PASTURE, FORAGE, AND LIVESTOCK IMPROVEMENT

Program Report 1984/85

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

Pasture, Forage and Livestock Program

Draft Annual Report 1984/85

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PASTURE, FORAGE, AND LIVESTOCK

The Pasture, Forage, and Livestock Program (PFLP) has the broad objective of improving livestock production and stability of rainfed farming systems in west Asia and north Africa. In attempting to do this it has identified two major agroecosystems: farms in the cereal zone whose basic product is wheat or barley, and marginal land within and adjacent to the cereal zone. The Program is structured into four projects: (1) annual pastures to replace fallow, (2) forage breeding, (3) marginal land improvement, and (4) livestock management and nutrition.

The first two projects are designed for the first agroecosystem, specificially to replace fallow in cereal/fallow rotations with either annually resown forages or self-regenerating pastures. In the case of forages, the objectives are to breed adapted cultivars of vetch (*Vicia* spp.) forage pea (*Pisum sativum*), and chickling (*Lathyrus* spp.). In the case of annual pastures the objectives are to introduce self-regenerating populations of annual legumes, and to devise management systems suitable for local economic and social conditions.

The objective of the marginal land project is to increase stability and productivity of the second agroecosystem, nonarable land within and adjacent to the cereal zone. The specific aim of the work is to define the resource base: nature and fertility status of soils, kind of plants found, soil productivity, and management practices. From these studies new proposals are being formulated to develop this greatly undervalued resource. The first of the proposals - use of superphosphate on marginal land - became the subject of experimentation this year, and a very large experiment involving two rates of stocking by sheep and three rates of superphosphate application, was initiated.

Livestock management and nutrition is the Program's integrating project. Under this heading scientists test the various production systems from the point of view of the Program's 'commodity', namely sheep. There is emphasis on 'on-farm' experimentation. Extensive work on nutrition, highlighted again by work on the quality of barley and wheat straw, was conducted.

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

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

Chickling - *Lathyrus sativus*

Forage pea - *Pisum sativum*

Medics - various species of *Medicago*: of these only barrel medic (*M. truncatula*), snail medic (*M. scutellata*), strand medic (*M. littoralis*) and gama medic (*M. rugosa*) have widely accepted common names. *M. polymorpha*, although often called bur medic, is referred to by its scientific name.

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

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

accession - an ecotype as collected in its native habitat and used in a breeding project.

selection - resulting from selection within an accession. In its numbering system ICARDA allocates both an accession number and, where applicable, a selection number.

variety - we use this term in its botanical sense, where it is a taxonomic unit beneath species.

cultivar - a genotype or ecotype which is used in agriculture, including locally evolved 'landraces'.

strain - is a general term to cover accession, selection, variety and cultivar.

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

self-regenerating pasture - pastures with the ability to re-seed themselves, used in this Report as a term to describe pastures which re-seed after the cereal phase of a pasture/cereal rotation.

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

marginal land - land receiving more than 200 mm of rain which is too dry, too steep, or in which the soil is too shallow for cultivation.

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

Research Highlights

Some of the research highlights are presented below.

(1) Based on six years data collection a linear program was used to analyse the profitability of different levels of management and contrasting 3-course rotations one of which included vetch and the other lentils. Including vetch and improved management practices in the rotation increased sheep number by 100% and farm profitability by up to 75%.

(2) Yields of barley after forage depended on the amount of cereal included in the forage mixture. Even small amounts of cereal reduced subsequent grain yield regardless of species of forage legume.

(3) Palatability of forage pea was less than that of common vetch or chickling at all growth stages, and less than barley at all except the straw stage. Sheep fed a diet of pure forage pea lost weight when the peas were fresh, when they were fed as hay, and when they were fed as straw.

(4) Resistance to root knot nematode (Meloidogyne artiella) was discovered in several strains of common vetch. This disease, which causes serious losses in herbage and seed yield, affects many food and forage legumes of potential importance in the Region.

(5) Strains of common vetch whose seed pods are non-shattering were hybridized with several well adapted strains: 524 successful crosses were made.

(6) Woollypod vetch was found to be well adapted to the Tel Hadya environment: not only did it produce large quantities of herbage and seed but it also tolerated frost and was resistant to broomrape (Orobanche sp.) and root knot nematode.

(7) The native medics (including M. rigidula, M, rotata, and M. noeana) were far more tolerant of frost than any of the Australian medic cultivars. Moreover strains originating from cold environments were more likely to be frost-tolerant. Tolerance of susceptible strains depended on plant density, and seemed to be related to leaf area ratio.

