen in much the same way in all years except 1989-90 (Table 4.2), a season with 233 mm rainfall following a year with 234 mm.

Table 4.2. Effect of nitrogen application on production of wheat straw (t/ha) in 1989/90.

Rotation	N application(kg/ha)		% increase
	0	90	
Wheat/Vetch	1.49	1.91	28
Wheat/Lentil	1.28	1.91	49
Wheat/Fallow	1.95	3.12	55

It is possible that stored water available in fallow treatments allowed more efficient use of fertilizer. It is also possible, under the conditions of this experiment, that lentil shows a greater response to N fertilizer than vetch. As shown in section 4.5 "Nitrogen Balances in Integrated Crop/Livestock Systems", lentil returns less N to the soil because the entire plant is removed during hand-harvesting. Although vetch is similarly harvested, it has a more branched root system and more of the root remains in the soil after harvest. Total soil N increased by 15% over the course of the six years in soils where vetch was rotated with wheat, while soil N concentrations remained the same in soils where lentil/wheat was practised. Thus, wheat after lentil could be more responsive to fertilizer N than wheat after vetch.

When the vetch and lentil portions of the rotation are compared (Fig. 4.3), a trend of higher production from lentil is clear but in most cases the differences were not statistically significant.

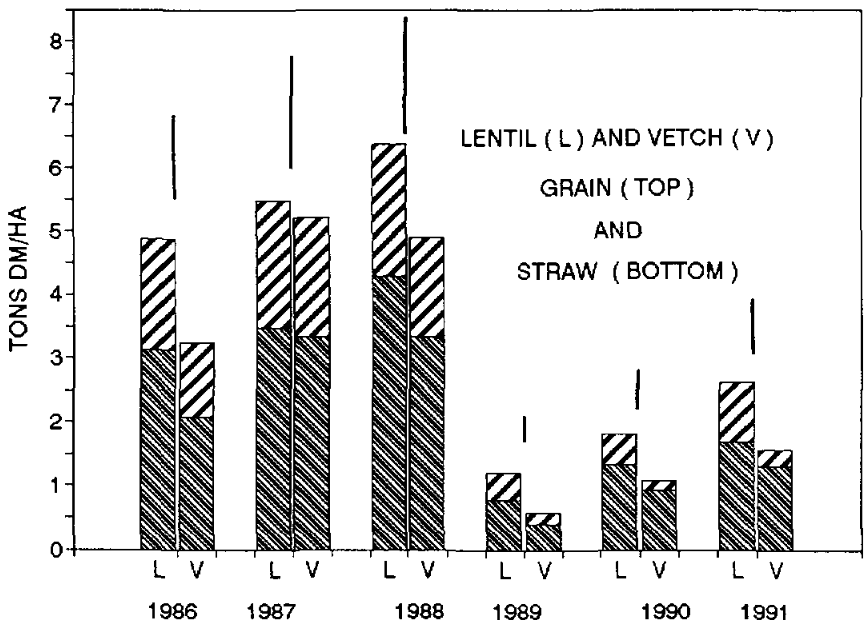


Fig. 4.3. Comparison of grain, straw and total yields of lentil and vetch for 1936 to 1991 at Tel Hayda, Syria. Error bars represent $\pm$1 S.E. of the mean for the two treatments within each year.

Harvesting vetch as hay resulted in lower total production (Table 4.3) and gross returns, using prices in Table 4.1, compared with harvesting as grain and straw. Vetch hay was cut from within plots to be harvested as grain and straw; thus, the possible gain in wheat production from a vetch hay/wheat rotation was not tested.

Biological yields for both phases of the rotation are summed and converted to a gross economic value in Fig. 4.4. On the assumption that farmers practising a legume/cereal or cereal/fallow rotation would divide their land into roughly equal parts to stabilize income over time, treatment pairs in this experiment were analyzed within each year, rather than summing the two parts of the rotation across successive years.

Table 4.3. Dry matter production and value of vetch used as hay versus vetch used as grain and straw.

	1986	1987	1988	1989	1990	1991	Mean
			Dry matter yield (t/ha)				
Vetch hay	2.39	1.61	2.65	4.10	1.10	1.51	1.61
Vetch grain	1.18	1.89	1.57	0.18	0.15	0.26	0.87
Vetch straw	2.08	3.33	3.33	0.40	0.93	1.31	1.89
			Gross crop value (Syrian Lira x 1000)/ha				
Vetch hay	6.98	7.07	7.74	2.85	7.28	7.26	6.42
Vetch grain	9.56	16.60	14.60	1.85	1.65	2.22	7.71
Vetch straw	5.14	12.20	7.96	2.34	5.13	5.25	12.20

In terms of total biomass production, results show that lentil/wheat and vetch/wheat rotations are more productive than wheat/fallow in years with average or above-average rainfall and as productive as the fallow system in dry years. Total yields of legume/cereal rotations were similar because of compensating effects: cereal yields are better when grown in rotation with vetch
but lentil produces more biomass than vetch. This may be a reflection of improvements achieved through centuries of human selection in local landraces of lentil. Vetches could also be improved considerably due to the great variation in species and accessions available to plant breeders (Abd El Moneim et al. 1986).

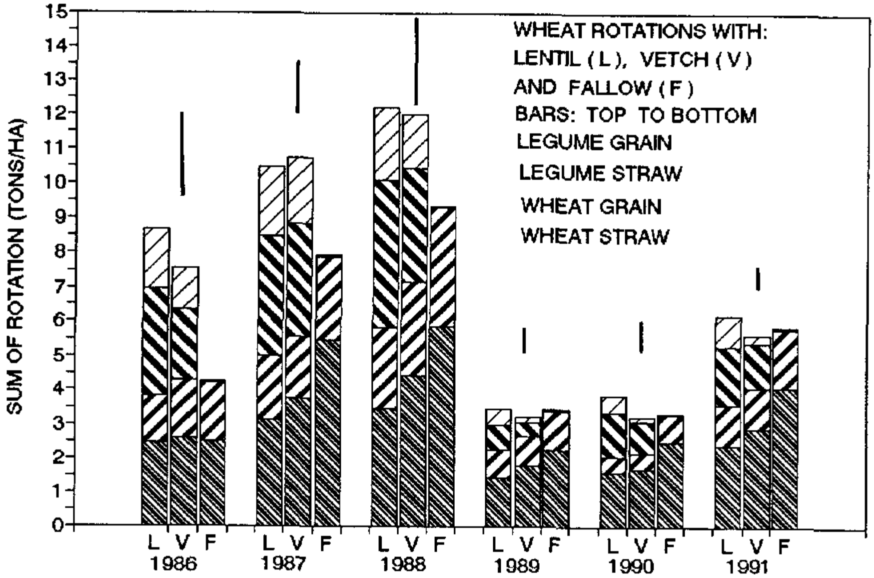
In terms of ranking, differences among rotations are not greatly changed, but are more pronounced when their gross values as commodities are shown (Fig. 4.4), especially in drier years. The main points to consider are the higher value of grain relative to straw and the higher value of legume straw relative to wheat straw. Gross returns do not necessarily reflect net returns as land in fallow has very low costs.

Table 4.4. Biomass production (t DM/ha), gross value, costs and net returns (1000 SL/ha) from lentil, vetch and fallow rotations with wheat averaged from data collected in NW Syria, 1986-1991.

	Crop rotation with wheat		
	Lentil	Vetch	Fallow
Mean biomass yield			
Legume grain	1.29 a[1]	0.87 b	-
Legume straw	2.45 a	1.90 a	-
Wheat grain	1.36 b	1.47 b	1.94 a
Wheat straw	2.41 b	2.85 b	3.77 a
Total yield/ha (Sum of Phases ÷ 2)	3.75 a	3.54 a	2.85 a
Gross values			
Legume grain	7.36	6.33	-
Legume straw	13.0	7.71	-
Wheat grain	4.94	5.85	7.85
Wheat straw	9.88	10.7	14.3
Total[2]	17.6	15.3	11.1
Costs			
Inputs	6.30	5.84	3.95
Labor	3.86	3.75	1.09
Net Rotation value	7.44	5.71	6.06

[1]Means followed by the same letter within a row are not different using Fisher's Protected LSD ($P<0.05$).
[2]Mean = sum of 2 phases of rotation ÷ 2

In Table 4.4 the yields and values associated with the three rotations are summarized across the six years of the experiment. The data are too variable to detect significant differences in total yields but when converted to gross crop values in Syrian Lira (SL) benefits appear to be in favor of the legume rotations. Budgeting including all cash costs and an allowance of 100 SL/day for labor, shows the highest net returns for the lentil-wheat rotation (7440 SL/ha), followed by the wheat/fallow rotation (6060 SL/ha), and



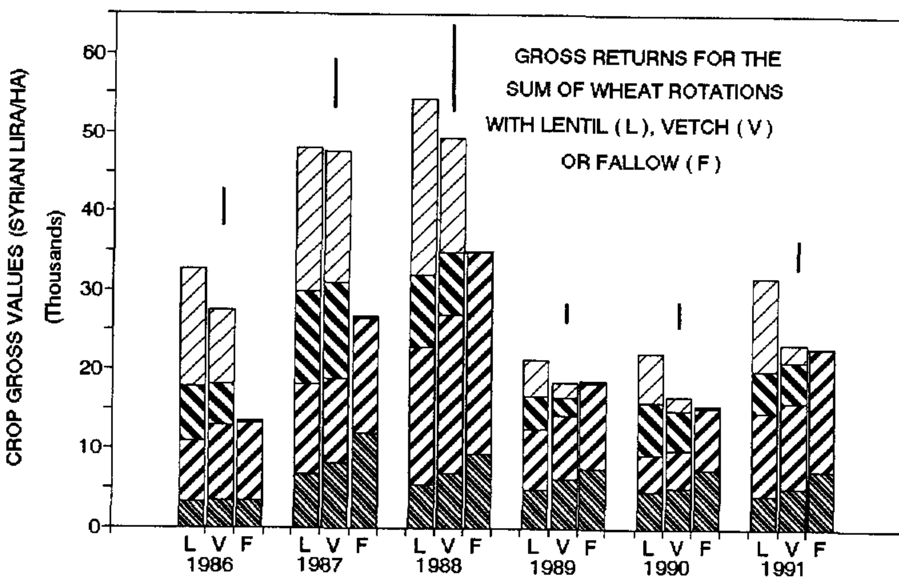


Fig. 4.4. Total yield and gross value of the rotations. Error bars are ±1 S.E. of the mean for the three treatments within each year.

wheat/vetch is the poorest crop option (5710 SL/ha). These results indicate that the popularity of lentil with farmers has a sound financial basis. It also seems likely that adoption of vetches will not be widespread unless the labor costs of harvesting can be reduced substantially.

The experiment was designed to run long enough to give long-term data on year to year variation in crop yields that are representative of the variable climatic conditions in northwest Syria. One of the six years had unusually high rainfall (the best year since 1940/41) followed by two years of drought. Whether the climatic conditions of this experiment are representative is open to question. It also raises the question of how long a long-term trial should last.

Program scientists are using a linear programming approach to assess the net economic consequences for all the rotations included in the current experiment, including medic pastures and summer crops, in the full context of livestock feeding and grazing activities.

Livestock are not considered in the simple budget analysis presented in this report and it was assumed that all crop products are simply sold off-farm. This may not be a realistic assumption for wheat straw, much of which may not be used by animals. In contrast, the legume straw is highly valued for livestock and constitutes a readily sold, valued commodity.

4.1.4. Conclusions

The results indicate that replacement of the fallow system with a lentil crop is a sound recommendation based on the net returns of the wheat/lentil rotation. Labor requirements for hand-harvested legume crops are substantial and mechanized harvesting could increase the profitability for both forage legume/wheat rotations relative to the wheat/fallow system.

Vetch, and other forage legumes such as lathyrus, may play an important role in areas of lower rainfall (250-275 mm) where lentil is not well adapted and where forage legume/barley rotations produce 40% more feed energy and nearly double the feed protein compared with the continuous barley option (see section 4.2).

It will be important for farmers to see how the adoption of a legume and/or harvest mechanization will affect their profit. We soon hope to quantify whole-farm profitability using linear programming techniques, which will also identify the characteristics of farms likely to benefit from the introduction of legume-based rotations. Then, the intention is to identify farmers in these catagories for on-farm testing of the rotations to assess their acceptability and profitability. - **N. Nersoyan, P. Cocks, T. Nordblom, and S. Christiansen**

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4.2. On-farm Forage Legume Trials at El-Bab (Preschedule L24)

The on-farm forage legume trials at El-Bab were started in 1986 with the aim of:

- quantifying the effect of replacing fallow or continuous barley rotations with common vetch (Vicia sativa) or chickling (Lathyrus sativus) on subsequent barley grain and straw yields,
- measuring yields of forage legume seed and straw harvested at the mature stage,
- determining the advantage of applied fertilizer nitrogen in the barley phase,
- measuring growth rate of lambs grazing forages in spring, and
- assessing farmers' reactions to forage legumes and fertilizer use and obtaining their opinions on most appropriate uses for the techniques demonstrated.

This experiment, begun in 1986/87, was replicated on eight farms representing different, mainly shallow, soil types at El-Bab, in northeast Aleppo Province. Before sowing, soils were analyzed for phosphorus and total nitrogen. Triple superphosphate was applied to barley according to the phosphorus status of the soil. N fertilizer (ammonium nitrate) was applied to half the barley area of each rotation to measure its effect and determine if the response to N differs following legumes, fallow and barley. The hypothesis was that nitrogen fixed by legumes could meet some or all of the cereal crop needs.

Each site covered 4 ha, divided equally into a first cereal phase and a second phase that included common vetch, chickling, fallow, and barley.

In 1989/90 and 1990/91, SMAAR was involved in conducting the trials through their extension personnel based at El-Bab and a staff member from the Livestock Research Division in SMAAR who spent seven months working with ICARDA's Sheep Unit staff on the project.

Table 4.5. Monthly rainfall (mm) data from El-Bab.

	1986/87	1987/88	1988/89	1989/90	1990/91
Oct	2	63	55	5	2
Nov	39	53	50	38	50
Dec	44	57	56	43	16
Jan	84	68	0	39	46
Feb	20	63	0	56	29
Mar	67	83	40	22	66
Apr	6	78	0	4	49
May	0	0	0	0	17
Total	262	465	201	207	275

Rainfall was below the average of 280 mm in four out of five years (Table 4.5). The first year was close to normal; the second year had a record rainfall. The third year was very poor in both rainfall amount and distribution. The fourth and fifth seasons were again below average but distribution was better.

An extraordinary frost was recorded on 17 March 1990. The minimum temperature dropped to -9C° at night. This frost caused severe damage to chickling with a lesser effect on vetch.

Grain and straw components of the barley crop reacted to 0 and 90 kg N/ha rates the same way for all rotations in both years; therefore, values for the two levels of nitrogen were averaged for each treatment. High variability probably prevented detection of differences in the response to applied nitrogen in barley grown after barley, fallow or after the legumes. The eight El-Bab farms varied in soil fertility and depth. Thus the farms, as replications in the analysis of variance, were nearly always a significant source of variation.

Nitrogen fertilizer increased barley grain and straw yields in 1989/90 but barley with or without additional N produced similar amounts of dry matter in 1990/91 (Table 4.6). Due to unusual late-season rain in 1990/91, barley yield was higher with more of the harvested yield as grain compared with previous year.

Table 4.6. Yield (t DM/ha) of barley, with and without ammonium nitrate as a spring dressing.

	1989/90		1990/91	
	Grain	Straw	Grain	Straw
N level				
N -	0.85	1.41	1.29	1.53
N +	0.96	1.82	1.33	1.77
LSD (0.05)	0.10	0.17	0.18	0.30

Although rainfall was higher in 1990/91, there was no response to N. Probably the good distribution of rainfall enabled the non-fertilized barley to obtain all its needs from mineralization of nitrogen-containing compounds in the soil. In 1989/90 when an effect from N was detected, all the treatments reacted the same way. This suggests that the legumes may not be adding significant quantities of N through nitrogen fixation. As shown later in Section 4.5, a legume rotation may take many years to build up soil fertility, especially in dry conditions.

Dry matter yields were measured for vetch, chickling, and barley from the continous barley treatment just prior to grazing the forage legumes. At that time, barley had greater dry matter production than vetch in the first year but the opposite was true in 1990/91; chickling had the poorest growth in both years (Table 4.7). This was partially attributed to spring frost, mentioned above. Legumes planted early in the autumn suffered more severe damage than late-planted legumes. Chickling planted early was frosted to ground level and nearly killed, and the dry matter harvested at the mature stage was entirely due to regrowth after the frost. For earlysown vetch, the top two-thirds of the vegetation was frosted but recovery was faster than by the chickling.

Table 4.7. Dry matter yields (t DM/ha) of vetch, chickling and barley cut at the hay stage.

	1989/90	1990/91
Vetch	0.89	0.72
Chickling	0.51	0.47
Barley	1.20	0.63
LSD (0.05)	0.18	1.20

When grown to maturity, vetch produced more straw than chickling in 1989/90 and 1990/91 but grain yields were similar in both years (Table 4.8). This result was opposite to those in several previous years at El-Bab and Breda where grain yield of chickling usually surpassed that of vetch. Indeed chickling is known for its high harvest index and seed production in dry zones compared with vetch; while vetch generally produces more early growth for use as hay (Jones, 1991). The analysis of all data following the final season of the trial in 1991/92 may provide a more certain conclusion.

The grain and straw yields of barley after fallow were higher than those of barley/forage legumes and barley/barley in 1989/90. In 1990/91, barley grain and straw yields after fallow, vetch and chickling were similar and barley after barley was the least productive crop (Table 4.8).

Total productivity for the rotation was greatest for barley/vetch and barley/barley in 1989/90 but in 1990/91 the continuous barley crop yields in the forage phase were much lower than in the previous year (Table 4.8) and also lower than the barley/barley in the cereal phase. This may be explained by the absence of nitrogen fertilizer application on the barley in the forage phase and clearly shows one of the unsatisfactory results from using the continuous barley system.

Table 4.8. Crop dry matter yields (t DM/ha) from each phase (P1 or P2) of four rotations. Total yields from the sum of both rotations are divided by two to express the yield on a per hectare basis.

	Barley	Fallow	Vetch	Chickling
1989/90				
P2-Legume Grain	-	-	0.24 a	0.17 a
P2-Legume Straw	-	-	1.42 a	0.57 b
P2-Barley Grain	0.61	-	-	-
P2-Barley Straw	1.14	-	-	-
P1-Barley Grain	0.76 b	1.08 a	0.92 b	0.86 b
P1-Barley Straw	1.36 b	2.01 a	1.57 b	1.53 b
Total Biomass	1.93 a	1.54 b	2.07 a	1.57 b
1990/91				
P2-Legume Grain	-	-	0.39 a	0.47 a
P2-Legume Straw	-	-	3.08 a	2.06 b
P2-Barley Grain	0.28	-	-	-
P2-Barley Straw	0.31	-	-	-
P1-Barley Grain	0.92 b	1.48 a	1.39 a	1.45 a
P1-Barley Straw	1.36 b	1.90 a	1.87 a	1.54 ab
Total Biomass	1.41 c	1.68 c	3.36 a	2.76 b

[1] Means followed by the same letter within a row are not different using Fisher's Protected LSD ($P<0.05$).

The eight farmers participating in the trial were allowed different options for utilization of the forage legume. The growth rates of lambs on the four fields where the farmers used the vetch and chickling for grazing from early April are shown in Table 4.9 Because of the small area of each legume field, the lambs were grazed on vetch and the chickling simultaneously and were supplemented with 300 g/head/day of barley. The mean total liveweight gains were 208 kg/ha in 1989/90 and 211 kg/ha in 1990/91.

Table 4.9. Lamb performance when grazing vetch and chickling on four farms for two years.

	1		4		7		8	
	1990	1991	1990	1991	1990	1991	1990	1991
Grazing days	21	33	31	43	34	-[1]	37	43
Stocking rate (lambs/ha)	68	32	78	42	33	-	60	36
Daily gain (g/lamb)	284	256	152	144	223	-	161	130
Total gain (kg/ha)	213	224	254	221	167	-	199	189

[1] Farm 7 did not use grazing as an option in 1991.

This management with supplementation made grazing a more acceptable option for the farmers compared with the 1988/89 season when total liveweight gains were 104 kg/ha (PFLP 1989a).

The El-Bab trials include agronomic practices that are not traditional in the area. In particular, the 120 kg/ha seeding rate for barley and the 30 kg/ha nitrogen fertilizer application are lower than the rates usually used. It is encouraging to see that most of the farmers in the trial who formerly sowed 220 kg/ha barley and applied 60 kg/ha nitrogen have now adopted lower rates from the trial on the rest of their farms with no adverse effect on yields. Other farmers in the area are now sowing forage legumes. Although it is clear that the yield of barley after fallow is greater than under the other rotations, the farmers recognize that the yield of animal feed from the whole cycle is greater from the barley/legume rotations. This is illustrated in Table 4.10 which compares the production of animal feed as metabolizable energy and crude protein from the four rotations averaged over the years 1989/90 and 1990/91.

Total production of feed energy from the cereal/legume rotations, which are sustainable without inputs of N fertilizer is about 40% higher than from continuous barley and the production of crude protein is twice as high.

Table 4.10. Yields of air dry matter (t AM/ha), metabolizable energy (ME) as Megajoules (MJx1000/ha) and crude protein (CP, kg/ha) of grain and straw from both phases of four crop rotations averaged over 1989/90 and 1990/91.

	Barley rotations with			
	Barley	Fallow	Vetch	Chickling
Legume Grain				
AM	-	-	0.31	0.32
ME	-	-	3.67	3.77
CP	-	-	81.0	83.0
Legume Straw				
AM	-	-	2.25	1.32
ME	-	-	14.9	8.98
CP	-	-	137.0	79.0
Barley Grain				
AM	1.29	1.28	1.15	1.15
ME	15.4	15.2	13.7	13.7
CP	133.0	132.0	118.0	118.0
Barley Straw				
AM	2.05	1.95	1.72	1.54
ME	12.1	11.5	10.1	9.09
CP	59.0	56.0	50.0	45.0
Total Production (Sum of Phases ÷ 2)				
AM	1.67	1.61	2.71	2.16
ME	13.7	13.4	21.2	17.8
CP	96.0	94.0	193.0	162.0

In addition, the barley/legume rotations result in higher yielding barley crops because of a reduced incidence of insects and diseases compared to the continuous barley rotation, even when nitrogen fertilizer is applied. Nevertheless, the El-Bab farmers say that the growing of forage legumes will not be widespread until inexpensive and efficient mechanized methods of harvesting 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, after which the crop is gathered from the windrows for threshing at a convenient location.