(8) An eco-geographic survey of native legumes in western Syria revealed information about the habitats of 21 medic species. M.

polymorpha, M. orbicularis, M. minima, and M. rigidula were the most common but in certain specific environments there were high populations of M. rotata, M. blancheana, and M. turbinata.

(9) Certain strains of self-regenerating M. rigidula produced large quantities of herbage and seed following wheat. In an experiment with 25 native medics the average quantity of seed after three years of pasture/cereal rotation was more than 700 kg/ha.

(10) Sheep grazing medic pasture in summer increased weight as long as the amount of seed on offer exceeded 10 kg/ha. At a stocking rate of 5.3 sheep/ha seed on offer remained above this figure until mid-September. Each sheep consumed about 450 g medic seed/day.

(11) When inoculated with an exotic strain of Rhizobium, medic nodulation was improved by use of a protective seed coating.

(12) A large experiment was established in which the reponse in productivity of sheep grazing marginal land top-dressed with superphosphate will be measured. In the first year, both herbage and seed yield were increased (especially with native legumes), and these increases, when analysed by a linear program, indicated that using superphosphate on marginal land will increase farm profitability.

(13) Studies on voluntary intake of barley straw confirmed that proportion of leaf is the most important factor determining straw quality. Proportion of leaf is itself dependent on maturity time and plant height, both of which are genetically controlled. Factors influencing straw quality in barley also appear to influence straw quality in wheat.

(14) Weight of Awassi ewes at mating had a marked effect on reproductive function between body weights of 38 and 50 kg.

(15) Work on farmer's fields was continued using both forage and pasture legumes. Preliminary results indicate that both systems will result in increased farm profitability.

The Program wishes to acknowledge many collaborators. The Italian Government and the University of Perugia are assisting with the marginal land project, the Tropical Development and Research Institute of the Overseas Development Administration, UK, is collaborating in the straw project, the Japanese International Cooperation Agency is collaborating in the animal health work, and the Syrian Agricultural Research Center and Steppe Directorate are major collaborators in all our work. - **P.S. Cocks**

ANNUAL PASTURES TO REPLACE FALLOWS

The idea of using annual pasture legumes to replace fallows in cereal/fallow rotations originated in southern Australia, where pastures provide nutritious grazing throughout the year, replenish soil fertility, and provide a disease-controlling break between cereal crops. In the 30 years since it was introduced the ley farming system, as farming using temporary pastures is called, has increased livestock numbers by up to four times and doubled cereal yields.

The main advantage of annual pastures over other forages is that the appropriate choice of species means that they do not need re-sowing after the initial year of establishment. This is particularly the case where certain pasture legumes are used, mainly Trifolium subterraneum (subterranean clover) and several Medicago (medic) species, which are able to regenerate in the pasture phase of the rotation from seed set in the previous pasture phase, two years earlier. Not only does this save farmers the expense of re-sowing but also the natural re-seeding rates are much higher than farmers can afford to use, resulting in rapid early establishment and a much longer period for grazing. Ideally, livestock are introduced to the pasture in early winter: since annual legumes are prostrate in winter, and many weed species are erect, winter grazing is a good method of controlling weeds. The sheep continue to graze in spring and summer: in spring the main problems are to ensure good flowering and seed set, and in summer, when sheep eat the nutritious seed pods, to ensure that an adequate seed population remains for pasture regeneration in later years. In summer and autumn the farmer also uses cereal stubbles for grazing.

In the second year the farmer waits until the autumn rains and then, after germination of weeds, prepares his seed bed and sows the crop. Most of the legume seed produced in the previous year remains dormant (through seedcoat impermeability, sometimes referred to as hardseededness), and it is important that depth of tillage is such that seeds are placed at a depth (no more than 10cm) from which they can emerge in the third year.

Success of the system depends on several factors. Firstly the time of greatest feed shortage is usually autumn and winter, when low temperatures and low light intensity inhibit plant growth. Indeed many people believe that one of the most important differences between west Asia and southern Australia is that winter temperatures are about 5^{o}C less in the former. Rapid pasture growth in winter, and resistance to frost are therefore important attributes. Secondly, the survival of pastures depends on their ability to produce enough material to provide grazing in summer, and enough seed for a dense germination in the autumn two years later. Thirdly the seeds must be able to resist germination in the crop year and germinate promptly in the third, or pasture year. Finally the pasture must fulfill its role as a source of nitrogen, and, in association with Rhizobium, fix sufficient atmospheric nitrogen for its own and the cereal's requirements.