An alternative is to combine harvest the vetch, in which case non-shattering varieties of forage legumes would assist the spread of vetch and chickling in the area. Drought and cold tolerance, early maturation and high harvest index also would contribute to increasing farmer interest in forage legumes. ICARDA scientists are urrently selecting for these traits in accessions of V. sativa, V. ervilia, V. narbonensis, L. sativus and L. cicera (PFLP 1989b). - **M. El-Wadi and B. Shero (SMAAR); F. Bahhady and S. Christiansen**

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4.3. Crop and Sheep Productivity of Wheat/medic Compared with Other Wheat-based Rotations

This report describes 1989/1990 data from a cereal rotation trial established in 1986/87 at the Hemo Research Station, near Kamishly, Syria. The trial is important because it takes place in the northeast of Syria, or Al-Djazereh, where a third of the country's

2.5 million ha of cereal is grown. Cereal-growing areas that receive more than 350 mm of rainfall represent one-fifth of the total cropped area in Syria and nearly half of this highly productive land is in Al-Djazereh. The major crop rotation there is continuous cereal but some farmers now rotate cereal with lentil, chickpeas and vetch.

The objectives of the trial were to quantify the productivity of a medic/wheat rotation compared with vetch/wheat, fallow/wheat and wheat/wheat, to monitor sheep productivity, using stocking rates of 5, 9 and 12 ewes/ha on the medic pasture, and eventually make economic analyses of the results. At the end of 1989/90 the project finished its fourth year.

Methods

The medic pastures were sown with a drill at a seeding rate of 30 kg/ha using a mixture of M. rigidula, M. noeana, M. rotata and M. polymorpha. The entire experimental area received 60 kg/ha P_2O_5 at the start of the experiment. Wheat and vetch (Vicia sativa) were planted with a seed drill at 100 kg/ha and the wheat was fertilized with 60 kg/ha N, split into autumn and spring applications. Cultivation of wheat after medic was done with a duck's foot implement to prevent medic pods from being buried too deep. Wheat crops were sprayed with herbicide to control weeds.

Each year, both phases of the rotations are represented in a randomized complete block design with three replications. Twelve Awassi ewes are grazed on medic pastures of 2.5, 1.4 and 1.0 ha to create the low (L), medium (M) and high (H) stocking rates of 5, 9 and 12 ewes/ha, respectively. During the winter, all ewes receive a maintenance ration until they have access to medic pastures. All feed inputs are recorded.

Ewes and their lambs are kept on pasture until weaned at an approximate weight of 30 kg/ha. They are weighed weekly and moved from medic to cereal stubble after harvest. In July, the three stocking rates within each replication are combined and two rams are added to breed the ewes. When feed runs out in the autumn the animals return to a maintenance feeding regime indoors.

Climatic conditions

In four out of five years, the experiment received less than average precipitation (Fig. 4.5). The 1989/90 season began with below-average opening rains, falling in a normal pattern until March, when only 10 mm was received. Plants in pastures were weakened severely by moisture stress until a heavy rainstorm moved through northeast Syria in April 1990 that permitted pasture and crop recovery. Total rainfall amounted to 309 mm; however, nearly one-third of the total fell in April, which helped the non-fallow rotations to produce a near average crop.

Wheat yields

Wheat yields from the wheat/fallow rotation in 1989/90 were more than double those of other rotations (Table 4.11) because the preceding season was extremely dry . In years with enough rainfall to recharge the soil profile, the subsequent crops yield the same as wheat after fallow (Melki et al. 1989).

Vetch production

Vetch cut as hay at 100% bloom attained a yield of 3 tons/ha. Rihawi et al. (1987) stated that it is difficult to make hay with forage legumes because they have thick stems which tend to dry slowly and there is a risk of crop losses due to untimely rainfall. Hay conditioning techniques now allow a more rapid drying of windrowed material. In six years of on-farm trials at Breda, Syria (Thomson and Oglah, 1987) the hay option was eventually dropped because yields were too low to be economically feasible. Breda, however, is a much drier site than Kamishly where 3 tons/ha of vetch hay, at 1990 prices, were worth 19800 Syrian Lira (SL).

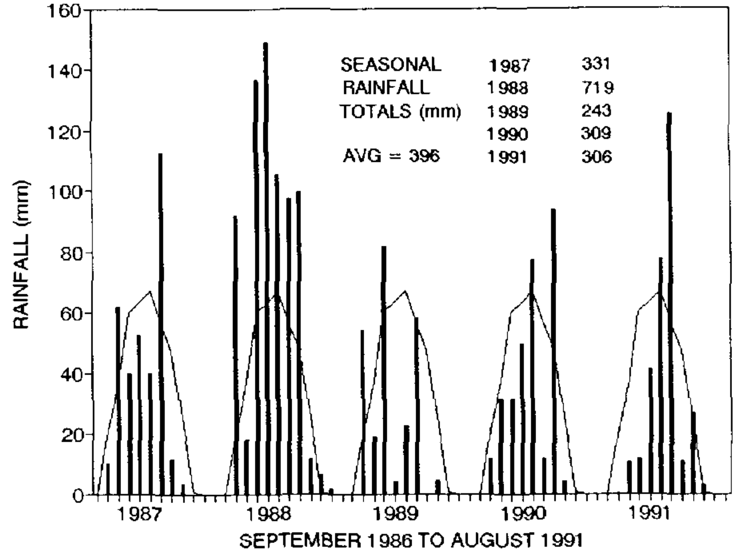

Fig. 4.5. Rainfall at Kamishly, NE Syria from 1987-1991.

Table 4.11. Wheat yields (t DM/ha) following medic at L, M and H stocking rates in 1989/90.

Crop After wheat	Grain	Straw	Total
Fallow	2.14	5.72	7.86
Medic (L)	0.96	3.40	4.36
Medic (M)	1.02	3.23	4.25
Medic (H)	0.91	3.18	4.09
Vetch	1.07	3.59	4.66
Wheat 1[1]	0.90	3.18	4.08
Wheat 2	0.62	3.83	4.45
LSD (0.05)	0.47	0.87	1.20

[1] Wheat in phase 1 and 2, respectively.

If allowed to grow to maturity for seed and straw, the vetch produced 0.68 and 1.64 t DM/ha, respectively. This is a loss in yield compared with the hay stage, mostly due to leaf drop. These mature vetch yields compare to 0.62 and 2.84 kg/ha of cereal grain and straw from continuous wheat treatments. The 1990 prices for vetch grain and straw were 11 and 5.5 SL/kg, compared with 9.5 and 3.0 SL/kg for wheat. Therefore, total gross value of the crop was 16500 SL for the vetch and 14400 SL for the wheat.

Pasture production

The L and M stocking rates permitted approximately one month longer grazing compared with H stocking rates before sheep were moved to wheat stubble grazing (Fig 4.6). Ewes were removed from the heavily grazed medic plots on 30 June and from the medium and lightly grazed

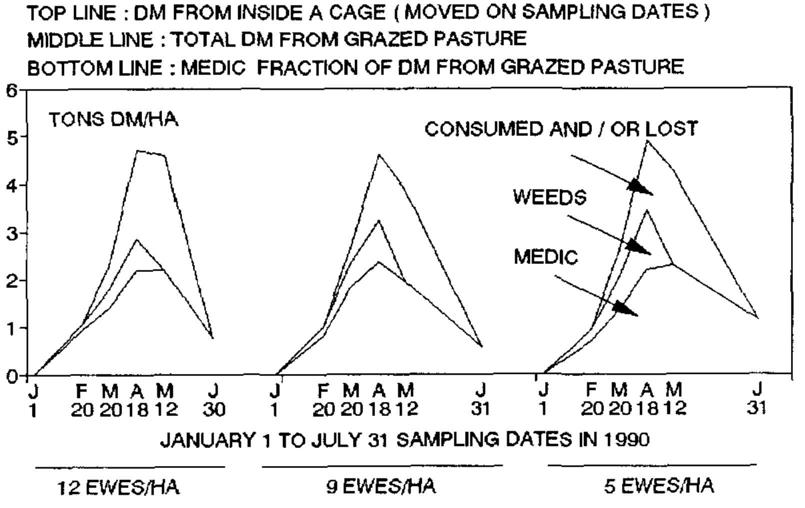

Fig. 4.6. Standing biomass and estimates of medic and weed consumption and/or loss from H, M amd L stocking rates on medic pastures in 1990.

medics on 31 July 1990. The residual medic dry matter on the pastures amounted to 0.75, 0.58 and 1.13 DM/ha, respectively. High stocking rates of sheep eliminated weeds sooner and to a greater extent than on the other grazing treatments (Fig. 4.6).

4.3.1 Sheep grazing management

Tables 4.12, 4.13 and 4.14 demonstrate the importance of management in deriving the correct balance between a sustainable stocking rate and optimum economic outputs. One objective of the trial is to maximize the number of days on pasture to reduce supplementary feeding.

The low stocking rate allowed more time on pasture (Table 4.12), decreasing the number of days of indoor feeding to 129 days, a gain of 66 days compared with higher stocking rates.

The days of feeding were increased for the H stocking treatment and feed requirements per flock were higher because more sheep needed supplementation. Table 4.13 shows that the total amount of supplementation fed was tripled for the H stocking rate. The consumption of feed per ewe at the H stocking treatment was 33% greater than at the L and M stocking rates.

Consequences of the stocking pressures and feeding are shown in Table 4.14: 334, 570 and 880 kg/ha animal product were produced for L, M and H stocking treatments. Outputs of milk and wool per ewe did not differ among stocking rates but lamb weaning weights were considerably higher at the low stocking rate.

At the start of the 1989/90 season, ewes at the low stocking rate had higher liveweights than ewes from the other two treatments (fig. 4.7), as a result of greater herbage availability the previous year. After lambing, during the periods of grazing both medic and wheat stubble, ewes at the low stocking rate maintained slightly higher weights until September 1990.

Table 4.12. Total days of grazing or supplementation for the medic/wheat rotations in 1990.

Feed	Stocking rate L	M	H
Grazing green medic	71	71	71
Grazing dry medic	75	75	42
Grazing wheat stubble	90	75	57
Total grazing days	236	221	170
Supplementary feed indoors	129	144	195
Percent days with supplement	35%	39%	53%

Table 4.13. Supplementary feed (kg) consumed by sheep in medic/wheat rotations.

Feed	Stocking rate L	M	H
Hay	415	895	1392
Barley	286	544	778
Cotton seed cake	70	139	214
Wheat bran	54	109	160
Total	825	1687	2544
Individual animal basis	165	187	212

Table 4.14. Output (kg/ha) of animal products from medic/wheat rotations.

Product	Stocking rate L	M	H
Meat	123	195	263
Milk	199	355	491
Wool	12	20	26
Total	334	570	880
Lamb weights at weaning	25	22	22

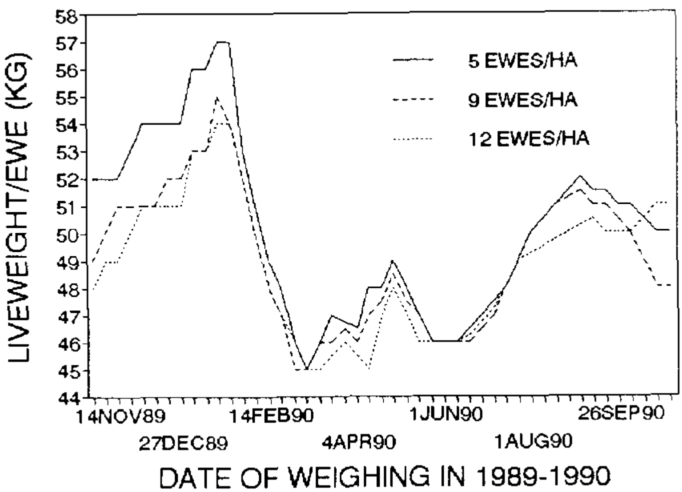

Fig. 4.7. Ewe liveweights during the 1989/90 season. Animals were fed indoors until February, then grazed medic pastures until 30 June (12 ewes/ha) or 31 July (9 and 5 ewes/ha).

4.3.2. Seed bank reserves

The key to successfully managed medic/wheat rotations is maintaining sufficient seed supplies in the soil. After two complete rotations, the seed banks at Kamishly were above the accepted guideline of 200 kg/ha (Table 4.15). The highest seed yields on the surface of the soil in 1990 were obtained from H stocking rate treatments. The reason for this is that weed competition was controlled by grazing and at flowering time there were few weeds to compete with the medic at the H stocking rate, unlike the M and L stocking rates.

The medic/wheat rotation is more complicated than other rotations because it necessitates correct crop agronomy, pasture management and animal husbandry.

Table 4.15. Medic seed bank (kg DM/ha) at the end of the fourth year at the Hemo Experiment Station in 1990.

Stocking rate	Sample location	Seed yield	Total
L	Soil surface	136	
	Below surface	150	286
M	Soil surface	91	
	Below surface	135	226
H	Soil surface	162	
	Below surface	100	262

Agronomically, the soils used for the cereal crop must be cultivated shallow to permit regeneration of the medic. Weed control is largely a function of medic pasture management. Grazing should commence early to eliminate cereal volunteers and to reduce the percentage of weeds in the botanical composition of the pasture. Proper grazing management will minimize the weed seed that carries over into the cereal phase of the rotation. In the current experiment, broadleaf weeds were controlled by 2,4-D but no herbicide was available to control wild oats and wild barley, both of which are undesirable weeds that compete vigorously with wheat. In the H stocking rate plots the annual grasses were completely controlled.

Acknowledgements

The authors would like to thank Mr Ahmed Khadri, Head of Hemo Agricultural Experiment Station, the support staff at Kamishly and the Livestock Research Division of the Syrian Ministry of Agriculture and Agrarian Reform in Douma for their help. - **G. Melki, S. Elias, L. Labban and A. Kronfuleh (SMAAR), and F. Bahhady and S. Christiansen**

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4.4. Harvest Mechanization of Forage Legumes

The single biggest expense associated with the growing of forage legumes is the high cost and difficulty of hand harvesting. Consequently, farmers who want forage legumes for feeding animals view mechanization of harvesting as essential for widespread adoption of forage legumes.

The agricultural plan in Syria at the moment calls for the elimination of fallow, which was an option for resting the land. Therefore, farmers in the barley/livestock zone are faced with a dilemma, to grow barley continuously, risking depletion of fertility and build-up of pests, or to rotate barley with forage legumes, which makes them dependent on an irregular and costly supply of manual labor at harvest time. Survey information from the area shows that 35 man-days of labor/ha (at 100 SL/day) are needed to harvest vetch, while all other operations (sowing, transporting, winnowing and bagging) total 23 man-days/ha/season.

Farmers understand that the total productivity of forage legume rotations with barley is higher than that of barley/fallow rotations and of continuous barley growing. Thus, it was no surprise when farmers in on-farm trials at El Bab asked for help to solve their harvesting problems.

A pilot project was started with the objective of comparing harvesting with a cutter-bar mower or a combine with a special header adapted to harvest food or forage legumes with traditional hand harvesting and threshing. Farmers grew one or more hectares of common vetch (Vicia sativa). The effect on harvested yield of rolling after sowing was compared in rolled and unrolled plots. All straw and grain measurements represent what was actually harvested from the field, and included transport and threshing losses.

Four farmers volunteered for the study and three continued with the program through the entire 1990/1991 season. The rainfall for the year totalled 246 mm; mechanized techniques were at a disadvantage because of low crop height and yield.

Results show that none of the mechanized techniques can match the efficiency of hand harvesting (Table 4.16). The combine performed better than the cutter-barmower and rolling improved the dry matter recovery for both techniques.

Farmers normally graze a vetch crop when the grain yield is less than 200-300 kg/ha. The yield of hand harvested vetch was only 427 kg/ha, suggesting that this was a marginal year. In a year with higher rainfall the mechanized techniques would perform better compared with hand harvesting.

Table 4.16. Yields (kg/ha) of vetch grain and straw harvested by hand or with machines, with and without rolling after sowing.

Technique	Grain	Straw
Hand harvest	412 a	1905 a [1]
Combine, rolled	277 b	1127 b
Combine, unrolled	239 c	838 c
Mower, rolled	200 d	770 cd
Mower, unrolled	169 e	559 d

[1] Means within a column followed by the same letter are not different using Fisher's Protected LSD ($P<0.05$).

Poor recovery of straw using the mower is partially explained by a windstorm (50-60 km/hr) that occurred the night after the vetches were cut and windrowed on 15 May 1991. Vetch from the combine treatment had not been harvested and the hand harvesting of vetch had been made earlier when the vetch was slightly greener, resulting in piles that were less affected by the wind.

Nevertheless, the farmers liked both machines and were satisfied with the performance of the combine. They considered the manufacture of a cutter-bar at local machinery units a more realistic possibility than making special headers for combines. The trial will continue in 1991/1992, and ICARDA will lend a cutter-bar mower to the El Bab Farmers' Cooperative to examine the feasibility of modifying and manufacturing similar units locally. - **S. Christiansen and A. Semaan**

4.5. Nitrogen Balances in Integrated crop/Livestock Systems

A major reason for the strong interest in legumes at ICARDA has been an appreciation of their potential to improve the N economy of farming systems in the region (Carter 1978; Cocks 1988; Saxena 1988). This strong interest has stimulated the need to understand the flows and transformations of N, so that inputs from legumes can be measured more accurately. Present data provide good estimates of

N fixation by some of the major legumes grown (Papastylianou 1987; Beck et al. 1991). However, a comprehensive understanding of the net flows of N within particular farming systems is lacking. Some work on the gross inputs and outputs of N from cropping rotations has provided simplified N balances for part of the system (Jones 1989; Beck et al. 1991) but, as yet, there are no data for systems with grazing animals included.

For livestock-based systems, much of our knowledge has been gained from data obtained from outside the region. For example, estimations of the N accretion under pasture grazed by sheep have largely been based on Australian experience (Carter 1978; Cocks 1988). There are difficulties, however, in applying such data because of the unique management systems in WANA. In particular, effects on N cycling of the exploitative grazing practices, where a very high proportion of the plant material is removed, are unknown. Also the level of return of N in urine and faeces has not been quantified. The assumption that grazing will return 90% of the N in herbage through dung and urine deposition does not apply because farm sizes are small and fences uncommon. Hence, animals are moved on and off the farm frequently and are associated with particular fields for only short periods. Furthermore, legume straw is often harvested, stored and later fed to animals indoors rather than being grazed as stubble in situ.

With these considerations in mind, the nitrogen cycling work within PFLP has aimed to, first, quantify the long-term trends in total soil N for particular crop/livestock production systems. This has provided a clear orientation as to direction and magnitude of the changes in total soil N that are likely to occur under the management regimes relevant to WANA. Second, for the 1990/91 season detailed measurements of the flows of N in specific cropping rotations were made to identify the major factors influencing the system. The third phase of the work will be to look at some of the primary N transformations (N mineralization, NH_4 volatilization, N fixation).

4.5.1. Long-term Trends in Soil N

The long-term rotation trial within PFLP (preschedule L13, 1985/86) offers a unique opportunity to study the trends in soil properties after an extended period of consistent management. The trial began in the season of 1985/86. Seven treatments were established: wheat rotated with medic grazed at 3 stocking rates (4, 7, 10 sheep/ha), vetch, lentil, fallow or watermelon. Both phases of the experiment were present each year and 2 rates of nitrogen fertilizer (+N,-N) were applied to the wheat. Soil samples were taken to a depth of 20 cm in all treatments prior to establishing the experiment and in the summer of every year thereafter. Further details of treatments, management and some results are described in PFLP's annual reports for 1987 (pp. 43-62), 1988 (pp. 125-142), 1989 (pp. 74-80). Particulars with direct relevance to the N balance of the rotations are summarized here in Table 4.17

Results clearly and consistently showed that rotations including medic or vetch added significant ($P<0.05$) amounts of N to the soil (Fig 4.8). After 6 years, averaged over phases, total soil N increased by about 20% when wheat was rotated with medic and by about 15% when rotated with vetch. This corresponded to a rate of N accretion in the top 20 cm of soil of approximately 30 and 40 kg N/ha/year for vetch and medic respectively (assuming a soil bulk density of 1.1 under medic and 1.0 under vetch; H. Harris, personal communication). Nitrogen fertilizer application did not affect the rate of N accretion and thus only data for the N treatments are presented here. There appeared, however, to be a trend developing in

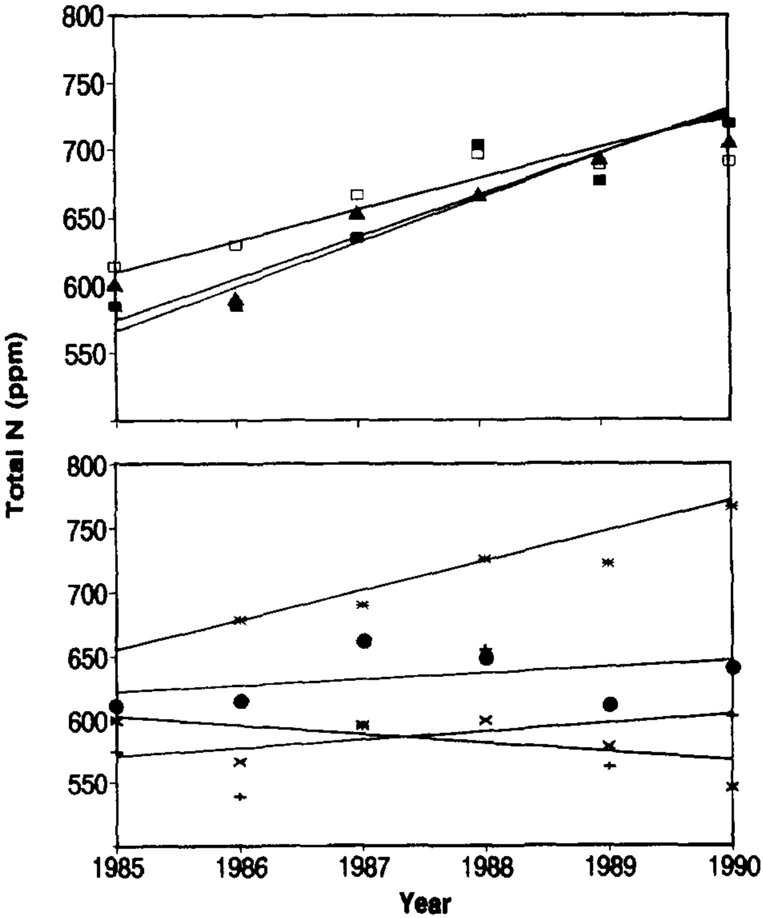
Table 4.17. Fertilizer applications, rainfall and harvesting methods relevant to the N cycle in trial L13.