It was reported in the 1984 Annual Report that certain native medics show great promise for use in the ley farming system. These are M. rigidula, M. rotata, M. noeana and M. polymorpha, all of which produced more herbage than Australian cultivars of M. truncatula, M. littoralis, M. rugosa, and M. scutellata. Our research is now directed towards fitting these species into workable farming systems: in particular the adaptation of native medics to crop rotations, their response to grazing animals, the impact of low temperatures on production, and plant/Rhizobium interactions.

All of these problems were the subject of study at ICARDA in 1985. In this Report we highlight the effect of frost, both on the ecology of its impact and sources of resistance; we report studies on flower and seed production in the presence and absence of grazing animals; and we report on the ability of promising medics to survive in a cereal/pasture rotation. We also conducted further studies on Rhizobium, especially on new methods of inoculation, and have made a beginning to finding out more about its ecology. Finally we report on our first attempt to introduce ley farming at the village level, and we present data which will help us to evaluate the future expansion of ley farming.

Because of the severe frosts which occured in late winter the opportunity was taken to measure the effect of frost in several experiments which were also continued for their original objectives. To avoid repitition in describing procedures, the experiments have been numbered from 1 to 6: where the same number is referred to in different sections different results from the same experiment are being described.

The impact of severe frost on native and introduced annual medics

Although introduced cultivars of M. truncatula, M. scutellata, and M. littoralis have grown well in parts of north Africa, they have often failed in the highlands and in west Asia. In his review of pasture and forage legumes, Kernick (1978)* records that in northern

* Kernick, M.D. (1978). Ecological management of arid and semi-arid rangeland in Africa and the Near and Middle East. Vol. IV, Rome FAO.

Iraq, frosts of a week or more in duration have killed seedlings of *M. truncatula*, and he quotes similar results in Syria, Jordan, Iran, and Yemen. That this should be so is perhaps not surprising in view of the mainly littoral distribution of these species: the native habitats of both are in areas of mild winters near the sea. Use of productive native medics is one method by which cultivars resistant to frost may be identified.

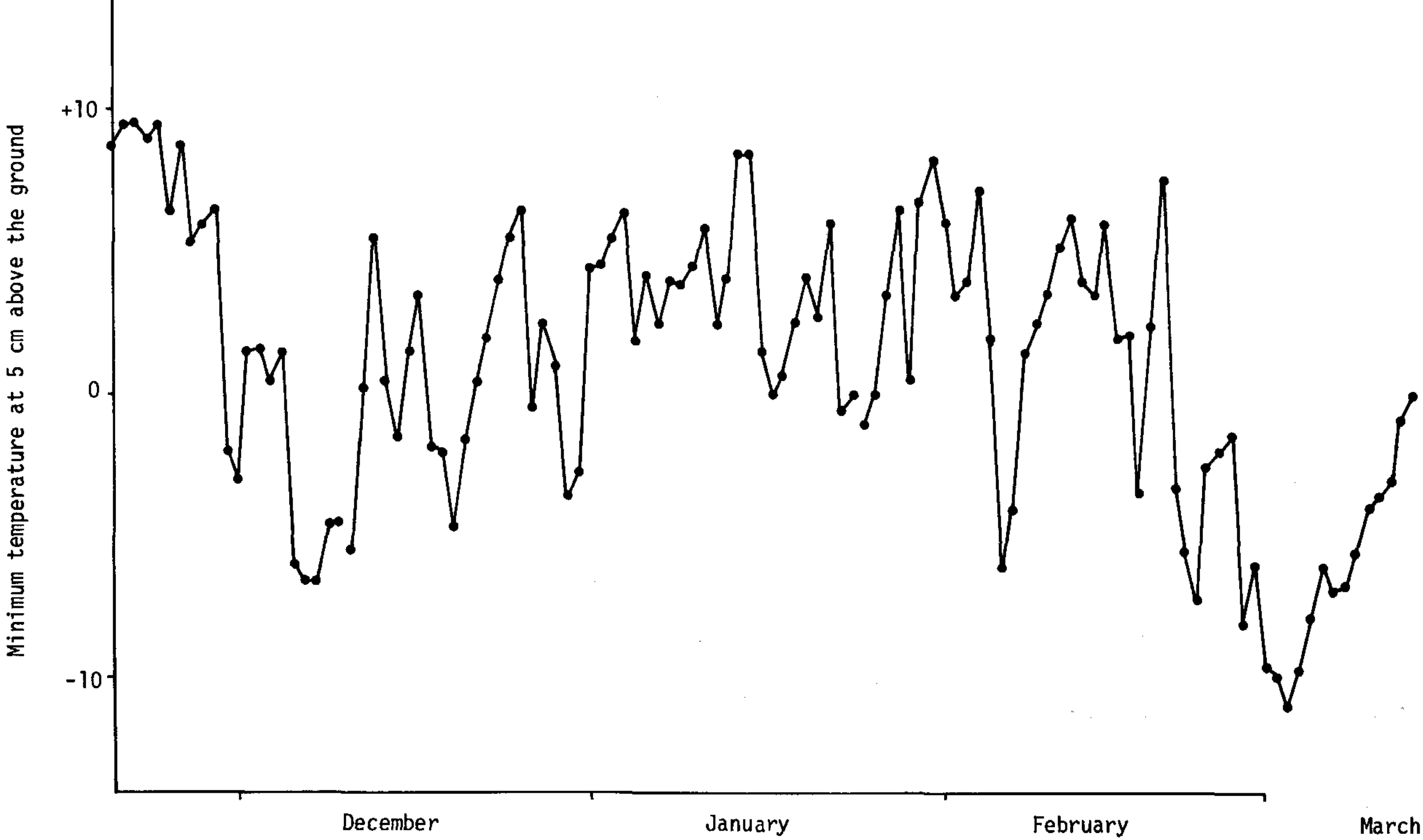
An opportunity to study frost-resistance presented itself in December 1984 and late February 1985 when on 46 days the minimum air temperature at Tel Hadya was $0^{\circ}C$ or less (Fig. 1). Many experiments were affected, including those where several introduced and native medics were being compared (Experiment 1), where a large collection of Syrian medics was being evaluated (Experiment 2), and an experiment where three medic species were growing at several plant densities (Experiment 3).