Year	85/86	86/87	87/88	88/89	89/90	90/91
N (kg/ha)	60	40	90	90	90	60*
P (kg/ha)	60	40	20	20	20	20**
Rainfall (mm)	316	358	504	234	233	294
Harvest method:						
Medic	grazed	grazed	grazed	grazed	grazed	grazed
Vetch	hand	hand	hand	grazed	grazed	hand
Lentil	hand	hand	hand	hand	hand	hand
Watermelon	hand	hand	hand	n.a.	n.a.	n.a.
Wheat	mech.	mech.	mech.	mech.	grazed	mech.

* Applied as urea to the wheat in the +N treatment only.
** Applied as triple superphosphate to the wheat phase only.
hand= Hand harvesting removing the entire shoot and a proportion of the crown roots.
mech= Mechanical harvesting.
n.a.= No crop was planted in these years because of the low rainfall.

which plots receiving N fertilizer had a slightly higher total N concentration than those not receiving N fertilizer. This may become more evident over time. The rates of N accumulation were also the same at all stocking rates.

In contrast to medic and vetch, the total N concentration in the soil remained the same over the 6 years of the experiment when wheat was rotated with lentil, fallow or watermelon. Application of fertilizer N also did not increase total soil N over time although, again, a divergence between treatments receiving N fertilizer and unfertilized treatments may become evident after a further 2 to 3 years. Certainly, in the last season (1990/91) treatments receiving N fertilizer had a higher ($P<0.05$) total N concentration than the treatments not receiving fertilizer N.



Equations for fitted lines

Medic low (■); $y = 549(\pm 24.7) + 29.1(\pm 5.9)x$; $r^2=0.85$; $P<0.01$
medium (□); $y = 606(\pm 16.2) + 16.7(\pm 3.9)x$; $r^2=0.82$; $P<0.05$
high (▲); $y = 568(\pm 15.8) + 23.9(\pm 3.8)x$; $r^2=0.91$; $P<0.01$
Vetch (*); $y = 654(\pm 11.5) + 20.7(\pm 3.6)x$; $r^2=0.92$; $P<0.05$
Lentil (+); $y = 562(\pm 41.5) + 7.7(\pm 9.9)x$; $r^2=0.13$; NS
Fallow (●); $y = 621(\pm 24.1) + 3.6(\pm 5.6)x$; $r^2=0.08$; NS
Watermelon (x); $y = 605(\pm 20.5) - 6.7(\pm 4.9)x$; $r^2=0.32$; NS

Figure 4.8. Total N concentration in the soil (top 20 cm) during a six year 1:1 rotation of wheat with medic (3 stocking rates) vetch, lentil, fallow or watermelon.

Removal of N through grazing or in harvested grain and straw together with recycling of N via urine and faeces is likely to account for much of the difference in the rates of N accumulation between rotations. This is reflected in the trends in soil organic matter during the experiment (Table 4.18). Total soil organic matter decreased (P>0.01) over time when wheat was rotated with lentil, fallow or watermelon but remained constant when rotated with vetch or medic. A decrease in soil organic matter is indicative of greater removal than return of plant material from the field.

Table 4.18. Organic matter concentration (%) in the top 20 cm of soil in each rotation of L13.

Treatment†	N fertilizer addition			No N fertilizer addition		
	1987	1988	1990	1987	1988	1990
Medic-low	0.99	1.07	1.06	0.96	1.11	0.99
Medic-medium	0.12	1.01	1.05	1.03	1.00	0.99
Medic-high	1.10	1.03	1.07	1.06	1.02	1.03
Vetch	1.04	1.08	1.08	1.03	1.08	1.09
Lentil	1.06	0.98	0.90	0.95	0.99	0.85
Fallow	1.10	1.04	0.98	1.10	1.08	0.90
Watermelon	0.97	0.94	0.82	0.99	0.96	0.74

s.e.d. 0.049, 1987; 0.081, 1988; 0.058, 1990.

† Soil samples taken both in the wheat and non-wheat phase of the rotation. Values presented are averaged over both phases of the rotation

4.5.2. Nitrogen Balance of Trial L13

At present all data are not yet available to allow a complete N balance of all the rotations of the L13. Nevertheless, it is worth illustrating the main differences between a pasture and a crop legume in the rotation. The results described below rely on the cumulative grain and straw yields in the trial and detailed measurements taken during the 1990/91 season. It is recognized that results for 1990/91 may not be directly applicable to any other one year in the trial, but, in terms of rainfall and yields, 1990/91 was close to the average of the previous 5 seasons. All figures are calculated from data collected from experiment L13 except where specifically indicated.

Inputs

Differences in soil N between the rotations including medic and lentil were not explained by differences in N fixation or fertilizer application. This is best illustrated by the large difference in total N input between the lentil/wheat(+N) and medic/wheat(-N) rotations. For lentil/wheat(+N), based on the biomass production, the N concentration in the plant material and the proportion of N derived from fixation (70%; Beck et al. 1991) inputs from N fixation averaged about 37 kg N/ha/year (74 kg/ha every second year). Added to the N fertilizer applied to the wheat (36 kg/ha/year) and the N input with planted seeds (4 kg/ha/year), total inputs were about 77 kg N/ha/year. For medics, assuming 75% of total N was derived from fixation then the N input from fixation totalled about 39 kg/ha/year. Added to the N input from planted seeds (2 kg/ha/year), the total N inputs were about 41 kg/ha/year.

There was, thus, 36 kg/ha/year more N added in the lentil/wheat(+N) rotation than in the medic/wheat(-N) rotation, yet total soil N only increased in the medic/wheat(-N) rotation. It should be noted here that these calculations do not include inputs from non-symbiotic N fixation and N deposition, estimated at about 5-10 kg N/ha/year for both rotations (Vlek et al. 1981).

Outputs

There was a net export of N (from the soil) with the lentil crops.

Based on grain and straw yields, total harvested N in lentils averaged about 88 kg/ha in every second year. Assuming 70% of total plant N was derived from the atmosphere (74 kg/ha) there was about 14 kg of soil-N/ha exported with the lentils. Nitrogen remaining as un-harvestable residue on the soil surface averaged about 5 kg/ha and that associated with the roots was about 11 kg/ha, about 10% of total plant N. In contrast, there was a net import of N (from the atmosphere) with the medic pasture. Total N removed (with sheep products, urine and faeces, see next section) averaged 17 kg/ha which was 19 kg/ha less than the amount added through N fixation.

When the wheat crop was included, total N output in the lentil/wheat(+N) rotation averaged 74 kg/ha/year compared with 31 kg/ha year in the medic/wheat(-N) rotation. Therefore, there was 43 kg/ha/year less N removed from the medic/wheat(-N) rotation than the lentil/wheat(+N) rotation.

Clearly there are limitations to this type of analysis. Calculations performed here are simply to illustrate that, despite there being a higher input of N in the lentil/wheat(+N) rotation, there were also higher outputs resulting in a negative balance. In WANA, therefore, where there is a high proportion of product removal, there is unlikely to be long-term increases in soil N unless there is a higher proportion of fixed N returned to the soil via crop residues or animal excreta.

In addition to the gross movements of N, the form in which the N is held is very important. For example, N contained in cereal straw residues with a high C:N ratio will be immobilized and not readily available for plant growth. In contrast, N in urine is easily mineralized and available for plant growth. Future work, as well as determining the gross nitrogen balance for all the rotations in L13, will involve a detailed analysis of the amounts of N held in different forms. The rate of flux between these forms (i.e, atmospheric N → organic N → mineral N) also will be investigated.

4.5.3. Nitrogen Removal from Pasture and Stubble by Sheep

In grazing systems, a complicating factor in the N cycle is the return or removal of N in the urine and feces of sheep. This is particularly pertinent under the management regimes in WANA where sheep are very mobile, moving on and off fields frequently.

To quantify these flows, an experiment was conducted during the 1990/91 season at Tel Hadya. Six plots (7500 m^2 each) were fenced. Three plots were sown to barley while the other 3 were established in an area of self-regenerating medic pasture. Six sheep per plot grazed the area during the day (7:00-17:30 hr) but were removed at night and housed. The aim of the experiment was to: (1) determine the total removal of N through urine and faeces deposition off the field and through milk off-take, (2) determine the amount of N returned to the fields, in what form (urine or feces) it was returned and how the partitioning of N in urine and feces changes during the season, with changes in the quantity of quality of the pasture consumed.

Fecal collection bags were fitted to the animals to collect the total urine and feces produced (slops). The bags were changed when the animals left the field each evening and again when they were put out to graze in the morning. In addition a sample of feces was taken directly from the rectum of the animal (grab-sample) each time the bags were changed. From the ADF:N ratio in the grab sample, the total N content of the slops could be partitioned between the contribution from urine and feces. Each collection period lasted 1 week and occurred once per month. The experiment spanned 5 months (5 collection periods) beginning in early April, at the start of grazing, and progressed to the end of August at which time all plant material in the medic plots was grazed. For the last 2 months of the experiment grazing was supplemented by barley grain (medic pasture) or cotton seed cake (barley stubble) fed to the animals indoors to ensure adequate energy and N intake by the sheep.

Preliminary analysis of the experiment showed that approximately 50% of the output of N from animals in the form of urine and feces was deposited off the field (Fig 4.9). When the off-take of N in the milk was included the total amount removed by animals was greater than that recycled to the pasture. The largest removal of N from the field occurred at the early part of the season when feed had a higher N content and herbage intakes by the animals were high (Table 4.19). The proportion of total N contained in the feces or urine changed during the growing season. Nitrogen in the urine represented only a small part of the total in late August when animals were grazing barley stubble with a very low N content.

Table 4.19. Nitrogen concentration and dry matter intakes of either medic-based pasture or barley for each of the 5 measurement periods throughout the growing season at Tel Hadya.

	April	May	June	July	August
		N concentration (% DM)			
Barley	1.75	1.40	0.87	0.57	0.41
Pasture	3.32	2.73	1.09	2.17	1.53
		Dry matter intakes (kg/ewe/day)			
Barley	1.7	1.8	1.2	1.3	1.2
Pasture	2.8	1.9	1.4	1.3	0.7

The amount of N in the urine and feces originating from the supplementary feed was only a small portion of the total N excreted by the animal. As the proportion of supplementary feed increases in the animal's diet, however, supplementary feeding may represented a transfer of N back onto the field. - **P. White**

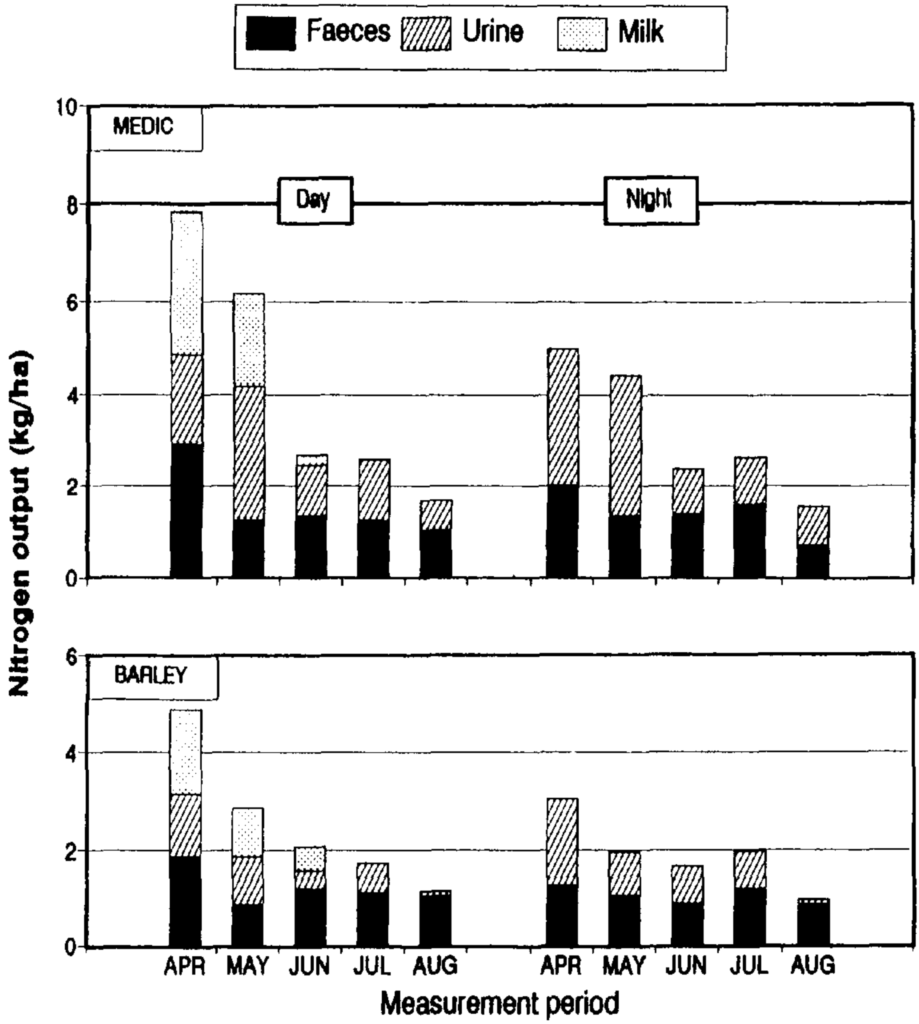


Figure 4.9. The amount of N produced during the day or night and present in feces, urine, or milk of animals grazing medic-based pasture or barley. Calculations based on 31 day monthly periods and assuming 7 sheep per hectare.

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4.6. Economic Analysis of Crop and Pasture Rotations with Wheat

The field trial (L13) established at the Tel Hadya Station in 1985 to measure yields and changes in soil and biotic parameters under the following seven crop rotations with dryland wheat:

1. fallow/wheat,
2. watermelon/wheat,
3. vetch/wheat,
4. lentil/wheat,
5. medic pasture (low stocking, 4 ewes/ha) - Wheat,
6. medic pasture (medium stocking, 7 ewes/ha) - Wheat,
7. medic pasture (high stocking, 10 ewes/ha) - Wheat.

After six years, these trials have produced good biological data. With the addition of information from farm surveys, it has been possible to conduct the first economic analysis of the results. Only an outline of the economic analysis (which will be completed in 1992) is presented here, together with a brief sample of the initial results.

Among the seven rotations, only lentil/wheat and watermelon wheat are common on Syrian farms in the same rainfall zone. They are often found in non-rigid rotations: sometimes as wheat/lentil/watermelon, barley-lentil-watermelon, and sometimes with sesame replacing watermelon in these rotations when a drier than normal season occurs. Planned fallows are rare, but fallow may replace sesame if the season appears too dry for this or other late-sown crops. Rotations which include forage legumes such as vetch or lathyrus are also rare. Medic pasture is virtually unknown outside the on-farm trials staged by ICARDA in collaboration with the Syrian Ministry of Agriculture and Agrarian Reform (Nordblom 1987).

One of the main purposes of the analysis is to identify the socio-economic niches for the seven rotations. This is needed for the successful design and targeting of larger-scale on-farm trials in collaboration with the National Program.

The economic success of the medic/wheat system needs to be demonstrated in farmers' hands as a key step toward release and multiplication of locally proven cultivars of medic. Not only is a technically viable package of locally adapted seed and management techniques needed, but the mix of socio-economic conditions also has to be right for medic pasture/wheat to compete with other systems.

Among the socio-economic conditions considered to play important roles in determining the relative success of a farming system on a given farm are:

1. amounts of family labor available for farm and off-farm work,
2. wages for family labor and hired labor,
3. availability of hired labor,
4. prices for farm commodity sales and for feed purchases,
5. skills and preferences for managing a particular enterprise,
6. farm size and inherent productivity,
7. access to free grazing areas, and
8. the practical ability to protect pasture from grazing by other's flocks.

Effects of various combinations of the above points are quantified in this study through use of a whole-farm linear programming model.

4.6.1. Elements of the Whole-farm Economic Analysis

The central role of sheep flocks in the use of pastures and crop residues complicates to the economic comparison of crop rotations. Medic pasture is a seasonal source of animal nutrition, viewed here in the bio-economic context of other crops, pasture and feed sources (i.e., wheat straws and stubbles). Gross analyses, which simply assign a price to each kg of pasture biomass, give biased results when there is failure to account for all costs of keeping sheep, or when there is failure to account for trampling, shattering and other causes of pasture disappearance. Sheep nutrition and productivity aspects also must be considered.

In the case of a breeding flock, producing lambs and milk for the market, nutritive requirements of sheep have to be defined for each season of the annual cycle. Nutritive qualities of the various pasture, roughage and concentrate feeds available in the different seasons also need to be specified. The model's quantitative assumptions on sheep nutritional needs for given levels of performance and on feed qualities (crude protein and metabolizable energy) are critical for an accurate assessment of differences among the rotations.

Another set of important data is the details of cash costs and labor requirements of seven crop rotations. These are based mainly on the L13 trial at Tel Hadya, with other data provided from surveys. Budgets for these rotations are based on the actual material inputs to large trial plots, designed to reflect farming practices in NW Syria. Labor requirements in the budgets reflect farm rather than experimental conditions. Farmer surveys were used to specify budget values as close as possible to farmers' conditions in 1990.

Commodity prices for feed, sheep, and crops over the 6- year period were collected in the Aleppo markets. Given the strong inflationary trend throughout the period, prices were deflated to 1990 Syrian Pounds and means of the 6-year deflated series were used.

Assumptions on family labor availability, and labor requirements of managing shepherded sheep that are hand-fed and milked, are based on survey results and first-hand experience. Labor costs, and off-farm work opportunities for family labor, are important variables in the economic analysis when combined with various farm sizes.

Several sizes of farms, corresponding to those of farmers in a recent survey, are used in the analysis (Table 4.20).

Table 4.20. Farm sizes: survey results and representative levels.

Survey results on farm size [1]		Representative farm sizes examined
5.0 ha or less	3 % of farmers	-
5.1 - 10 ha	17 % of farmers	8 ha
10.1 - 20 ha	35 % of farmers	16 ha
20.1 - 40 ha	27 % of farmers	32 ha
40.1 - 80 ha	11 % of farmers	64 ha
more than 80 ha	8 % of farmers	-

[1] Mohamed Khazmeh, personal communication 1991.

Physical results of the L13 trial over the 6-year period (1985/86-1990/91) were summarized. Crop yields (quadrat samples adjusted for field losses), pasture measurements and records of sheep grazing days on pasture have all been used to provide the estimates of production for the economic analysis. This is the first sound basis for a study on economics of medic pasture in Syria.

4.6.2. Physical results of L13

Medic pasture offtakes (calculated as sheep grazing days multiplied by dry matter intake per day) have been lower than the hand-harvested recovery of lentil straws. This result ignores the fact that the pastures produced more biomass than the lentil straws; these amounts were not consumed by the sheep, however, because conservative grazing management was designed to build up a 200 kg/ha seed bank in the trial fields.

Further analysis will be made of six years of pasture production data from clippings inside and outside cages, to have an alternative measure of offtake by sheep. These may be considered the upper limits on medic offtake, in contrast to the lower limits estimated from grazing day records and assumptions on daily dry matter intake.

Yields of wheat grain following medic pasture were the lowest among all rotations. Such results have not been reported in the literature from Australia where medic pastures are common. We hypothesize the chief cause of the reduction was greater soil water depletion by the medic pasture relative to the other rotations; continuous slow grazing allows regrowth of leaf area, unlike the other crops which progress undisturbed to maturity. To test this hypothesis, barley was sown on subplots in 1991/92 to see if a cereal cultivar with earlier maturity has similar yields after medic compared with the other rotations.

4.6.3. The Whole-Farm Model

The farm family has basic minimum cash requirements which need to be met by farm income or off-farm employment. Farm families have different levels of resources for crop and livestock production: their own labor and the amounts of farm and grazing land that they own or to which they have access. The farm family also is linked to markets for the sale of their crop and livestock products and their labor, and for the purchase of crop inputs, livestock feeds and hired labor.

Farm size and markets are linked directly with crop production and profitability. Different crop rotations produce various feedstuffs and pasture sources to link indirectly (but powerfully) with markets through livestock products. In the model, the market can provide additional feed, as can communal grazing areas.

All of these linkages are expressed in a whole-farm linear programming model designed to calculate optimal farm plans to maximize returns to the family's land, labor and management. The number of sheep is optimized for each set of operating conditions posed to the model. The model only considers "an average" year in terms of yields and prices, but these and other factors are easily altered in sensitivity analyses. This whole-farm model allows explicit consideration of labor constraints and costs as well as cash flows.

Constraints on intakes by ewes of dry matter, crude protein and metabolizable energy are defined. These vary with the annual production cycle through the four seasons. The constraints can be satisfied by various combinations of available feeds and pastures; the model will find the least-cost diet from the viewpoint of the whole farm, balancing stored, purchased and seasonal feeds over time.

4.6.4. Initial results

Initial results confirm the dominant economic position of the lentil/wheat rotation which has long been popular in this rainfall zone of Syria. Lentil/wheat was identified by Nordblom (1987) as the most profitable among the area's traditional rotations. Wheat grain and straw production after a lentil crop are good, as are the values of lentil seed and straw. The lentil straw yields have been higher than vetch straws. Both have higher feed values and prices than wheat straw.

The low wheat grain yields, combined with low medic pasture offtakes (calculated from grazing days), gave the medic/wheat rotations on small farms (8 and 16 ha) the lowest economic returns, and lentil/wheat the highest returns, in our initial analysis. Contrary to earlier expectations, watermelon/wheat and fallow/wheat, which had the highest yields of wheat grain, also outperformed medic/wheat.