Experiment 1

Experiment 1 was sown to compare the effect of stocking rate on flower and seed production by seven medic genotypes. There were three stocking rates, controlled by the size of plots: 2.25 ha, 1.125 ha, and 0.75 ha. Each 'main' plot was replicated twice, and within each two replicates of each genotype were sown as subplots. The plots were sown on December 3 at a seed rate of 100 kg/ha.

On 7 February frost occurred and it was decided that before any plants died a count of the establishment of seedlings should be made with a view to quantifying the damage. On 12 March, after severe

Fig. 1. Minimum daily temperatures 5 cm above the ground at Tel Hadya in the winter of 1984/85. There were a total of 46 frosts.



frosts in the preceeding 3 weeks the seedlings were re-counted in the same quadrats (three, 12.5 x 50cm) in each subplot, and the percentage survival of each genotype were calculated. The results are given in Table 1.

The medics fall into two distinct groups: a low survival group comprising the Australian cultivars and a high survival group comprising the native accessions. Within the Australian group, survival of cultivars Jemalong and Circle Valley were superior to those of Robinson and Cyprus, and within the native group M. rigidula appeared to survive a little better than M. rotata, although the difference barely reached significance. The loss of plants in the native group was hardly enough to effect productivity, while three of the four Australian cultivars were so badly damaged that they were excluded from the experiment. - **P.S. Cocks**

Experiment 2

Annual legumes were collected from 95 sites throughout north-western Syria, including the coastal plain, the mountains, and the cereal belt to the east of the mountains. The exact position of each site was recorded and an area of approximately half a hectare was chosen for sampling. Within the area one or two strip quadrats about 40m long were chosen for detailed study, the size and direction of the strips depending on heterogeneity of the site in terms of topography and species richness. At least 25 pods of each species were sampled to capture as much of the genetic diversity as possible.

Table 1. Establishment, and survival after severe frosts, of seedlings of seven accessions (five species) of medic, including four Australian cultivars.

Species and genotype	Number of seedlings per m^2	Survival %
M. scutellata cv. Robinson	232	5[e]*
M. truncatula cv. Cyprus	536	7[de]
cv. Jemalong	432	14[cd]
M. polymorpha cv. Circle Valley	856	21[c]
M. rotata sel. 2123	1144	90[b]
M. rigidula sel. 716	816	95[ab]
sel. 1919	864	98[a]

* Survival percentages with the same superscript not significantly different at ($P < 0.05$): analysis of variance of data after angular transformation.

Table 2. Statistical parameters obtained for the relationship between genotype survival and minimum temperature of the site at which genotypes were collected: n is the number of genotypes collected, b is the slope of the regression line for relationship, and 100 r^2 is the percentage of variation accounted for.

Species	n	b	100 r^2
M. rigidula	50	NS	0
M. polymorpha	102	0.523***	13.2
M. turbinata	23	0.607*	20.1
M. orbicularis	43	0.240*	11.6
M. minima	43	NS	1.2
M. scutellata	11	1.000**	56.4

NS Not significant; * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.

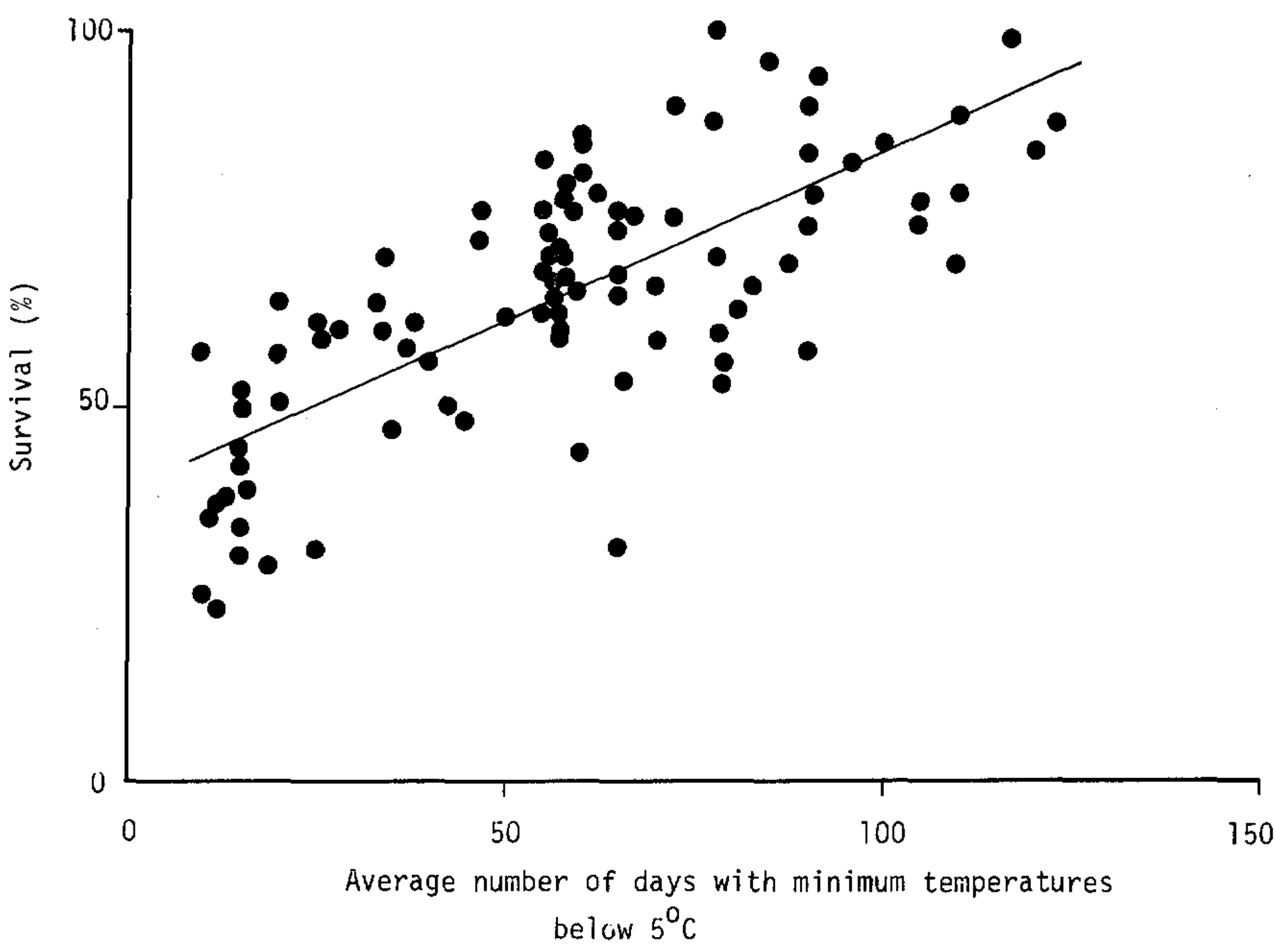
A much smaller area was sampled more intensively to measure population size and obtain detailed physical and chemical characteristics of the soil. An homogenous area of about $25m^2$ was chosen, typical of the site as a whole, and all legume seeds in 5 quadrats of 1m x 0.25m were collected. At the centre of each quadrat the soil was sampled to a depth of 10cm. The seed was sorted into species, threshed, and weighed to determine total yield.