In solutions constrained so that (1) family labor does not work off-farm, (2) shepherding time is committed and unavailable for other uses, (3) wages of hired labor are quadrupled and (4) the sale of straws blocked, the lentil/wheat rotation still gave the best results for small farms of 8 ha. On farms of 16 ha, however, watermelon/wheat gave the highest returns. On 32 ha farms, vetch/wheat was best, and on larger farms of 64 ha, the medic pasture/wheat rotation was most profitable. The high labor requirements of hand-harvested lentil and watermelon crops meant some land would be left unplanted on the larger farms; labor was too costly. The combination of the above four constraints may arguably be less than realistic today for many farms in Syria. This example is only intended to illustrate the sorts of questions which can be examined with the model.

Our main aim is to identify sets of "target conditions" on Syrian farms which will be the best for economically successful demonstrations of the medic pasture/wheat rotations, and which ones will be best for vetch/wheat rotations.

Our initial results demonstrate that no rotation is best for every farm. This should not be surprising: neither are barley, chickpea or faba bean crops suitable for every farm. Further, not every farmer keeps sheep, or is able or willing to do so. Farmers who do not own sheep are unlikely to find success with self-regenerating medic pasture because of the need for careful management of seed reserves in the soil. When grazing rights are sold, pastures are inevitably grazed clean.

With an expansion in the range of choices, farmers should be able to select the most profitable and productive set of farming activities for their own particular conditions. The completion of the economic analysis, based on this and other trials, on- and off-station, will clarify the options and give direction for efficient targeting of on-farm demonstration trials in collaboration with the Syrian Ministry of Agriculture and Agrarian Reform. - **T. Nordblom, N. Nersoyan, S. Christiansen and D. Pannell (Western Australian Dept. of Agriculture)**

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4.7. Dryland Pasture and Forage Legume Network

A meeting to establish a network on pasture and forage legumes for Mediterranean zones took place 28 April to 2 May 1991. The establishment of a network on this subject was first proposed at the Perugia workshop in Italy in June 1989.

At the founding workshop, 60 delegates discussed the objectives of the network and drew up terms of reference. The name Dryland Pasture and Forage Legume Network was adopted and it was agreed that work would relate to legumes for 3 areas: (1) cereal cropping zones with 250-300 mm rainfall and shallow soils; (2) the "barley-livestock" zone, and (3) non-cultivated pasture in arable zones.

The major objective is to improve communication between scientists and extension workers studying legumes so that their research and development work is more effective. In the long term, it is hoped that this will help this area of research attract more support from the institutions in which they work, their governments and international funding bodies.

Initially, Morocco, Algeria, Tunisia, Libya, Cyprus, Jordan, Syria, Turkey and Iran have expressed the wish to join the network and it is hoped that other countries will join. FAO, ACSAD, and IPGRI (ex-IBPGR) are observers. The South Australia Department of Agriculture recently nominated a representative to attend the Network Steering Committee meeting and the West Australia Department of Agriculture is likely to do the same.

In the past, ICARDA has collaborated with many of the groups now joining the Network. At the founding workshop it was decided that there should be a National Steering Committee in each country. The chairpersons of these National Steering Committees will meet annually to discuss the Network's activities at the Network Steering Committee Meeting. It is intended that the National Steering Committees will improve communication and collaboration within each country by drawing together representatives from all institutions in a country that are interested in the problems of pasture and forage legumes and their utilization. The committees will eventually, it is hoped, have an important role in formulating research priorities of this vitally important area of agricultural development.

The network produces an informal quarterly newsletter, called the "Dryland Pasture and Forage Legume Network News", to disseminate information. Three issues were distributed in 1991 with the aid of a grant from IPGRI to cover mailing costs. The newsletter is a useful means of connecting people with similar interests in different parts of the world. For example, on three occasions in 1991, the newsletter brought together germplasm collectors from outside the region with NARS hosts in the ICARDA - mandated countries. - **S. Christiansen**

5. Germplasm Collection and Evaluation

5.1. An ecogeographic Survey of Native Legumes in Jordan

Collection of new accessions of wild legumes is an important part of the process of developing adapted genotypes of pasture legumes. An ecogeographic survey of wild legumes was conducted in Jordan in 1990 to extend the range of germplasm from the region. Sixty-one sites were sampled from Baqa'a in the middle of the country to Aqaba in the far south and from Jordan Valley west to the eastern desert. The sites were selected to obtain wide heterogeneity in elevation, precipitation and soil. Elevation of the sites ranged from 400 m below sea level in Ghor el Safi to over 1500 m above sea level in Rashadia, Tafila. Rainfall followed a gradient from 50 mm in Ma'an and the eastern steppe to over 500 mm in Swaileh and El Salt.

Soil samples collected from each site were analysed for chemical and physical characteristics and any rhizobia present were isolated.

The pods and seeds collected were divided into two parts, one brought to GRU at Tel Hadya to be grown in the greenhouse and/or in a field for further identification and seed multiplication. The other part was kept at NCARTT, threshed, scarified and sown at Mushaggar Research Station in Jordan for primary evaluation. A total of 678 samples were collected from 19 genera and at least 72 species (Table 5.1).

The most abundant species of the genus _Medicago_ was _M. rotata_, which was found in 28 sites, followed by _M. orbicularis_ and _M. rigidula_, which were found at 21 and 20 sites respectively. _M. littoralis_ was very rare and only occurred at one site. The most common species from the genus _Trifolium_ were _campastre, tomentosum_ and _stellatum_ in 22, 19 and 14 sites respectively.

Table 5.1. Frequency of occurrence of the collected legumes in south east Jordan.

Species	No.of sites	Species	No.of sites
Medicago aculeata	5	Astragalus asterias	24
M. coronata	6	A. boeticus	1
M. laciniata	8	A. corrugatus	5
M. littoralis	1	A. hamosus	35
M. orbicularis	21	A. guttatus	10
M. polymorpha	14	A. schimperi	1
M. praecox	5	A. tribuloides	15
M. radiata	18	Astragalus sp.	31
M. rotata	28	Trigonella arabica	13
M. rigidula	20	Tg. caelesyriaca	1
M. scutellata	3	Tg. cylindraca	8
M. truncatula	7	Tg. grandiflora	1
M. turbinata	4	Tg. monspeliaca	25
Trifolium angustifolium	5	Tg. spicata	1
T. bullatum	1	Tg. spinosa	1
T. campestre	22	Tg. stellata	7
T. clusii	16	Tg. filipes	3
T. clypeatum	2	Trigonella sp.	11
T. eriosphaerum	12	Vicia anatolica	2
T. pilulare	8	V. benghalensis	1
T. purpureum	10	V. ervilia	2
T. scabrum	6	V. palaestina	1
T. stellatum	14	V. peregrina	1
T. tomentosum	19	V. sativa	19
Trifolium sp.	2	Vicia sp.	10
Lathyrus aphaca	1	Pisum julvum	5
L. pseudocicera	2	Pisum sp.	4
Lathyrus sp.	6	Anthyllis tetraphylla	1
Biserrula pelecinus	4	Coronilla scorpioides	13
Hippocrepis unisiliquosa	33	Cicer arietinum	2
Onobrychis crista-galli	49	Hymenocarpos circinnatus	27
Ononis sp.	17	Lotus sp.	1
Ornithopus compressus	7	Lotus halophilus	3
Scorpiurus muricatus	5	Lens culinaris	1
S. sulcatus	1	Lens negricans	1
Scorpiurus sp.	1	Lens orientalis	1

Onobrychis crista-galli was the most frequently sampled single species of all the collected legumes (49 sites). One point of interest is the presence of Astragalus and Trigonella species in the driest parts of the Jordanian steppe (east and south). While A. asterias, A. tribuloides and T. stellata were relatively abundant, species from other genera were absent or very rare in these particular areas. In the south at Aqaba and deep in the eastern steppe no legumes were found because they are rare in the area and their establishment was reduced by drought in 1990. - **M. Turk and A. Shehadeh**

5.2. ITGC/ICARDA Germplasm Collection Mission in Algeria

A forage and pasture legume germplasm collection in Algeria was carried out by a team from the Institute Techniques des Grandes Cultures (ITGC), Algeria and ICARDA from 10 June to 7 July 1991. The collection mission was initiated to ensure that ICARDA's germplasm collection contains representative accessions of Algeria's native legumes. The team consisted of Abdulhamid Khaldoun (Algiers), Sonia Hamrit (El Khroub), Abdelmadjid Hammadeche (Oued Smaar), Mohamed El Hadi Maatougui (Sidi Bel Abbes), Mahfoud Makloufi (Setif), Ali Shehadeh (GRU) and Walid Bou Moughlabay (PFLP).

The team covered 6000 km, traversing: 1) central Algeria (Algiers, Blida, Medea and Bouira); 2) west-southwest Algeria (Tiaret, Ain Defla, Tissemsilt, Saïda, Mascara, Sidi Bel Abbes, Tlemcen, Ain Temouchent, and Oran); and 3) eastern Algeria (Bordj Arreridj, Setif, Mila, Jijel, Batna, Khenchela, Oum El Bouaghi, Constantine, Skikda, Guelma, Annaba and El Tarf). Most of the areas normally receive more than 350 mm precipitation (range of 200-1200 mm) per year. Altitudes ranged from 25 to 1750 m above sea level between latitudes N 36°50' and N 34°25'.

The western and eastern segments provided the majority of the material, as collection in the central section was limited because plants had not matured, due to high rainfall in the mountains.

The complete set of the collected material was brought to GRU for multiplication, taxonomic verification, characterization and preservation. Accessions with sufficient quantities of seed were divided in two and one half was left at ITGC. The accessions not held by ITGC will be sent to Algeria after seed multiplication by GRU in the greenhouse in 1991-1992. Data were stored in the Mediterranean Forage Legume Database. Collection data will be analyzed to relate the distribution of species and their genetic characteristics to soil, climate and natural vegetation.

A total of 1421 accessions (Table 5.2) from 21 genera were collected from 108 sites. The 248 accessons of Vicia greatly increased the representaton of this genus in the ICARDA collection.

Table 5.2. Summary of genera and number of accessions from each genus.

Medicago	384	Aegilops	14
Trifolium	280	Onobrychis	14
Vicia	248	Anthyllis	11
Astragalus	114	Ononis	10
Scorpiurus	69	Hedysarum	9
Trigonella	49	Ornithopus	7
Lathyrus	45	Pisum	4
Melilotus	44	Potereum	4
Hippocrepis	43	Tetragonolobus	2
Coronilla	41	Hordeum	1
Lotus	28	Total	1421

Acknowledgements

ICARDA expresses its appreciation to ITGC's Director General Mohamed El Seghir Mellouhi and Secretary General Kamel Feliachi, who authorized and facilitated the planning of the trip. **- A. Shehadeh and W. Bou Moughlabay**

5.3. Collection and Ecogeographic Survey of Legumes in the Syrian Rangeland

More than half of the Syrian territory is rangeland which receives less than 250 mm rainfall. It is intensively grazed by sheep and goats, and normally suffers from severe overgrazing and soil erosion. Legumes, which are well adapted to dry conditions, can still be found growing in this area. The objective of this study was to collect these legumes and evaluate them in relation to their environment (soil, climate, etc.) to enable selection of germplasm suitable for rehabilitation of degraded steppe. The study is in collaboration with the Justus-Liebig University, Giessen, Germany.

In the summers of 1984 and 1985 annual legumes were collected in northwestern Syria including the wet coastal plain, the mountains separating the coastal plain from the interior, and the cereal belt east of the steppe. The present survey was made in the drier areas of the steppe. Transects from Raqaa through Deir El Zor and Boukamal in the north; from El Qoum and El Sukhna through northern Palmyrites mountains in central Syria; from the southern Palmyrites mountains to El Tanaf in the east, and from Sweeda to El Zalaf in southeastern Syria were covered. Semi-dry, dry, and very dry areas were visited during May-June 1991. Seeds of legumes were collected using 5 quadrats (100 cm x 25 cm) within an area of 25 m^2 in each site. Soil samples were also collected from the sites for chemical and physical analysis.

All the sites, except three, were heavily grazed resulting in few seeds being collected in most cases. A total of 219 accessions belonging to 13 genera and 37 species were collected (Table 5.3). Astragalus (91 accessions) represented 42% of the total number of accessions, Trigonella (53 accessions) 24%, and Medicago (30 accessions) 14%.

Seeds will be multiplied at ICARDA and used for further agronomic and utilization studies. - **G. Kattach and A.E. Osman**

Table 5.3. Legume species and number of accessions collected in the Syrian steppe in summer, 1991.

Genus	No. of species	No. of accessions
Astragalus	9	91
Hippocrepis	1	8
Hymenocarpis	1	4
Lathyrus	1	1
Lotus	1	2
Medicago	6	30
Melilotus	1	3
Ononis	1	1
Onobrychis	1	12
Scorpiurus	1	1
Trifolium	6	11
Trigonella	7	53
Vicia	1	2

5.4. Utilization of Perennial and Annual Self-reseeding Species in Forage Chains

Thirty-six ecotypes and varieties of perennial and annual self-reseeding species, mainly originating from Central Italy, were evaluated for forage production and seed bank yields in 1990/91 at Perugia. The objective was to identify forages with patterns of production that can be utilized in sequence to extend the grazing season of either mixed or single-species pastures.

Dry matter yield was measured monthly from plots. The first cut was 4 April; the last on 17 September 1991. Cuts were made at flowering for perennials and monthly thereafter if the herbage was higher than 10 cm. Annuals were managed as pasture, with monthly cuts when the herbage was higher than 10 cm.

The seed bank of the annual legumes was monitored in summer by collecting soil samples from 50 x 20-cm area to 5-cm depth in each plot. Soil was sieved and seed was handsorted from debris.

The seed bank of the annual species is reported in Table 5.4. The highest yields of seed were for T. subterraneum cv. 'Manciano' and M. arabica cv. 'Trasimeno'.

Dry matter yield for each entry is reported in Table 5.5. Medicago sativa cv. 'Casalina' gave the highest production of the alfalfas; Lotus corniculatus cv. 'Polcanto' the highest yield for bird's foot trefoil. Among the annuals, a persian clover, Trifolium resupinatum cv. 'Guadamello' produced the most. - **L. Russi, M. Falcinelli, and F. Lorenzetti**

Table 5.4. Mean seed bank of annual legumes (kg/ha) and s.e. assessed during the summer of 1991.

Species	CV / Ecotype	x	s.e.
M. polymorpha	ICARDA (SY)	257.5	113.3
M. polymorpha	Capoliveri	677.5	161.5
M. arabica	Trasimeno	1372.5	198.8
M. arabica	Cupramontana	497.5	166.3
M. arabica	Montalto	717.5	271.2
M. rigidula	Pornello	567.5	52.9
M. rigidula	Asciano	565.0	150.1
T. subterraneum	Commercial Seed (AUS)	210.0	24.1
T. subterraneum	Tuoro	482.5	131.9
T. subterraneum	S. Manciano	1517.5	159.8
T. subterraneum	Panicarola	450.0	276.7
T. resupinatum	Guadamello	120.0	52.1
T. resupinatum	Tuoro	287.5	134.1
T. resupinatum	Pescarina	175.0	69.5
T. campestre	Valderchia	312.5	126.0
T. campestre	Rocca di Corno	207.5	41.5
T. campestre	Picenze	375.0	128.2

Table 5.5. Seasonal and total dry matter (t/ha) during 1991.

Species	CV / Ecotype	Spring	Summer	Total
M. polymorpha	ICARDA (SY)	0.33	-	0.33
M. polymorpha	Capoliveri	0.17	-	0.17
M. arabica	Trasimeno	0.94	-	0.94
M. arabica	Cupramontana	0.99	-	0.99
M. arabica	Montalto	1.18	-	1.18
M. rigidula	Pornello	1.02	-	1.02
M. rigidula	Asciano	1.06	-	1.06
T. nigrescens	Pornello	0.87	-	0.87
T. subterraneum	Commercial Seed (AUS)	0.33	-	0.33
T. subterraneum	Tuoro	1.44	-	1.44
T. subterraneum	Panicarola	0.91	-	0.91
T. resupinatum	Guadamello	2.96	-	2.96
T. resupinatum	Tuoro	2.15	-	2.15
T. resupinatum	Pescarina	2.52	-	2.52
T. campestre	Valderchia	0.19	-	0.19
T. campestre	Rocca di Corno	0.13	-	0.13
T. campestre	Picenze	0.18	-	0.18
T. repens	Colfiorito	1.45	0.31	1.76
T. repens	Vada Rosignano	1.21	0.29	1.50
T. repens	Comunali	1.25	0.63	1.88
T. repens	cv. Huia (NZ)	1.43	0.34	1.77
L. corniculatus	Macerata	3.64	2.02	5.66
L. corniculatus	Polcanto	4.78	2.28	7.06
L. corniculatus	S. Marino	4.03	2.12	6.15
L. corniculatus	Sarsina	4.89	3.26	8.15
L. tenuis	Roseto	5.56	1.14	6.70
L. tenuis	Ancona	4.17	1.24	5.41
L. tenuis	Abbadia S.S.	3.76	1.00	4.76
O. viciifolia	Querce al Pino	1.43	0.92	2.35
O. viciifolia	Tolentino	2.72	0.59	3.31
O. viciifolia	Castello di Serr.	2.81	0.33	3.14
O. viciifolia	Marchigiana	2.28	0.37	2.65
M. sativa	Casalina	5.16	6.14	11.30
D. glomerata	cv Cesarina	2.01	0.62	2.63
L. perenne	cv Vejo	3.37	-	3.37
LSD (P<0.05)		1.04	0.88	1.16

6. Improvement of Mediterranean Grassland and Marginal Lands

6.1. Response of Mediterranean Grassland to Phosphate Fertilization: Results of 1989/1990 and 1990/1991 Seasons

The Mediterranean grassland, sometimes referred to as marginal land, constitutes a large proportion of the total land surface (30-40% in Syria and Lebanon). Communally owned, it is intensively grazed by sheep and goat and, generally, suffers from severe overgrazing and soil erosion.

Despite problems, grasslands are important to farmers. Nordblom and Thomson (1987) used a linear programming model to demonstrate that farmers with access to grasslands could own more sheep and have more profitable livestock enterprises than farmers without access. They are particularly heavily grazed in spring, when large amounts of supplementary feeding are fed to small ruminants. Improved productivity of grasslands should reduce supplementation needs and increase carrying capacity.

Soils in west Asia are diverse, but calcareous soils predominate. Calcium carbonate has a pronounced influence on the chemistry of these soils and deficiencies in major plant nutrients, such as nitrogen and phosphorus, are widespread (Vlek et al., 1981; Cooper et al., 1987). Grassland vegetation is predominantly annual, although perennial species are important in areas of high rainfall. Legumes are common, especially annual medics (Medicago spp.) and annual clovers (Trifolium spp.).

Phosphate fertilizers are widely used on grasslands in the Mediterranean-type climates of Australia and California. In both cases, the practice is linked with the seeding of introduced medics and subterranean clover due to the lack of native herbaceous legumes in Australia (Donald, 1970) and the low productivity of native legumes in California (Jones et al., 1970). Phosphate fertilization results in sharply increased livestock production (Russell, 1960; Crespo, 1985).

The objective of this investigation was to test the hypothesis that application of superphosphate to grassland containing annual legumes would stimulate the legumes, reduce nitrogen deficiency, and so lead to increased herbage production. The experiment was started in the 1984/85 season. Results of the first five seasons were discussed in PFLP annual reports and in Osman et al. (1991). The present report covers results in the last two seasons (1989/1991).

An experiment was conducted at Tel Hadya on undisturbed native grassland; the predominantly annual vegetation included a few low shrubs, perennial grasses, and herbs. The soils are calcareous, pH ranges between 7.8 and 8.4. Soil organic matter and available phosphorus averaged 3.5% and 5.8 mg/kg, respectively. The slope is moderate (3.7° to 7.2°), 30-40% of the ground is covered with stones and the soil depth varies from 1 to 50 cm. Three rates of triple superphosphate supplying 0, 25, and 60 kg/ha of P_2O_5 annually in September and two stocking rates, low (0.8 sheep/ha per year) and high (1.7 sheep/ha per year), were tested. The experimental design was a randomized complete block with three replications, and the total area of the experiment was 85.5 ha.

Animals were introduced at the beginning of the second season (1985/86) following completion of fencing. Initially, 90 Awassi ewes were allocated to groups with five ewes aged 2 to 6 years old. Each group was permanently assigned to plots of 6.5 or 3.0 ha, representing the low and high stocking rates respectively, in each of the fertilizer treatments. At the beginning of the fifth season (1989/90), two more ewes were added to each flock, raising the stocking rates to 1.1 and 2.3 sheep/ha per year, respectively. The ewes grazed the plots for the whole year, from early morning to sunset, being sheltered at night. Sheep were fed a supplement of barley grain during late pregnancy and early lactation (December to February) and in July and August each year in preparation for mating. Barley and hay were also provided whenever the liveweight of individual ewes fell below 43 kg. Each year the oldest ewe was replaced. The lambs were weaned when 8 weeks old.

Every year soil phosphorus content and herbage and seed yields were measured and botanical composition of the pasture was recorded. Herbage was sampled every 3 to 4 weeks from December to May to estimate yields of legumes, grasses, and other species. Seed yield was assessed at the end of each season in June.

Changes in phosphorus

Available phosphorus was less than 10 mg/kg in all treatments when the experiment began, but significantly ($P<0.01$) increased as a result of the fertilizer (Table 6.1). In 1990 and after six annual phosphate applications, the level of available phosphorus was about 3 and 6 times higher under P_{25} and P_{60} than P0. A decline in available phosphorus occurred in the P_0 treatment.

Table 6.1. Available phosphorus in the soil (mg/kg) before any phosphate application in 1984 and at three rates of phosphate application.

Seasons	Phosphate rates (kg/ha P_2O_5) 0	25	60	S. E.
1984	7.9	6.6	7.2	1.34
1989/90	5.9*	20.6	42.4	---
1990/91	6.5	20.8	40.1	2.20

* Each value is an average of two stocking rates as there was no significant stocking rate by phosphate interaction.

Botanical composition

Table 6.2 shows that, in all years, proportion of legumes in the pasture increased after phosphate application and the increase was greater in the last two seasons, indicating that the effect of phosphorus was cumulative. Legume percentage was also greater under low stocking in the last two seasons.

Table 6.2. Annual legumes as a percentage of the whole aboveground biomass in April of 1990 and 1991 as affected by phosphate and stocking rate[1] compared with the first season.

	Year		
	1985	1990	1991
Phosphate (kg/ha P_2O_5)			
0	20	13	9
25	27	22	28
60	30	30	23
S.E.	3.8	4.0	3.1
Stocking rate			
Low	25	27	22
High	27	16	19
S.E.	3.1	3.3	2.6

[1] Means in each phosphate treatment are averages of two stocking rates and those of stocking rates are averages of three phosphate treatments.

Herbage and seed yield

Total herbage production and yield of legume component are shown for the two seasons in Figures 6.1 and 6.2. Significant differences due to application of phosphorus were recorded in each of the two seasons. Differences in total herbage yield were greatest in the spring. Differences between P_{25} and P_{60} were significant in the dry season of 1989/90 (total rainfall 233 mm).

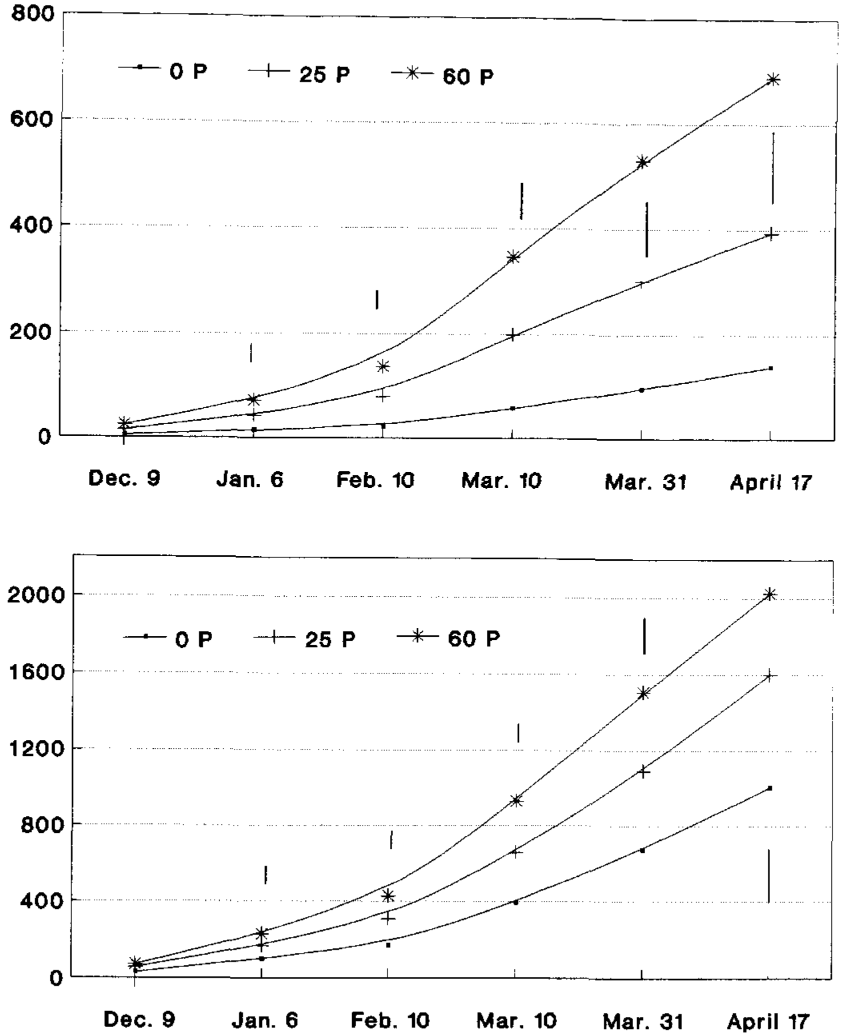

Fig. 6.1. Total herbage yield of legume (a) and all species (b) in the 1989/90 season at 0, 25, and 60 kg P_2O_5/ha.

Bars represent LSD at 1% level.

Total rainfall during the season 233 mm.

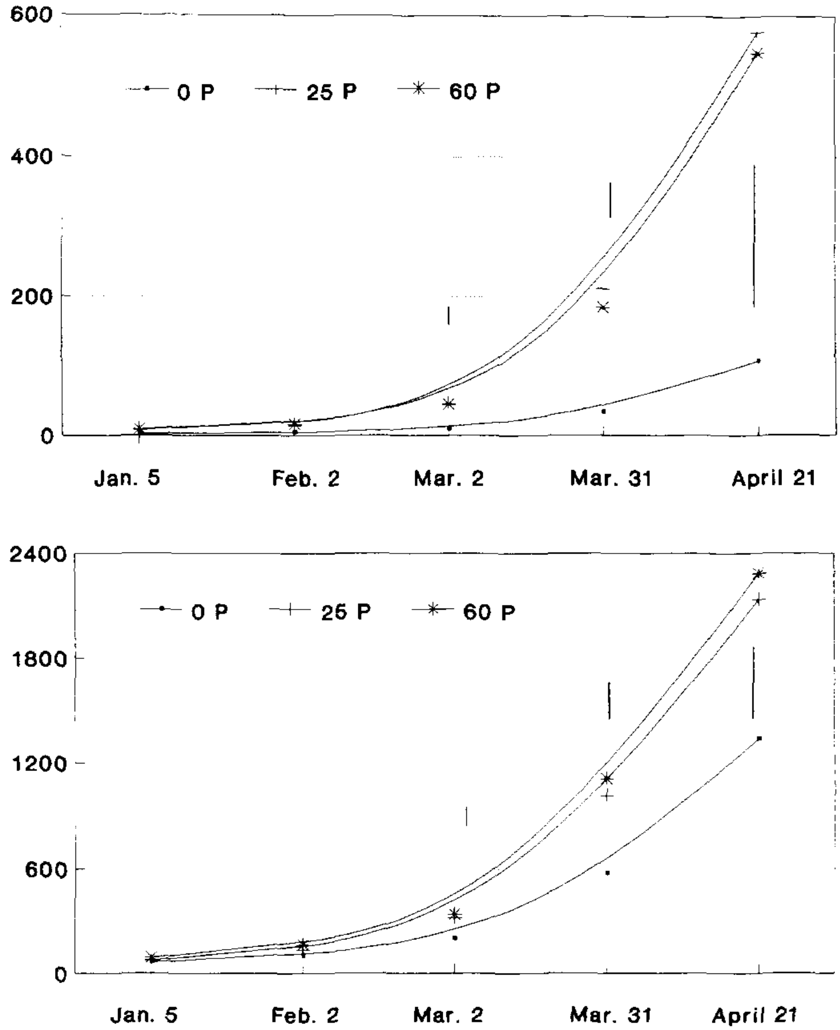

Fig. 6.2 Total herbage yield of legume (a) and all species (b) in 1990/91 season at 0, 25 and 60 kg P_2O_5/ha.

Bars represent LSD ar 1% level.

Total rainfall during the season 293 mm.

This result is in agreement with earlier results showing the critical level at which pasture responds to phosphorous increases in drier seasons (Osman et al., 1991). The mass of seeds on treatments P_{25} and P_{60} was more than 3 times the level at P_0, while the seed numbers were more than 4 times higher in spite of the drought in 1990 (Table 6.3).

Table 6.3. Mass of legume seeds in the top 1 cm of soil (g/m^2) and number of seeds per m^2 at three rates of phosphate (mean of two stocking rates) in the summer of 1990.

	Phosphate (kg/ha P_2O_5)			
	0	25	60	S.E.
Mass of seeds	1.6	5.3	6.3	1.97
Number of seeds	2075	8311	8769	2605.3

Conclusions

The hypothesis that applying phosphate to undisturbed grassland would stimulate legume seed production, legume growth, and production of biomass is correct. These results were achieved in the presence of grazing animals, which means that users of grasslands would suffer no loss of grazing as they would, for instance, in a resowing program where animals would be excluded for up to a year. The ability to continue grazing is most important where farm incomes are low, and where the land is communally owned.

Practical implications

Degradation of the grasslands poses problems in both the developing south and east Mediterranean, and in the relatively developed north, but the problems have different dimensions. In the south and east, livestock numbers are increasing, better grasslands are now being cultivated, and the remaining grasslands are heavily overgrazed. In the north livestock numbers are falling, cultivation is diminishing and the main problem is an accumulation of biomass with its associated fire hazard. In both cases the grasslands represent resources which governments wish to protect and utilize more efficiently (Veronesi, 1987). The implications of these results depend on (i) whether legumes are as frequent on grasslands in general as they are at Tel Hadya, (ii) whether soil phosphorus is normally as low as at Tel Hadya, and (iii) whether grazing can be controlled so that the benefits from the expenditure on fertilizer accrue to the person or group making the outlay.

Independent surveys in Syria and (Cocks and Ehrman, 1987) Morocco (Bounejmate et al., 1989) found that legumes were widespread in unimproved grasslands. In 95 Syrian sites, more than 1,229 separate legume accessions were collected, while in Morocco, from 161 sites, 1,194 separate accessions were collected. Both collections were dominated by Astragalus, Medicago and Trifolium, with mean seed yield of 8 to 10 kg/ha. It is clear that, although suboptimal, there are sufficient wild legumes to encourage the use of superphosphate.

The Tel Hadya site can be considered low to very low in soil phosphorus (Murphy et al., 1973). This view is supported by Osman et al. (1977) who found that calcareous soils with less than 10 mg/kg of phosphorus ($NaHCO_3$ extract) do not provide the 0.2 mg/kg of phosphorus in the soil solution necessary for maximum growth (Andrew, 1962; Asher and Loneragan, 1967). In Syria, soils with less than 10 mg/kg occurred on about 25% of the grasslands (T.A.M. Ehrman & P.S. Cocks, unpublished) and more than 40% (Turk, 1988). Furthermore, the responsiveness of pastures to 60 kg/ha compared with 25 kg/ha of phosphorus in 1989/90, when available phosphorous at P_{25} approached or exceeded 20 mg/kg, suggests that a critical value of 10 mg/kg is far too low. If this is true, most grasslands in Syria suffer from phosphorus deficiency.

These results suggest that a simple technology, such as the use of phosphorus, if implemented, would have enormous impact on the productivity of huge areas of Mediterranean grasslands. Its application will depend, however, on extension of the results, and this is in turn will depend on knowledge of existing land tenure systems and adequate understanding of the decision-making process in farming communities. - **A.E. Osman**

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6.2. Seeding Edible Shrubs on Degraded Marginal Lands

Degradation of natural grazing lands in countries of west Asia and north Africa is well documented (Pearse, 1971; FAO, 1972; Carter, 1978; Huss, 1978; Novikoff 1983). In addition to the problems of overstocking, these lands are continuously modified through the spread of cultivation and excessive cutting of bushes for fuel, which lead to decline in productivity.

Rangeland in Syria, which originally supported woodland and shrub vegetation, now supports only annual vegetation. It produces an average of 400 kg/ha per year (PFLP, 1986) in contrast to the attainable expected yield of 1,200 kg/ha per year of Mediterranean rangelands in general (Le Houerou and Hoste, 1977) and more than 2,000 kg/ha per year under a similar rainfall in Libya (Gintzburger, 1986).

The degradation is often accompanied by severe soil erosion, especially wind erosion as in Tunisia (Novikoff, 1983), Greece (Arianoutsou-Faraggitaki, 1985) and Syria. Planting of shrubs is known to reverse the degradation of rangelands. These shrubs are also important in animal production as a source of protein and nutrients, in providing green feed for animals when grasses and forbs are dry, and providing a drought reserve (McKell, 1980).

Re-establishing vegetation is an expensive process, and policy makers need guidelines on the economic benefits of marginal and steppeland rehabilitation. While it is widely recognized that environmental considerations should be included in the assessment of the benefits, it is unlikely that decisions to proceed with improvement will be made unless it is shown to be economically worthwhile. In most cases, areas of shrubs have been established from transplanted seedlings, which is costly. A recent development in Syria is the identification of two native shrubs (Atriplex halimos and Salsola vermiculata) that can be established by direct seeding, and more importantly, are capable of self-sown reseeding; both characters reduce the cost of rangeland rehabilitation.

A large area of marginal land at Maragha, 120 km southeast of Aleppo, where the average rainfall is 200 mm, has been improved by growing shrubs. The study was started in 1989/90 on 100 ha improved land by direct seeding of Salsola vermiculata and Atriplex halimos, and 100 ha of native unimproved pasture. The objectives were to determine the productivity of marginal lands improved by seeding with edible shrubs, monitor the effects of three stocking rates on biomass production and on sustainability of livestock production, and measure the economic return.

Three stocking rates, one sheep/2.25 ha, one sheep/1.5 ha and one sheep/0.75 ha, referred to as low, medium and high stocking rates respectively, on both improved and unimproved areas were achieved by grazing 8 ewes/plot, with plot sizes of 18, 12, and 6 ha. Each treatment is replicated three times. The plots are fenced.

Animals were introduced into the experimental plots on February 1, 1990. Thereafter, the ewes grazed the plots from early morning to sunset, being sheltered at night. Animals on both pastures were supplemented with barley, cotton seed cake and hay, when the liveweight was not sustained by the grazing and in late pregnancy and early lactation.

This report highlights results in the 1989/90 and 1990/91 seasons.

Herbage and seed sampling

Total herbage production of annual plants was measured on March 25 in the first season and on May 5 in the second season, inside 20 protective cages distributed along transects across each plot. The samples comprised four cores (10.5 cm diameter) to a depth of 10-15 cm, which removed plants and portions of the roots. The yield of shrubs was measured in April in the first season and in May during the second season, inside protective cages (1x2x1 m) using the *reference unit method (Kirmse and Norton,* 1985). Seed yield was measured in June and September. Twenty samples consisting of four cores of 10.5 cm diameter were taken from inside and outside the protective cages. Seeds were separated from the soil and vegetation. Animals were weighed weekly, and supplementary feeding was offered or adjusted depending on their weights.

Results

The first season was very dry (Fig. 6.3). At the experiment site, herbage biomass was little more than 100 kg/ha and 250 kg/ha on the unimproved pasture and the area seeded with shrubs respectively.

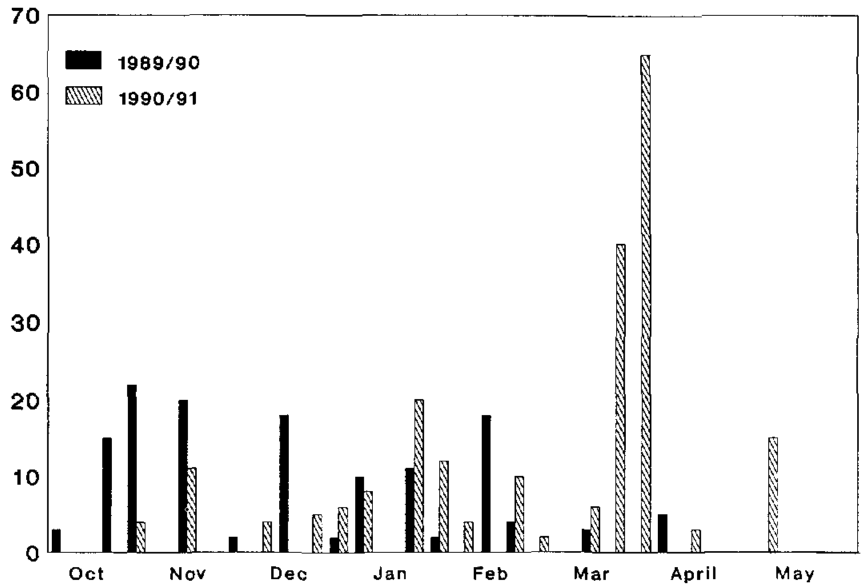

Fig. 6.3. Mean weekly rainfall in mm during two seasons at Maragha, northern Syria.

Forage biomass was greater in the second season (370 and 680 kg DM/ha respectively). Rainfall in the second season was 217 mm compared with 135 mm in the first season; most of the rain in the second season was received in the spring. Forage biomass does not reflect the total aboveground biomass of shrubs, as the reference unit technique measures only the foliage yield, which was considered to be a realistic estimate of the feed available to the sheep. When the sampling was done (April and May), the shrubs had begun new vegetative growth, but this had not reached its maximum. Forage biomass was significantly higher at medium and low stocking rates than at the high stocking rates.

On the native unimproved pasture, the grazing season in 1989/90 was short (81 days) due to the wind storms. In parts of the pasture the vegetation was buried with sand, while in others the top few centimeters of soil were removed. This was not the case in 1990/91 where the grazing season was also longer (112 days). In both seasons, however, the area seeded with shrubs provided grazing all the year round.

In June, the number of seeds of annual species was higher (Fig. 6.4) in the unimproved pasture, because plowing to establish the shrubs destroyed many of the annuals. However, by September, many of the seeds had been grazed or blown away from the unimproved pasture, especially at high stocking rates. Figure 6.3 also shows the higher seed yield in the second season.

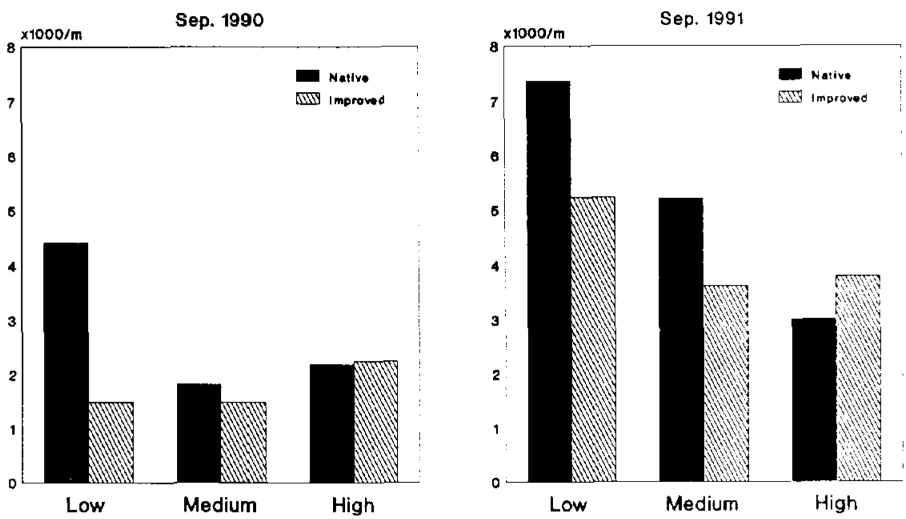

Fig. 6.4. Total number of seeds of herbaceous species on native and improved pasture in September 1990 and 1991 as affected by stocking rate.

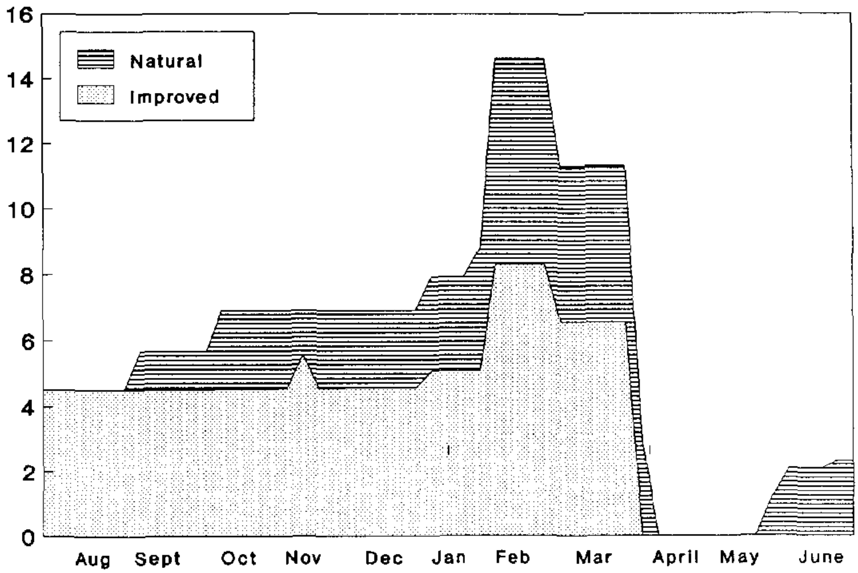

Fig. 6.5. Total Supplementary **feed consumption in MJ/animal/day by sheep grazing on two types of pastures.**

The patterns of consumption of supplementary feed per individual animal in the second season are shown in Figure 6.5. The mean total intake was 2152 MJ/ewe per year for the native pasture and 1361 MJ/ewe per year for the improved pasture (37% less). The only period when animals grazing the shrubs required more supplementation than those on the native pasture was in April and May of the first season when the accumulation of salts on the shrubs during wind storms caused the pasture to be temporarily unsuitable for grazing. During the rest of the first season and throughout the second season, requirements for supplementary feed were greater on native pasture, especially in winter. The long period of supplementary feeding at a high level on the native pasture resulted in a selenium/vitamin E deficiency at lambing in winter 1991, which caused the death of four lambs from nutritional muscular dystrophy. Lambs that survivied after treatment, however, showed no difference in growth rate from those on the improved areas. **- A. Khalik El Asa'ad Steppe Directorate MAAR, N. Hassan ACSAD, A.E. Osman and F. Bahhady**

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6.3. Analysis of Rangelands Vegetation using Remote Sensing

The study was started in 1990 in collaboration with Tropical Agricultural Research Center (TARC), Japan, with the objectives of identifying the vegetation types on rangelands, using aerial photography and ground survey, and classifying these lands using small scale images. Eventually it is intended that the dynamics of plant communities will be analysed, in relation to environmental conditions and grazing intensities.

The equipment for the aerial photography system (Fig. 6.6), plus the computer hardware and software, were provided by TARC. The hardware included: image-processing hardware STIPS (Steppe Information Processing System), an ACER IBM PC/AT 386 40MB HDD, Graphic board MATROX PG641, High resolution color display 1024x1280 dots, a Mathematical co-processor 80387 (16MHz), Color image scanner Epson GT 4100, Digitizer GRAPHTEC KD4300, and Printer HP 3630A Paint Jet, Plotter GRAPHTEC MP4400. The software was ILWIS (Integrated Land and Watershed Management Information System) issued by ITC (The Netherlands), MSWIN386, and EPSCAN2.

The project also used Satellite data from LANDSAT 5 TM, Path 173, Row 35 Subscene 3 for March 21 1989, April 22 1989, March 8 1990, July 14 1990 and April 28 1991. The Satellite imagery was used to produce a map of the experimental station at Maragha, 100 km southwest of Aleppo, at a scale of 1:60,000. The location was determined as 35° 33' 03.5"N, 37° 40' 04.7"E. The vegetation index for Maragha was also calculated using the formula:

$$\left\{\frac{(\text{Band } 4 - \text{Band } 3)}{(\text{Band } 4 + \text{Band } 3)} + 1\right\} \times 127$$

where Band 4 is near infrared rays, and Band 3 is visible red rays.

The satellite images are verified using photographs taken from a height of 200 m and detailed mapping of plant species along transects. It has been tested at Maragha on unimproved range and areas improved by planting Atriplex halimus and Salsola vermiculata.

The photographs to verify the satellite images were taken from a helium-filled ballon, using a 35 mm camera, with a wide angle (28 mm) lens, mounted beside a video monitoring camera, which can be rotated through 360° and altered in angle using a radio controller. The exact position of the area being studied is located using a SONY PYXIS Global Positioning System. Vegetation distribution is derived from the red band of the photographs using an edge enhancement technique to improve the definition of the borders of vegetation areas and then converted to black and white imagery. Vegetation maps are made from these images after verification, using detailed species mapping along 70-m transects (Fig. 6.7). **- S. Takahata and A.E. Osman**

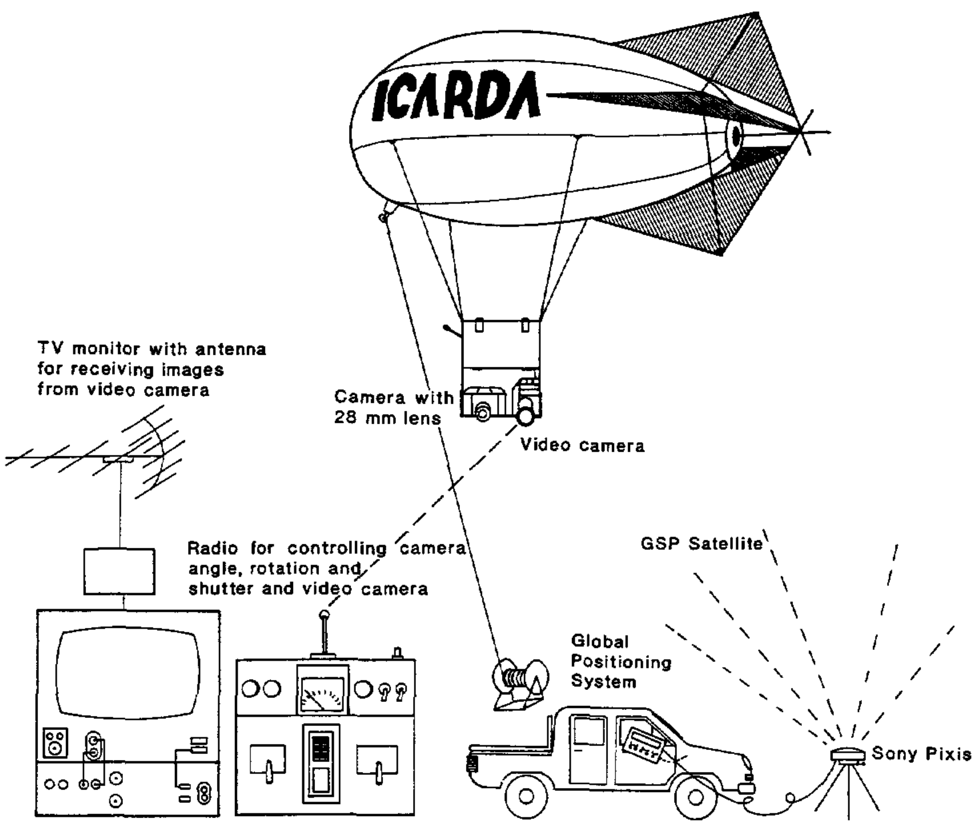

Fig. 6.6. Balloon aerial photo system.

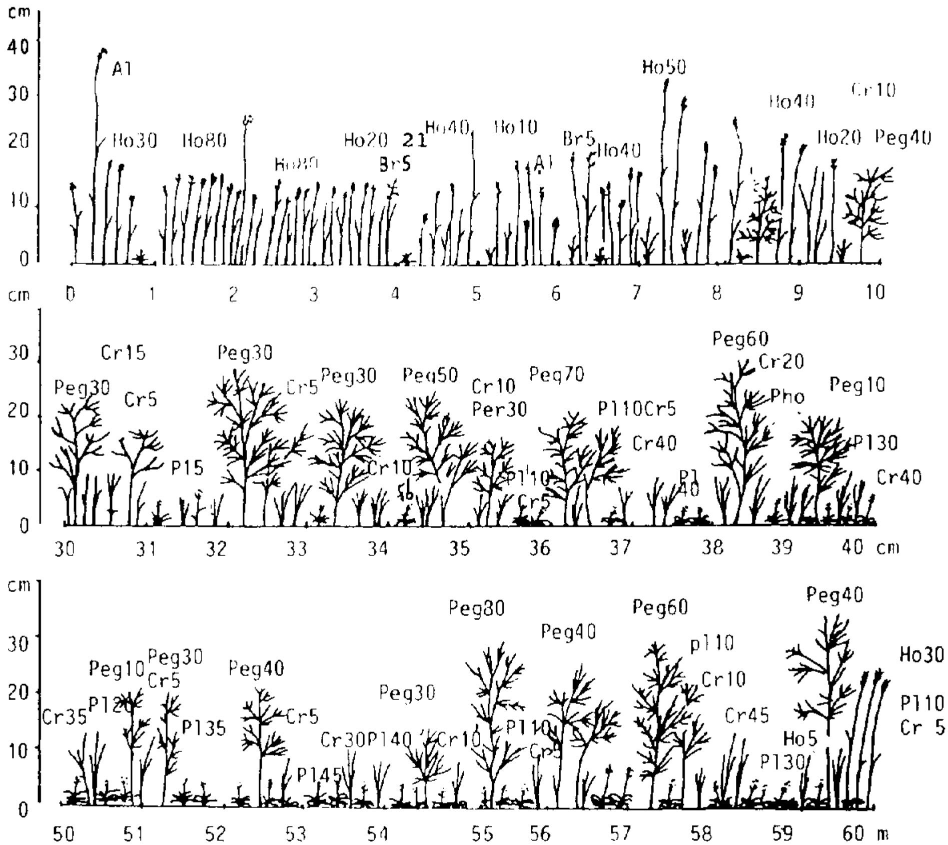

Fig. 6.7. Plant height and coverage on the line interception 5-6 May 1991 Maragha Natural Plot 3.

Number of the behind species is plant coverage (%) in each 10-m line. Vertical line is plant height, horizontal line is distance.

Ho=Hordeum, Br=Bromes, G=other grasses, Al-Allium, Cr=Carex, Pl=Plantago, Peg=Peganum.

6.4. Economics of Bedouin Production Systems

Both agro-pastoral and nomadic pastoral systems exist in the dry marginal lands of Aleppo Province, Syrian Arab Republic. Production of barley and small ruminant livestock are the most important agricultural activities in the zones with 100-300 mm annual rainfall.

Grazing and, particularly, cultivation are overwhelming the natural potential of the marginal lands. The effect is a progressive degradation of soil and vegetation which, in turn, lowers the performance of both cultivated and pasture lands.

There is virtually no control of the stocking rates on this land. A reason for this behavior could be the weakening or destruction of the local-level institutional arrangements of tribal control in the past. The loss of these controls allowed conversion of former common property into open access lands. The distinctions between these types of land-use management are often overlooked (Bromley and Cernea, 1989).

The dry marginal lands face serious problems:

- high levels of risk in production, especially for rainfed crops;
- low productivity and low intensity of production;
- poor land-usemanagement, leading to rapid loss of system sustainability through degradation of soil and other resources.

Knowledge of the historical development of land use, and of the reasons and motivations for the behavior of the Bedouins today, is lacking. Research is needed to fill information gaps and allow better prediction of the potentials for adoption and impacts of new technologies and policies in such areas. Seasonal movement of Bedouin flocks to higher rainfall areas indicates a traditional integration of the steppe and the sown croplands where ICARDA's main thrusts have been focused.

Below 300 mm annual rainfall there are three main production systems:

- sedentary agro-pastoralism,
- semi-nomadic agro-pastoralism, and
- fully nomadic pastoralism.

In reality, there is a continuum of all degrees and forms between nomadic and sedentary Bedouins. The different Bedouin production systems are a reflection of the abundance or absence of water (rainfall, ground water or surface water).

Semi-nomadic and sedentary agro-pastoralists combine animal production with the production of cereals, mainly barley. Even with their own rainfed production of grain, straws and stubbles, the majority of Bedouins are obliged to move their flocks to the higher rainfall areas, for summer and autumn months, where they can graze crop residues at low cost.

Irrigated farming with well water in the dry marginal areas is used by some not only to produce cash crops and food for the household, but also to provide enough fodder to avoid movement of the flock. This groundwater resource allows some agro-pastoralists to remain sedentary.

At about 200 mm annual rainfall and below, the use of marginal lands by fully nomadic pastoralists becomes more common. The fully nomadic pastoralists grow no crops and feed their flocks on native pastures, supplemented by transported feedstuffs and water, and seasonal grazing of crop residues and other sources in the higher rainfall zones.

An area in the southeast corner of Aleppo Province has been selected as the basis for a Socio-economic survey of Bedouin households. Breda Village is in the northwest corner of the survey area, which stretches southeastward some 130 km to the edges of

Raqqa and Hama Provinces. In all, it covers over 3000 square km and includes farms with some irrigation, areas of seasonal cultivation and abandonment, and large areas of uncultivated natural pasture.

An informal survey of the area in mid-1991 helped focus the ideas and points to be followed up in formal surveys. A two-stage sampling plan was completed by (1) random selection of some 40 villages and seasonally occupied places, followed by (2) visits to each of these, to list and randomly sample households. The first round of formal interviews included 112 Bedouin households. This part of the survey covered general conditions and histories of production: access to land, ownership of sheep and machinery, production practices and yields in the last two seasons, livestock feeding calendars, sheep movements, etc.

Two more survey rounds are planned for completion by March 1993 to collect further information, including household conditions, goals, decision intaking, and marketing as well as production data from 1992/93.

This study is part of a project funded by BMZ of the German Government through the Institute of Agricultural Economics and Social Sciences in the Tropics and Subtropics, University of Hohenheim, Stuttgart. Project title: "Land Use Management for Marginal Lands in the Barley/Livestock zones of Jordan and Syria". - **Rolf Wachholtz and Tom Nordblom**

Reference

Bromley D.W and M.M. Cernea, 1989. The management of common property resources: some conceptual and operational fallacies. World Bank Discussion Paper No. 57. The World Bank, Washington, D.C.

7. Evaluation of Feeds

7.1. Straw and Stubble

7.1.1. Survey of methods of feeding barley straw and of grazing stubble in Syria

Between 1979 and 1984, ICARDA collected a large amount of information on the levels of feeding of flocks in Syria (Thomson _et al_ 1989; Jaubert and Oglah 1985). This information is becoming out of date as systems change. Also, it did not contain detailed information on the practice of feeding during the day, which may have an effect on intakes of feeds and on the efficiency of their utilization. In preparation for starting new areas of research on the effects of frequency and timing of supplementary feeds on the intake of straw and grazed stubble and on the effect of milling to produce _tibn_ on the intake of straw, it was decided to undertake a small survey of farmers to collect information on:

- the methods of collecting and processing cereal straw before feeding.
- management during grazing of stubble.
- detailed management of feeding during autumn and winter.

Data were collected under the following headings:

1. General information on the flock and crop areas.
2. Details of the barley crop.
3. Methods of harvesting the cereal crops.
4. Collection and processing of straw.
5. Stubble grazing.
6. Calendar of use of different resources and the flock-owner's estimate of levels of intake of feeds fed by hand.
7. Methods of feeding and watering, with emphasis on exact timing of feeds.

8. Current problems of feeding sheep.

9. In addition, the survey included a number of open-ended questions designed to gain general impressions of nutritional problems, the reasons for particular practices, and whether it is the farmer, the flock-owner or the harvesting or processing contractor who makes the critical decisions. The latter information is important, as it indicates whether a particular practice, which may affect the intake or efficiency of use of feed, can be changed by the flock-owner or is dictated by somebody else and cannot easily be changed.

The survey was carried out just after harvest in June and July 1991 in the zone of barley cultivation in north and east Syria. The numbers of villages visited in each province were: El Hasake 12, Raqqa 12, Aleppo 12, Idleb 2, and Hama 1. In each village one farmer was interviewed, but information obtained from the open-ended background questions reflects the opinion of a group in the village, as it was rarely possible to interview the farmer in isolation. The same person conducted all the interviews.

Two flocks were omitted from statistical analysis: one in Raqqa province, whose owner had 100 ha of barley grown under irrigation, and the other in Idleb province, which had 1000 sheep, twice as large as the next largest flock.

The average number of sheep in the 37 flocks in the survey was 170 (range 10-500), of which 70% were mature ewes. The average areas of crops of farmers in the sample were: rainfed barley 23 ha (0-100), irrigated barley 2 ha (0-15); rainfed wheat 5 ha (0-30), irrigated wheat 7 ha (0-60); other rainfed crops 1 ha (0-27) and other irrigated crops 4 ha (0-40). Only 35% of the flock-owners used common grazing or steppe at any time in the year.

In the previous season, feeding of straw and grain started in November and ended in March in the majority of flocks, although in

20% feeding continued until stubble became available in May. The farmers were, in general, aware of the advantages for feed economy of grouping sheep by feed requirement. Seventy percent of them separated productive sheep from barren ewes and replacements. In general, this was done after lambing, when the quantities of feed offered to lactating ewes were increased. In lactation, feed was offered twice daily in 30% of the flocks and three times daily in the rest.

In December and January, when the greatest amounts of feed were offered, the means of farmers' estimates of the amounts fed were straw 1010 g/day (sd 382, range 500-2000) and barley 910 g (sd 313 range 500-1700). The figures below indicate that the straw was either barley or a mixture of barley and wheat, or, in a smaller number of farmers, lentil. Straws were always offered in a coarsely milled form called <u>tibn</u>.

The concentrate was based on barley with variable amounts of wheat bran, cotton seed cake and sugar beet pulp, when these were available.

Straw and concentrate feeds were always fed together in the same trough.

The percentage of farmers using each feedstuff was:

Barley grain	97%	Cotton seed hulls	38%
Barley straw	90%	Lentil straw	38%
Wheat straw	74%	Sugar beet pulp	20%
Wheat bran	64%	Wheat grain	18%
Cotton seed cake	62%	Other feeds	15%

In 1991, 68% of the flocks grazed standing unharvested barley, mainly in May and June, although some was grazed as early as April and as late as August. The average numbers of days grazing standing barley was 47 (range 10-90).

Grazing of stubble started immediately after harvest and lasted for a mean of 97 days (15-160). On 70% of farms, grazing commenced before the piles of harvested straw had been removed from the field. Farmers generally prefer barley stubble, although a small number (13%) reported that the stubble of some varieties of wheat (e.g. ACSAD) also was very palatable. The mean daily duration of grazing was 12.5 hr (8-16). 38% of farmers grazed in the night as well as day, because they felt that it increased straw intake. Supplementation with other feeds during stubble grazing is very rare, as farmers believe feeding supplements reduces the intake of straw. Forty percent of farmers supplemented to a very limited extent, if their flock grazed their own land.

All farmers grew local landraces of barley, with Arabi Aswad predominating in El Hasake and Raqqa and Arabi Abiad in Aleppo and Idleb province. The cutting height of the combine varied between 10-25 cm. The majority of farmers (77%) prefer low cutting heights to get the maximum yields of grain and straw. A small proportion (18%) preferred stubble to be taller if it was to be grazed by their own flocks only; these tend to be farmers with large flocks.

Most combine harvesters now have a collector which drops the straw in 4-5 kg piles. These piles are then collected into 50-100 kg piles in preparation for transporting to the village or processing in the field.

Processing of the straw to _tibn_ is considered very important by the farmers because they believe that it makes the straw more palatable, reduces wastage, facilitates transportation and storage and makes mixing with concentrated feeds easier. In El Hasake and Raqqa provinces, processing is generally done with modified combines after the harvest season. Farther west, specially made hammer mills with 12-20 mm screens are used, often operated by specialized contractors with mobile machines. Collection and processing costs are high and may equal 50% of the value of the straw.

The open-ended questions, designed to gain knowledge of the farmers' problems, elicited many comments on the decline in profitability of sheep production in the last 2 years. This and the declining availability of good grazing in the steppe in spring have led to some farmers reducing their flock size, in some cases quite radically (e.g., to 100, in flocks formerly as large as 750 or 1000). - **T. Treacher and A. Termanini**

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7.1.2. Particle size distribution and chemical composition of tibn

In the Middle East, straw is a valuable component of sheep diets. It was traditionally broken into small pieces (called tibn) by the action of a heavy animal-drawn threshing roller called a jarjar. Nowadays, cereals are generally harvested by combine harvester and tibn is made by milling straw through a hammer mill with a coarse screen (12-20 mm). Tibn is a mixture of fine particles and coarser, more easily identified, pieces of straw.

It is possible that rumen fermentation is facilitated by such processing. The smaller particles, having a large surface area, may be a source of rapidly fermentable nutrients, but this alone is not sufficient to ensure fibre digestion, as small particles may leave the rumen rapidly. On the other hand, larger particles may fulfil the function of roughage in the sheep's diet, stimulating the rumen wall and helping to sustain a larger population of cellulolytic microbes.

A new project has been started to characterize tibn and to assess the effects of processing on the nutritional characteristics of the straw. As a first step the particle size distribution of barley tibn made by different machines was measured.

Large samples (c. 100 kg) of baled barley straw were taken to three farmers in the Tel Hadya region, who owned tibn mills. Five samples of tibn were mechanically shaken for 10 minutes on a series of five soil sieves with mesh sizes of 5, 2, 1, 0.5, 0.2 and 0.1 mm. Graphs were made of the quantity of material retained by each sieve. Chemical analyses were made on the fractions retained by each sieve.

Table 7.1. Size distribution and chemical composition of particles in barley tibn retained by sieves of different mesh sizes.

Mesh size, mm	2.0	1.0	0.5	0.2	0.1	<0.1	Total
Particle size distribution (g/kg)							
	142	494	177	139	38	10	(1000)
Analysis, g/kg DM							
Ash	75	68	88	96	102	274	72
Crude protein	27.8	25.3	29.6	40.8	46.3	45.3	31.4
NDF	862	841	823	728	709	652	833
ADF	454	487	440	438	429	422	463
In vitro digestibility, g/g							
DMD	0.381	0.375	0.333	0.385	0.426	0.464	0.368

The quantity of tibn retained on the sieve with a 5 mm mesh size was negligible. Figure 7.1 shows that the particle size distribution differed between mills, with significant differences in the amount retained by 1 and 2 mm sieves. Since digesta particles less than 1 mm in size can leave the rumen more readily than larger particles, this would imply that the products of different tibn mills would stay for different lengths of time, and would probably be digested to different extents in the rumen.

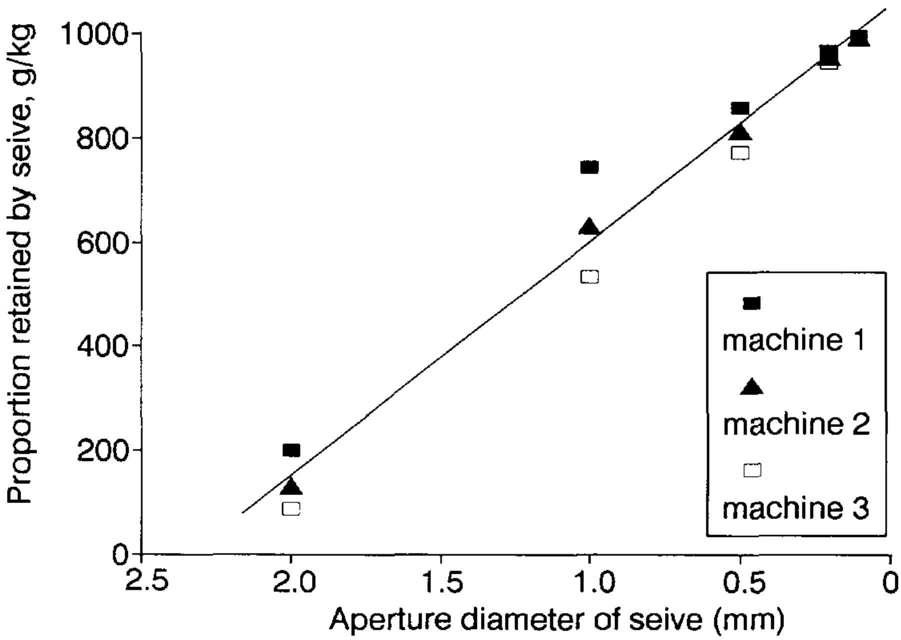

Figure 7.1 Particle size distribution of barley straw milled with three machines.

As particles decreased in size, there was a general trend for nutritional characteristics to improve; crude protein, in vitro digestibility and ash increased and fibres decreased. A clear difference in protein and NDF content occurred between the three largest particle sizes (retained by a 0.5 mm sieve) and the finest 18.7% of the material. This suggests that the finer particles are derived from leaf, and the high ash content in the very finest particles is from soil. - **A. Termanini, A. Goodchild and T. Treacher**

7.1.3. Influence of nitrogen source on the voluntary intake and digestibility of barley straw

The main objective of the experiment was to quantify the effect on the voluntary intake and digestibility of coarselymilled barley straw (tibn) of feeding equal quantities of nitrogen (N), either as non-protein N (urea) or as protein in the form of cottonseed cake.

The treatments were: barley straw (N0), three levels of supplementation with urea/sulphate solution poured on top of the tibn offered each morning (U1, U2, U3), and three levels of supplementation with cottonseed cake offered in 1 meal in the morning (C1, C2, C3). The respective supplementation levels were intended to the ratios of dietary nitrogen to digestible organic matter (DOM) to 19.2, 24.0 and 28.8 g/kg or 8, 10 and 12 g crude protein/MJ of metabolizable energy. Anhydrous sodium sulphate was fed with urea in the ratio of 1:9, and provided a N:S ratio of 18.3:1. A mineral mixture was fed to all animals at the rate of 6 g/day.

Each diet was offered to three ewe lambs (body weight range 32-40 kg), kept in digestibility crates, and to two ewe lambs in individual pens. Only data from the animals in digestibility crates are reported here. Initially vetch hay was offered ad libitum for 3 weeks and the intake in the last 10 days was used as a covariate in the analysis of the voluntary intakes of the experimental diets measured over a period of 28 days. During the last 10 days the digestibilities of the diets were measured.

The barley straw and the cottonseed cake (CSC) offered in the experiment contained 38 and 308 g/kg crude protein, 42 and 186 g/kg of acid detergent fibre and 911 and 944 g/kg dry matter respectively. The urea had a nitrogen content of 466 g/kg, equivalent to a crude protein content of 2912 g/kg.

The experimental rations varied in crude protein concentration from less than 4 % to over 8 % (Table 7.2). The designated ratios of N to DOM were achieved with both the urea and the CSC supplementation. Supplementation with CSC significantly increased the voluntary intake of straw, but there was no response to increasing the level of CSC. Supplementation with urea had no effect on straw intake.

Table 7.2. Voluntary intake and digestibility, and average daily gain, in sheep fed barley straw without or with cottonseed cake or urea supplements.

	N0	C1	C2	C3	U1	U2	U3	SEM
LW, kg	35.8	36.7	37.7	37.8	36.0	37.8	37.3	-
TOMI, g	713	832	993	898	696	703	728	9.6
NI, g	4.8	8.0	10.6	12.4	6.2	9.0	10.2	0.44
CP, g/kg	39.3	53.3	65.8	75.4	52.3	67.6	80.7	-
OMD, g/kg	598	563	621	584	589	573	615	20
DOMI/LW	13.3	12.8	15.0	13.9	11.2	11.2	12.0	0.74
CP:ME	4.8	7.0	7.8	9.7	6.5	8.4	9.6	-

LW, Liveweight, kg; TOMI, Total OM intake, g/d; NI, Total N intake, g/d; CP, Dietary crude protein, g/kg DM; OMD, Ration OM digestibility, g/kg; DOMI/LW, DOM intake g/kg liveweight/d; CP:ME, Crude protein:ME ratio, assuming that 1 kg DOM contains 15 MJ ME; SEM, standard error of means.

The supplements had little effect on the digestibility of the rations, therefore intakes of DOM reflected differences in intake of straw. The medium level of CSC (0.11 of the diet) gave the largest DOM intake, but differences between responses to level of CSC supplementation were not significant.

The crude protein:energy ratio of the barley straw was 4.8 g/MJ ME, well below the ratio of 8.2-8.6 g/MJ ME required for maximum microbial growth in the rumen (ARC 1984). Urea supplementation increased the ratio to 7.0-9.7 but did not increase straw intake. The response of straw intake to CSC supplementation was larger, but had reached a plateau at the lowest level of CSC, when the protein:energy ratio of the ration was only 6.5 g/MJ ME. This would suggest that cottonseed cake provided nutrients in addition to those provided by urea and sulphate; for example, protein which was not degraded in the rumen.

The protein to energy ratio needed to optimize rumen functioning in Awassi sheep may be much lower than in temperate breeds of sheep, possibly as a result of more efficient recycling of urea into the rumen. Earlier work at ICARDA also has shown negligible increases in the intake of straw containing 46 g crude protein/kg DM or 6 g/MJ ME in response to supplementation with soybean meal (PFLP Annual Report, 1988). These results suggest that more research is required to measure the protein metabolism and requirements of Awassi ewes. - **Atif Abdul Malik, T. Treacher, A. Termanini and A. Goodchild**

Reference

ARC (Agricultural Research Council). 1984. Report of the Protein Group of the ARC Working Party on the Nutrient Requirements of Ruminants. Commonwealth Agricultural Bureaux, Slough, U.K.

7.1.4. Nutritive value of barley stubble

Stubble grazing is the main source of nutrients for the small ruminant flocks in WANA region for the 3-5 months from cereal harvest in late May or June. As the flocks are mated at this time, the prolificacy and hence level of annual productivity of the flocks may be affected if nutrition is poor. There have, however, been very few studies of the process of grazing stubble that have defined nutrient intakes and the need for supplementation to sustain particular levels of weight change close to mating.

The survey of farmers' practices during stubble grazing (section 7.1.1 above) found that 80% of farmers grazed stubble until all above-ground material was removed. Obviously, this minimizes the return of organic matter to the soil and leaves the soil totally exposed to wind erosion. It also reduces the daily intake of nutrients at the end of the grazing period to well below the requirements for maintenance. A fuller understanding of the process of removal of stubble during grazing may enable the establishment of guidelines that give both adequate levels of nutrition to the animals and leave sufficient stubble to protect the soil from wind erosion.

In June 1991, a new research line was started to quantify the intake of nutrients by sheep grazing stubble alone and when supplementary concentrate feeds are fed. The work forms part of the research for a PhD thesis being undertaken at Reading University, England. The first experiment examined the removal of the different fractions of stubble from areas grazed at stocking rates of 20, 40, and 60 sheep/ha for 3 successive periods of a month. The sheep grazed from 6:30 to 11:30 hr, returned to the yards for watering and then grazed from 13:30 until 18:30 hr. No supplements were fed at night. At the end of each period, all sheep were grazed at 20 sheep/ha for 4 days to equalize gut fill before weighing.

The experiment was carried out in a field of barley, cv. Arabi Abiad, harvested at a height of 10 cm using a combine fitted with a straw collector that deposited the threshed straw in piles, at intervals of 40-50 m. This straw was baled and transported from the field. The stubble was sampled to ground level prior to grazing and on days 3, 5, 7, 9, 14, 19, 24 and 29 using a 2m^2 quadrat (4.25 x 0.47 m) placed at right angles to the direction of harvesting. This enabled accurate sampling of different areas of stubble across the full width of the combine cut. The material was separated into heads, leaf and stem, weighed, and analyzed for crude protein and _in vitro_ digestibility.

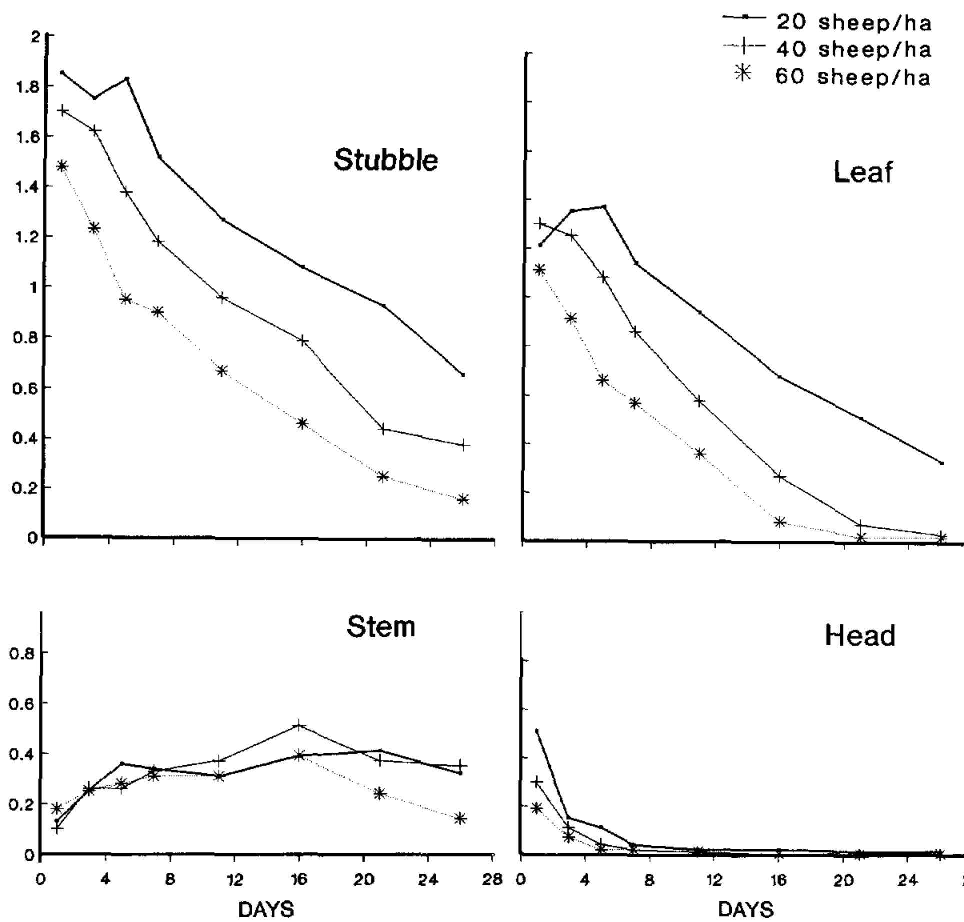

Figure 7.2 Daily removal (kg/sheep) of barley stubble and leaf stem and head fractions.

Prior to grazing there was 1000 kg DM/ha available on the stubble. This declined to 550, 200 and 150 kg/ha at 18 days and 400, 40 and 0 kg/ha at 29 days at 20, 40 and 60 sheep/ha respectively. Figure 7.2 shows the removal per sheep per day of heads, leaf, stem and total dry matter over each sampling interval at the 3 stocking rates. This approximates to the intake of each fraction with some small errors resulting from material being blown from the plots or trodden into the soil. The small amount of heads was consumed by day 5 or 7. The rate of removal of leaf declined steadily throughout the period at 20 sheep/ha. At the two higher stocking rates, reduced availability severely limited intake after day 16. The rate of removal of stem increased initially, then remained almost constant at 20 sheep/ha, but declined after day 16 at the higher stocking rates.

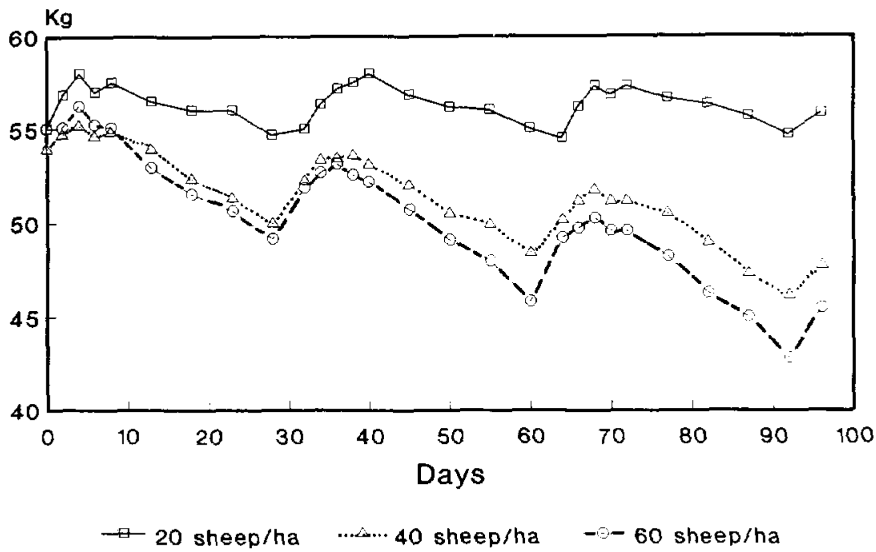

Figure 7.3 Liveweight changes

The weight changes, adjusted for gut fill, over the 96 days of grazing were 0.8, -6.2 and -9.5 kg at 20, 40 and 60 sheep/ha respectively (Figure 7.3). The feed intake at the lowest stocking rate gives a good estimate of the maintenance requirement of dry sheep grazing stubble. - **S. Rihawi, T. Treacher, A. Goodchild and E. Owen (Reading University, England)**

7.2. Factors Affecting Voluntary Intake of Pea Forage by Awassi Sheep

7.2.1. Forage legume straw as a supplement for cereal straw.

Cereal straw is an abundant by-product fed to ruminants the world over. Its rumen-degradable nitrogen content is often low, which can limit its value by restricting microbial activity in the rumen; in such cases straw intake and ration digestibility improve when a supplement containing degradable nitrogen such as oilseed or urea is fed. But sometimes, as was reported in 7.1.4, ruminants require more protein than can be synthesized by rumen microbes. In such cases, supplements containing undegradable nitrogen such as oilseeds (but not urea) can improve straw intake. Legume hays or straws can be valuable supplements containing both kinds of protein, and feeding them with cereal straw would help to dilute and minimize the effects of any anti-nutritional factors that they may contain.

An intake and digestibility trial studied diets containing pea straw (P) or vetch straw (V) with barley straw in the following ratios: 33:67 (diets 33P and 33V), 66:34 (diets 66P and 66V), and 100:0 (diets 100P and 100V). A control diet of barley straw alone (100S), and a standard diet containing cottonseed cake with barley straw in the ratio 15:85 (15CSC) were also fed. Each treatment was given to six sheep, using a two-period crossover design to increase the precision of comparisons between diets containing identical levels of legume straw. There was a single covariance period of 14 days, and in each period an adaptation period of 11 days and a collection period of 7 days. Each sheep was fed 1.2 of the mean quantity consumed during the previous three days, and received 10 g/day of a vitamin and mineral supplement.

The chemical composition of the dietary ingredients is shown in Table 7.3. The unsupplemented straw (100S) had an extremely low

Table 7.3. Chemical composition (g/kg DM) of dietary ingredients or the standard ration.

	Organic matter	ADF	NDF	Nitrogen
Barley straw	924	502	889	3.5
Straw + 15% CSC	928	475	825	10.3
Pea straw	902	479	693	12.6
Vetch straw	911	487	722	12.5

nitrogen concentration (equivalent to 20 g crude protein/kg as fed), and sheep consumed significantly less of it than of any other diet. Diets supplemented with cottonseed cake (15CSC), 66% pea or 66% vetch all contained about 10 g N/kg DM. Increasing the proportion of legume straw in the diet gave a large and significant ($P<0.001$) linear response in dry matter intake (Table 7.4). The intakes of diets containing vetch straw were greater than those of diets containing similar levels of pea straw, in spite of the vetch having a similar N content and OM digestibility. The DM or digestible OM intake at a nitrogen:energy ratio similar to that of the standard diet (20.9 g N/kg DOM or about 8.7 g crude protein/MJ ME) would rank 15% cottonseed cake as a supplement of intermediate effectiveness, between 66-100% vetch and 66% pea. Digestibilities of DM and NDF differed significantly between diets, DM digestibility increasing with inclusion of legume straw and NDF digestibility tending to decline.

Table 7.4. Voluntary intake (g DM and g digestible OM/kg live weight) and apparent digestibilities of OM in DM, ADF and NDF.

Diet	Voluntary intake		DOMD,	Digestibility, g/kg	
	DM	DOM	g/kg	ADF	NDF
100S	15.7	7.2	459	453	551
15CSC	25.0	12.3	492	444	560
33P	19.1	9.1	479	461	546
66P	21.4	9.8	457	428	481
100P	24.4	11.9	488	462	500
33V	21.3	10.3	485	467	568
66V	26.9	13.4	499	488	556
100V	31.5	16.2	515	478	527
SE mean	0.85	0.44	15	17	15

Table 7.5 shows the nitrogen status of the animals fed the different diets. The negative nitrogen balance in sheep receiving 33% or less legume straw implies loss of body protein. Nitrogen retention increased linearly with legume straw inclusion level, with diets containing 66% pea, 66% vetch and 15% CSC not differing significantly. The increases in intake and nitrogen retention with vetch and pea straw compare well with other legume straws (McMeniman et al. 1988), and the pattern of response to legume levels parallels that seen with *Trifolium* hay (Mosi and Butterworth 1985). There was little difference in N balance between pea and vetch straws at each level of inclusion despite differences in digestible OM intake. The small output of urinary N in all treatments except 100V suggests that N balance was limited by digested N rather than by energy intake.

Table 7.5. Nitrogen intake, excretion, balance (g/day) and apparent digestibility of nitrogen (g/g) for the eight diets.

Diet	N intake	Fecal N	Urinary N	Nitrogen retention	Apparent N digestibility
100S	2.1	3.7	0.88	-2.52	-0.787
15CSC	10.3	7.5	0.77	2.03	0.273
33P	4.8	4.5	0.39	-0.05	0.072
66P	7.9	5.4	0.42	2.10	0.317
100P	12.3	5.8	0.90	5.59	0.528
33V	5.4	5.3	0.54	-0.42	0.019
66V	10.0	7.0	0.73	2.32	0.300
100V	16.3	9.2	1.98	5.11	0.436
SE of mean	0.487	0.372	0.795	0.393	0.025

Further research is being carried out on the diets with 66% legume straw inclusion to observe whether metabolic parameters, rumen microbial activity and rumen fill can explain the differences in voluntary intake and nitrogen retention. - **E. Carter, A. Goodchild and M. Gill (NRI, England)**

References

McMeniman, N.P., Elliott, R. and Ash, A.J. 1988. Animal Feed Science and Technology 19:43-43.

Mosi, A.K. and Butterworth, M.H. 1985. Animal Feed Science and Technology 12:241-251.

7.2.2. The effect of plant factors on palatability

Palatability is a significant aspect of quality in forage crops, but it is often relegated to the last stages of evaluation in variety trials. Palatability is generally assessed by simple and relatively unstressful animal methods, such as observations of grazing (Johnston 1988) and measurements of rate of intake (Kenny and Black 1984). As a sequel to work reported in the 1989 PFLP Annual Report, relationships between plant physical or chemical properties and the rate of intake of pea forage by Awassi sheep were studied.

Eighteen lines of pea (IFPI, International Forage Pea Identification), common vetch (V. sativa) and woolly pod vetch (V. villosa subsp. dasycarpa) were planted in plots 25 m long in each of 4 blocks. In addition, seven of the pea varieties and both of the vetch species were grown in 3 adjacent blocks for intake trials with fresh forage. Plants were measured at 2-week intervals, sampled on 18 March, 4 and 20 April and 6 May and harvested for straw between 13 and 20 May. At each sampling date, morphological, phenological, disease and subjective measurements were made and the leaf:stem:pod ratio was estimated on 100-150 g of whole plants. A pooled sample of each genotype was analyzed for OM, Ash, N, NDF, ADF, total sugars and starch.

Rates of intake were measured at three stages of plant maturity: fresh (vegetative) herbage, hay and straw. Fresh herbage was cut daily immediately before testing, starting on 4 April. Hay was cut on 16 April, at the full flower stage, and straw on 13 May starting.

The sheep for these trials were selected for consistent rates of intake from a larger flock. When measuring rates of intake, quantities of one pea variety or vetch species were fed to each sheep each day, except for fresh herbage, when two varieties were tested. Consecutive meals of 5 minutes' duration were offered with short breaks between meals. The number of meals varied with the quantity of forage available; 2 for fresh herbage, 2 or 6 for hays and 4 or 6 for straws. For fresh herbage, the 2 vetch species and 7 pea varieties were fed to 9 sheep in a latin square layout. For hay, 21 sheep were used for 7 days in three latin squares, each square including one or two vetches. For straw the layout was similar, the same pea varieties being fed to the same group of 7 sheep.

The rate of phenological development was similar for all pea varieties, with the exception of IFPI 44 which flowered later than others and, as in 1989, failed to produce grain. On 18 March, 4 April and 20 April respectively, the pea varieties were on average 15, 32 and 49 cm tall and had 8, 13 and 14 nodes. Colored flower varieties showed purple pigmentation on their leaf and stem. By 6 May the herbage of most varieties was senescing. The estimated yield of straw DM ranged from 0.8 to 2.1 t/ha for peas and was about 1.9 t/ha for vetches.

The proportion of leaf decreased from about 0.6 to 0.4 at the same four sampling dates, with pods appearing on 20 April and reaching 0.2 or more of DM on 6 May. The variation between pea lines in the leaf: stem ratio at each sampling date was less than 10%. The gross chemical composition of the forages varied by date of sampling, with neutral detergent fibre increasing and water-soluble carbohydrate decreasing, but did not vary significantly between varieties.

The intake of fresh pea in 2 meals of 5 minutes was significantly ($P<0.01$) lower than that of fresh common vetch (Fig. 7.4). When hays and straws were compared there was no difference in the intake in the first two meals. However, the rate of intake between 10 and 30 minutes was significantly lower for pea hay than for common vetch hay ($P<0.05$).

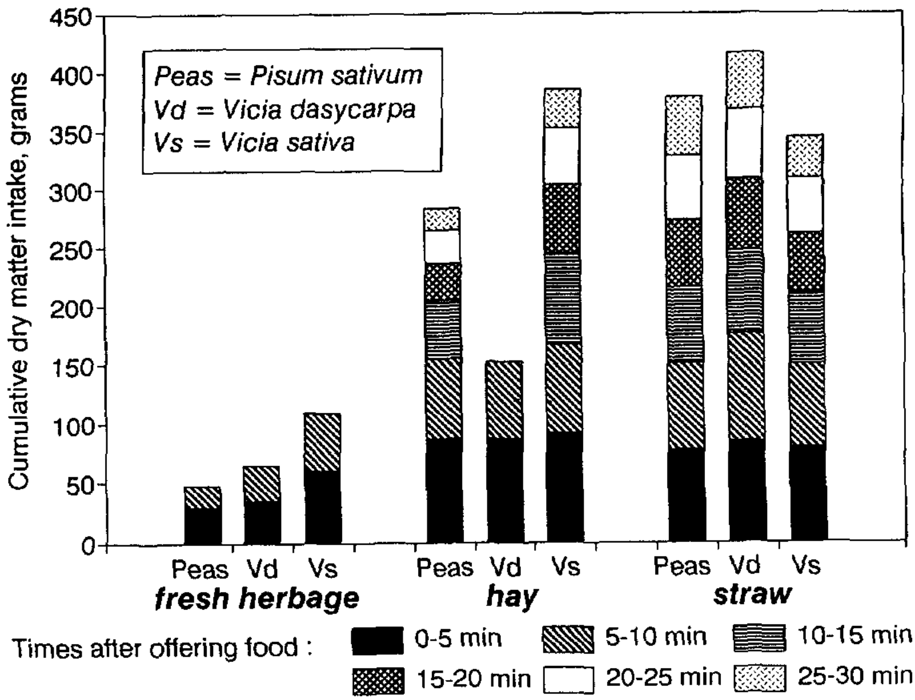

Figure 7.4. Intake, in successive meals of 5 minutes' duration, of pea and vetch forages at three stages of maturity.

No significant differences were observed between the pea genotypes at any stage of maturity, implying that no correlation with morphology or chemistry would be significant. The high moisture content of the fresh forages (80%) probably accounts for their relatively low rates of DM intake. At all stages of maturity, intakes in successive 5-minute periods decreased in size significantly ($P<0.001$), but the total intake of hay and straw in the 30 minute feeding period was between 300 and 400 g DM, about one-fifth of daily voluntary intake. - **E. Carter and E. Thomson**

7.2.3. The effect of environment on palatability

The rates of intake of Syrian peas (variety 205) and common vetch grown at Setatt, Morocco, were compared with intakes of the same genotypes grown in Syria, and with intakes of Moroccan genotypes grown in Morocco. The herbage was cut as hay and offered to Awassi sheep at Tel Hadya.

Table 7.6. Rate of intake (g in a 5 or 10 minute period) of pea and vetch forages grown in Syria and Morocco.

Origin of seed	Where grown	Pea 0-5 min	Pea 0-10 min	Vetch 0-5 min	Vetch 0-10 min
Syria	Syria	85.8	140.0	86.3	164.8
Syria	Morocco	97.2	165.9	75.0	137.0
Morocco	Morocco	67.8	127.0	37.5	57.0

The site where the hay was grown had a smaller effect on rate of intake than the country of origin of the seed. Syrian varieties were consumed more rapidly than Moroccan (Table 7.6), possibly because the Syrian sheep had past experience of these forages. The chemical composition of all forages was similar with NDF and crude protein contents of approximately 350 and 160 g/kg DM. Successive meals decreased in size ($P<0.001$). The rate of intake of the Moroccan vetch, which resembled V. villosa, was significantly lower ($P<0.001$) than of all other feeds. - **E. Carter and E. Thomson**

7.2.4. Differences in nutritive value between fresh and dried pea and vetch forage

In previous grazing trials in which sheep were allowed to choose between plots containing pea varieties and others containing vetch species, animals refused to eat pea forage. The sheep did not even try to taste the pea forage, suggesting that smell was the aversive stimulus. In another trial, sheep ate hay more rapidly than fresh forage, although the hay was cut at a more mature stage than the fresh forage; the difference was greater with peas than with vetch (Fig. 7.4). The unpublished analyses by gas chromatograph of volatile compounds show different patterns for pea forage and vetch. An experiment was carried out to examine the differences in digestive physiology between sheep fed pea and vetch fodder in the fresh and dried states, harvested at the same stage of maturity and restricted to the same level of intake.

In March and April 1991, the digestibilities of dried and fresh forage of Syrian local (205) pea and common vetch were measured with 4 ruminally cannulated sheep on each forage. Dry matter intake was restricted to 20 g/kg liveweight. Rates of passage of digesta fluid and stained particle fractions, rates of degradation of leaf and stem in sacco, rumen pH, rumen ammonia, and blood urea also were measured.

Both the pea and vetch crops received a total of 350-400 mm of water, including supplementary irrigation. Crops were harvested daily from 28 March (vegetative stage) to 21 April (late flowering/early podding stage). Half of the forage was fed fresh and the remainder was bagged in cotton sacks and sun-dried for feeding to the same sheep in May.

Drying the forage significantly reduced the digestibility of DM, NDF and N ($P<0.05$), DOM in DM ($P<0.01$) and total water intake ($P<0.001$) and increased nitrogen retention by about 3 g/day ($P<0.05$) (Table 7.7). Sheep fed vetch forage consumed and retained much more nitrogen than those fed pea whether fresh or dry ($P<0.001$). There were no differences in urinary or faecal N excretion between the forages

Table 7.7. Dietary N and NDF, DOM in DM, digestibilities of N and NDF, N retained by the animal (g/d) and water intake (litres/d) of sheep fed pea or vetch forage before or after drying.

Dietary component	Fresh pea	Dried pea	Fresh vetch	Dried vetch
Dietary N, g/kg DM	23.7	26.8	35.6	36.0
Dietary NDF, g/kg DM	509.9	545.2	422.5	510.8
DOM in DM, g/g	0.737	0.626	0.705	0.637
N digestibility, g/g	0.837	0.811	0.881	0.833
NDF digestibility, g/g	0.785	0.660	0.752	0.685
N retention, g/day	10.0	12.6	20.1	23.3
Water intake, i/day	7.04	4.66	6.68	4.76

Drying increased the lag phase of in sacco degradation of leaf and stem. Pea leaf was the most degradable fraction at all incubation times, followed by vetch leaf and vetch stem. Pea stem was the least degradable fraction; similar results occurred in 1989. The means of rumen pH, rumen ammonia-N and blood urea-N, in the first 9 hours after feeding and in the second half of each 24 hours (day and night), are shown in Table 7.8. The pH was significantly affected by forage moisture content ($P<0.01$) and by time of day ($P<0.05$). It took longer for the pH to fall to its minimum level in dried forages; the lowest level (ca. 5.9) was with dried pea forage. Rumen ammonia was significantly lower in dried than in fresh vetch forage ($P<0.05$) and it fell during the day ($P<0.01$) for all forages. Blood urea level decreased between day and night in the sheep fed pea forage and tended to increase in those offered vetch, but neither this effect nor that of diet or moisture content was statistically significant.

Table 7.8. Mean rumen pH, rumen ammonia N, and blood urea N of day and night samples from sheep fed pea or vetch forage before or after drying.

	Pea		Vetch		SE mean,
	Day	Night	Day	Night	10 d.f.
Rumen pH					
Fresh	6.37	6.88	6.55	6.83	
Dried	6.85	6.67	7.17	6.85	0.040
Rumen ammonia, mg N/litre					
Fresh	281.4	154.4	274.2	172.7	
Dried	284.3	152.9	188.2	125.0	22.7
Blood urea, mg N/litre					
Fresh	242.1	224.8	228.7	250.0	
Dried	269.4	210.0	210.5	214.8	16.7

The fractional rate of outflow of rumen liquid (Fig. 7.5) was measured using Cobalt-EDTA. Rates were faster for fresh than for dried forages (0.062 vs. 0.038/hr). Rumen volumes in litres, estimated from time-zero Co-EDTA concentrations, were 7.2, 8.4, 6.0 and 6.5 for sheep on the fresh pea, fresh vetch, dried pea, and dried vetch diets respectively. Analyses of rates of passage of solids is continuing.

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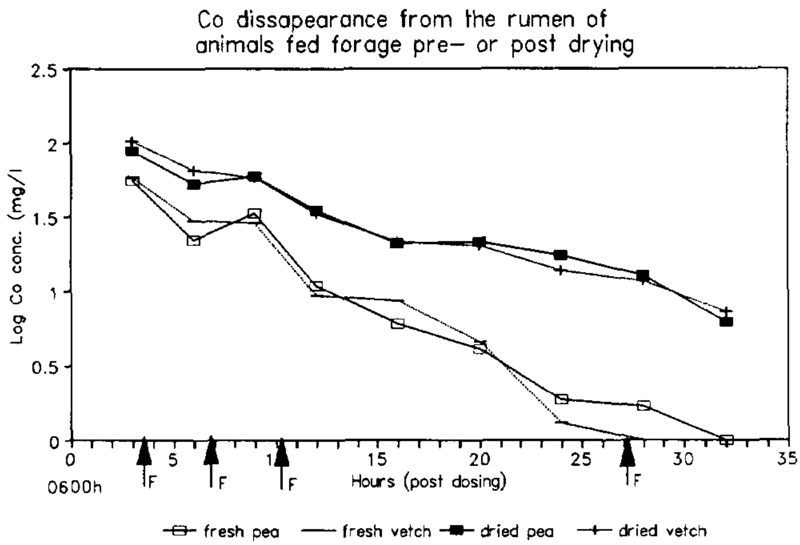

Figure 7.5. Cobalt concentrations in the rumen of sheep fed dried or fresh forage in the first 32 hours after dosing them with cobalt-EDTA.

7.3. Evaluation of Legume Seeds for Anti-nutritional Factors

Although members of the Leguminosae are widely used as protein sources by both humans and animals, it has long been recognized that their nutritive value and protein digestibility is poor, and they may in fact be toxic, unless subjected to some form of heat treatment. The anti-nutritive effects generally have been ascribed to a number of constituents common in legumes, such as trypsin inhibitors, haemagglutinins, phytin, tannins and non-protein amino acids. Thus, before the adoption of a legume in human or animal feeding, tests for anti-nutritional components are essential.

Within WANA, the two genera of legumes requiring evaluation, as supplements to cereal straw and grains in sheep feeding or as part replacement for soya bean in poultry diets, are Vicia and Lathyrus. For example, V. narbonensis has considerable promise in the 250-300 mm rainfall zone with some lines having seed yields in excess of 3.0 t/ha and harvest indexes of 40%. These lines flower early, are resistant to avian attack, mature in 34 days and hence escape attack by Orobanche (ICARDA Annual Report for 1989). Similarly, Lathyrus species have tremendous potential and, indeed, could be important grain legumes for animals and humans. The major drawback to their full utilization is, however, the presence of the potent, low molecular weight neurotoxins, β-N-oxalylamino-L-alanine (BOAA) or β-N-oxalyl-α,β diaminopropionic acid (ODAP). These non-protein amino acids have been implicated in the development of the neurodegenerative condition, lathyrism. Lathyrism causes an irreversible spastic paralysis of the legs and, in extreme cases, death. In spite of this obvious health hazard, Lathyrus continues to be preferred by some poor laborers in India, some of whom actually receive the seeds in lieu of wages (Bharati and Neupane 1989). The attraction of Lathyrus in these regions derives from its ease of cultivation, drought tolerance, low fertilizer requirements, high resistance to pests and reasonably good yields.

Information on the composition and nutritional characteristics of Vicia and Lathyrus seeds is poor. Such information is important as it provides a basis for any in vivo and/or in vitro studies, as well as an overall quality enhancement. Currently 214 lines of Vicia and Lathyrus are being analyzed for crude protein, trypsin inhibitor activity (TIA), tannins and BOAA content. The concentrations of these constituents are being correlated with climatic factors, seed size, seed and flower colors and fertilizer applications. Tannins are generally associated with poor palatability but both tannins and TIA are implicated in poor protein digestibility. Paradoxically, at specific dietary levels, tannins are believed to reduce the degradation of dietary proteins that pass through the rumen (Reid et al. 1974; Barry 1985).

Preliminary crude protein (CP) analyses are shown in Table 7.9. Protein-precipitable tannins (PPT) have been analyzed by the method of Hagerman and Butler (1978) and catechin equivalent (CE) by the vanillin-HCl method of Burns (1971), as modified by Price and Butler (1977) and Price et al. (1978) (Table 7.10).

Table 7.9. Crude protein content (g/100 g dry matter) of Lathyrus and Vicia species.

Species	Minimum	Maximum	Mean	S.E.	No. of lines
L. sativa	28.4	35.0	31.6	1.80	(36)
L. cicera	26.7	34.2	29.7	1.98	(16)
L. ochrus	28.3	32.2	30.4	1.18	(16)
V. narbonensis	25.0	32.8	28.9	1.68	(96)
V. sativa	28.4	35.9	32.0	1.94	(23)
V. ervilia	25.6	27.9	26.5	0.67	(16)
V. palestina	32.8	35.7	34.3	0.91	(16)

Table 7.10. Vanillin-HCl catechin equivalents (CE, g/100 g) and protein-precipitable tannins (PPT, g/100 g) of Lathyrus and Vicia species. nd = none detected.

Species	Catechin equivalent				PPT				No. of lines
	Min.	Max.	Mean	S.E.	Min.	Max.	Mean	S.E.	
L. sativa	nd	0.50	0.26	0.08	nd	0.45	0.41	0.02	36
L. cicera	0.28	0.55	0.36	0.09	nd	0.40	0.39	0.05	16
L. ochrus	1.30	2.58	1.87	0.04	nd	0.48	0.40	0.03	16
V. narbonensis	nd	0.45	0.19	0.07	nd	0.52	0.41	0.02	91
V. sativa	0.03	0.75	0.26	0.18	nd	nd	nd	nd	23
V. ervilia	0.08	0.30	0.18	0.06	nd	nd	nd	nd	16
V. palestina	0.18	0.38	0.28	0.05	nd	nd	nd	nd	16

The species with the lowest and the highest CP were V. ervilia

(25.6-27.9%) and V. palestina (32.8-35.3%) respectively. CE, which detects simple flavonoids as well as condensed tannins, was no more than 0.75% in all species of Vicia and Lathyrus, except for L. ochrus, in which CE was in the range 1.3-2.6%. However, the PPT level in L. ochrus was similar to that in the other species of Lathyrus and in V. narbonesis (means 0.39-0.41%, maxima 0.40-0.52%). PPT was not detected in any line of V. sativa, V. ervilia or V. palestina.

TIA is being assayed in terms of the extent to which an aqueous extract of the defatted legume flour inhibits the action of bovine trypsin on the substrate: benzoyl-DL-arginine-p-nitroanilide hydrochloride (Kakade et al. 1969) with modifications by Smith et al. (1980). The BOAA content of the samples will be analyzed using the technique of Rao (1978). We intend to establish the relationships between the concentrations of anti-quality components and certain agronomic and morphological characteristics highlighted above. - **V. Aletor, A. Abdul Moneim (LP) and A. Goodchild**

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8. Training

The major constraint on agricultural research and development in countries of ICARDA's region, especially in the area of pasture, forage and livestock, is the shortage of trained manpower to conduct independent research.

PFLP encourages problem-oriented training, designed to complement its research. Our training strategy was set out in detail in the PFLP Annual Report for 1989.

8.1. Training in 1990

This strategy was followed during 1990 by offering diverse training opportunities to a total of 46 participants from 34 countries (Table 8.1).

8.1.1 Fallow Replacement Training Course

For a number of years, FRMP and PFLP have been conducting research on the replacement of fallow by developing crop rotations and identifying pasture and forage legumes for inclusion in the rotations. A training course was conducted from 18 March to 18 April with the following objectives.

1. To review the advantages and disadvantages of fallowing in dry, rainfed arable farming systems and options for its replacement.
2. To discuss the introduction of pasture and forage legume species that appear to offer potential for fallow replacement in the particular area.
3. To promote contacts and information exchange between ICARDA and national programs in the field of fallow replacement, and pasture and forage legume development.

Table 8.1. Summary of training activities

Type of training course	No. of participants	No. of countries represented
<u>Headquarter courses</u>		
Fallow replacement	7	6
Breeding methodology for for food and feed legumes	14	12
<u>In-country</u>		
Techniques in rhizobiology of pasture and forage legumes, (Morocco).	14	5
<u>Individual</u>		
Biological N-fixation of forage legumes	1	1
Grazing management	1	1
Quality assessment of forages	2	2
Screening for diseases and nematodes	1	1
Reproductive performance of sheep	1	1
Winter feed requirements	1	1
On-farm trials and improvement of sheep feeding	1	1
Effect genotype, year, and environment nutrition value of wheat straw (PhD)	1	1
Agronomic & ecological evaluation of some native legumes (M.Sc.)	1	1
The use of N^{15} to establish nitrogen balance in wheat related with medic (M.Sc.)	1	1
TOTAL	46	

Seven trainees from 6 countries (Syria, Jordan, Libya, Algeria, Afghanistan and Iran) participated. Comments from participants indicated that, in general, they felt that the objectives were appropriate and had been effectively achieved.

8.1.2. Breeding methods for food and feed legumes

From 6 to 17 May 1989, PFLP and FLIP conducted a short course on Breeding Methods for Food and Feed Legumes to train scientists working on feed and food legumes in breeding methodology, increase their efficiency in handling material, expose them to new techniques in plant breeding, and emphasize the utilization of germplasm of the different legume species.

8.1.3. Sub-regional course on Techniques in Rhizobiology

A sub-regional training course on Techniques in Rhizobiology of Pasture and Forage Legumes was held at the University of Sidi Mohammed Ben Abdallah, Meknes, Morocco, from 22 April to 3 May, 1990. The course was partially funded by FAO and a specialist in training on biological nitrogen fixation from NifTAL (a USAID project at Hawaii University) assisted with the teaching. The objectives were to provide training in manipulation of rhizobia from isolation to seed application as inoculum, basic knowledge on rhizobial ecology, selection of superior strains and production of inoculants and information on methodologies conducive to the improvement of nitrogen fixation by pasture and forage legumes.

8.1.4. Individual non-degree short-term training

This kind of training comprises field and laboratory work in a specific discipline, as requested by national programs, over a period not exceeding 4 weeks. In 1989/90, 5 candidates were trained in various disciplines (Table 8.1).

8.1.5. Individual non-degree long-term training

This type of highly specialized training involves junior scientists from countries of WANA in research of mutual interest to ICARDA and national programs. In 1989/90 three candidates from Syria were based at the Program's Sheep Unit and conducted projects on the following subjects:

- Reproductive performance of sheep grazing marginal lands at three stocking rates.
- Winter feed requirements of Awassi sheep.
- On-farm trials and improvement of sheep feeding.

8.1.6. Graduate degree training

The Program works jointly with universities in the region to select and supervise graduate students. In 1990 there were 3 students (1 Ph.D and 2 M.Sc.) doing research under the supervision of senior staff in the Program.

8.2. Training in 1991

During 1991, PFLP also supported human resource development for NARS in West Asia and North Africa. Table 8.2 shows the various training activities conducted on individual as well as group courses.

8.2.1. Pasture and range management

The Pasture and Range Management course from 3 to 14 March at Tel Hadya was attended by five participants from Syria. This practical, hands-on course covered the characteristics of grasslands and marginal lands as well as constraints on improvement. The course provided the participants with practical field experience in assessing changes in pasture, which necessitated field and laboratory work to collect and analyze data.

Table 8.2. Summary of training activities during 1991

Type of training course	No. of participants	Countries
Headquarter courses		
Pasture and Range Management	5	Syria
Forage Quality	3	Syria
Design of Long-Term Medic-Cereal Rotation Experiments	11	Syria, Libya, Algeria Morocco
Design of Livestock Research	2	Syria
In-country		
Sheep Nutrition and Management	17	Syria, Jordan, Iraq
Individual Non-degree		
Research Fellow	13	Morocco, Algeria, Syria, Jordan
Senior Research Fellow	1	Syria

8.2.2. Mechanical harvesting of food and feed legumes

A short course on legume harvest mechanization was run at Tel Hadya from 12 to 23 May, 1991 in cooperation with the Legume Improvement Program. Ten participants (from Algeria, Morocco, Lebanon, Egypt, Iran, Syria, Tunisia) attended. The course showed a range of production and mechanization systems and equipment, including mowers, combines, and lentil pullers. Trainees presented the current situation in legume production and mechanization in their own countries.

8.2.3 Forage quality assessment

A forage quality training course was held from 20 to 27 March for 3 trainees from Syria. The participants learned laboratory skills by analyzing forage samples for protein, phosphorous, digestibility, and moisture contents. The participants will use these skills to analyze samples in their research department at ARC, Damascus.

8.2.4. Design of long-term medic/cereal rotation experiments

A course on the design of long-term medic/cereal rotation experiments was attended by 11 participants from four countries (Syria, Libya, Algeria, Morocco). It was designed as a training workshop with group discussions and activities leading to the formulation of plans for long-term, on-station and on-farm grazing trials, to include medic pasture/cereal rotations in the four participating countries. The workshop was held from 26 to 30 May, 1991. The academic level of participants was high and this was reflected in the plans designed. During 1992 the ICARDA pasture forage specialist will make follow-up visits to the participants.

8.2.5. Design of livestock research

A course was conducted to train Syrian scientists in the design of livestock programs from 2 to 11 February. Participants designed experiments that they will conduct when they return to their research stations.

8.2.6. Sheep management and nutrition in-country course

The sheep nutrition and management course was held in Amman, Jordan, from 26 October to 7 November, 1991 and attended by 17 participants from Jordan, Syria, and Iraq. It was conducted in collaboration with ACSAD and financed as part of the Mashreq project. Instructors were from ACSAD, Jordan University, and ICARDA. The course emphasised a practical, integrated approach to sheep nutrition and management and covered the Awassi breed, feed cycles, principles of nutrition of the ewe, flock and weaned lambs, grazing systems, and diseases. The participants presented reports on some of these topics in their own countries.

8.2.7 Individual training

Degree-oriented research. Table 8.3 lists the graduate students who conducted their thesis research under supervision of PFLP scientists. Ten students from universities in Morocco, Germany, Sudan, and Syria made use of the research facilities available in the program. This effort adds to PFLP research capacity, enhances the human resources in the countries involved, and strengthens cooperation.

Table 8.3. Graduate research training during 1991

Name	Date	Degree	University	Country
Nadia Lahrach	1989	Ph.D.	Sidi M.Ben Abd Allah	Morocco
Iman Thahmi El Alami	1990	Ph.D.	Gissen	Morocco
Atef A/Malek	1989	Ph.D.	Gezira	Sudan
Ahmed Haloubi	1990	M.Sc.	Aleppo	Syria
Ghufran Kattach	1991	Ph.D.	Giessen	Syria
Rolf Wachholtz	1991	Ph.D.	Honenhiem	Germany
Farouk Shomo	1990	M.Sc.	Khartoum	Sudan
Sadallah Filo	1991	M.Sc.	Aleppo	Syria
Safouh Rihawi	1990	Ph.D.	Reading	England
Eunice Carter	1988	Ph.D.	London	U.K.

Non-degree individual instruction. Fourteen trainees were instructed in various topics on an individual basis, with flexible training plans tailored to suit their particular needs. The Senior Research Fellow worked with PFLP scientists to appraise the ley farming systems in Syria and produced a report recommending the release of the medic system in Syria.

9. Publications

Papers in Refereed Journals

1990

Abd El Moneim, A.M., Cocks, P.S. and Mawlawi, B. Genotype-environment interactions and stability analysis for herbage and seed yields of forage peas under rainfed conditions. Plant Breeding. 104: 231-240.

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Osman, A.E. and P.S. Cocks 1991.Prospects for improving Meterranean grasslands in Lebanon through seeding, fertilization and protection from grazing. Experimental Agriculture (in press).

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1990

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