Seeds from both the larger and smaller area were germinated in 'Jiffy' pots in greenhouse and, after hardening outside for two weeks, were transplanted into the field in rows containing up to 15 plants each.

All frosts in Fig. 1 seemed to affect the plants, some ecotypes more severely than others. The late frosts were especially severe and the opportunity was taken to record survival. The results are shown in Fig. 2 which relates mean survival of all species occuring at a site to the mean number of days on which the temperature fell below 5^oC at that site. Frost resistance proved to be an excellent character demonstrating the benefit of choosing adapted species from among native populations. There was a strong relationship ($100\ r^2 = 50$, $P<0.001$) between frost resistance and number of days below 5^oC, a relationship even more impressive than the statistics suggest since no account was taken of microclimate, temperatures being read from isotherms in published maps.

Fig. 2 gives the mean survival of all species occurring at a site. Some species showed ecotypic differentation in regard to frost resistance, ecotypes from cold environments being more resistant to

Fig. 2. The relationship between frost survival and the average number of days below 5°C at 95 sites in western Syria from which annual legumes were collected. Since, at some sites, more than one accession was collected , each point represents the mean frost damage of all accessions collected at a site.



frost than those from milder areas. The slope of the regression line and significance of this relationship for seven of the medics is shown in Table 2: note that neither M. rigidula nor M. minima showed variation in frost resistance, ecotypes from almost all sites being resistant. On the other hand, some ecotypes of M. scutellata exhibited strong resistance and the relationship with the environment was also strong, while in M. turbinata, M. orbicularis, and M. polymorpha, resistance, though strong in some ecotypes, was only weakly related to the incidence of cold in their native habitats.

Other results from this survey will be discussed later. - **T. Ehrman (Genetic Resources Unit) and P.S. Cocks**

Experiment 3

Three medic species (M. rigidula sel. 1919, M. rotata sel. 2123, and an Australian cultivar of M. polymorpha cv. Circle Valley) were sown at 11 seed rates (1 - 500 kg/ha) on 31 October 1985. The treatments were combined factorially using two replicates. Plot size was 15m x 2m, weeds were controlled using chemicals, and the whole area received a basal dressing of 15 kg/ha of phosphorus.

From 18 December herbage yield was measured, initially at approximately three-week intervals, and after 29 January, at two-week intervals, the final harvest being on 20 April. The samples were cut to ground level in quadrats of 1m x 0.5m at the first six harvests, and 1m x 1m at the final three harvests. Plant numbers were estimated at each harvest by weighing 50 plants, and leaf area index calculated from the area in a sub-sample.

The yield of herbage on 20 April varied markedly between species and densities (Fig. 3). Yield of M. rigidula was highest and that of M. polymorpha lowest, in both species yield falling at high density. The yield/density relationship of M. rotata showed very little decline at high density which is normal for this kind of relationship. Note that the yield of M. rigidula exceeded 9 t/ha at a sowing rate of 60 kg/ha, a very high yield indeed.

The time course in leaf area index (LAI) of two of the density treatments (60 and 500 kg/ha) reflected the differential loss of leaf of the three species following severe frosts at the end of winter (Fig. 4). All species suffered some leaf loss at high density although that of M. polymorpha was by far the greatest, LAI falling from 3.2 to 0.25 between 27 February and 13 March. The previous frosts, on 3 and 4 February also affected the LAI of M. polymorpha and possibly M. rigidula, but the first frosts (in December) apparently had no effect on any species. Note that the late winter frosts also reduced the LAI of the lower density treatment of M. polymorpha, but at that density did not affect the other two species. Indeed all 11 densities of M. polymorpha were affected by the frost whereas the other species were affected only at 500 kg/ha.

Clearly there is an interesting interaction between species and density, which is partly explained by the ratio of leaf area to leaf weight (leaf area ratio): low ratios indicate that the leaves are relatively thick, and high ratios that they are thin . Damage by frost, indicated in Fig. 5 by the percentage change in leaf area between 27 February and 13 March, is related to leaf area ratio, the frost accounting for 55% of variation in change of LAI. At a leaf

Fig. 3. The herbage yield of three medics (M. rigidula, M. rotata, and M. polymorpha) after sowing at 11 seed rates.

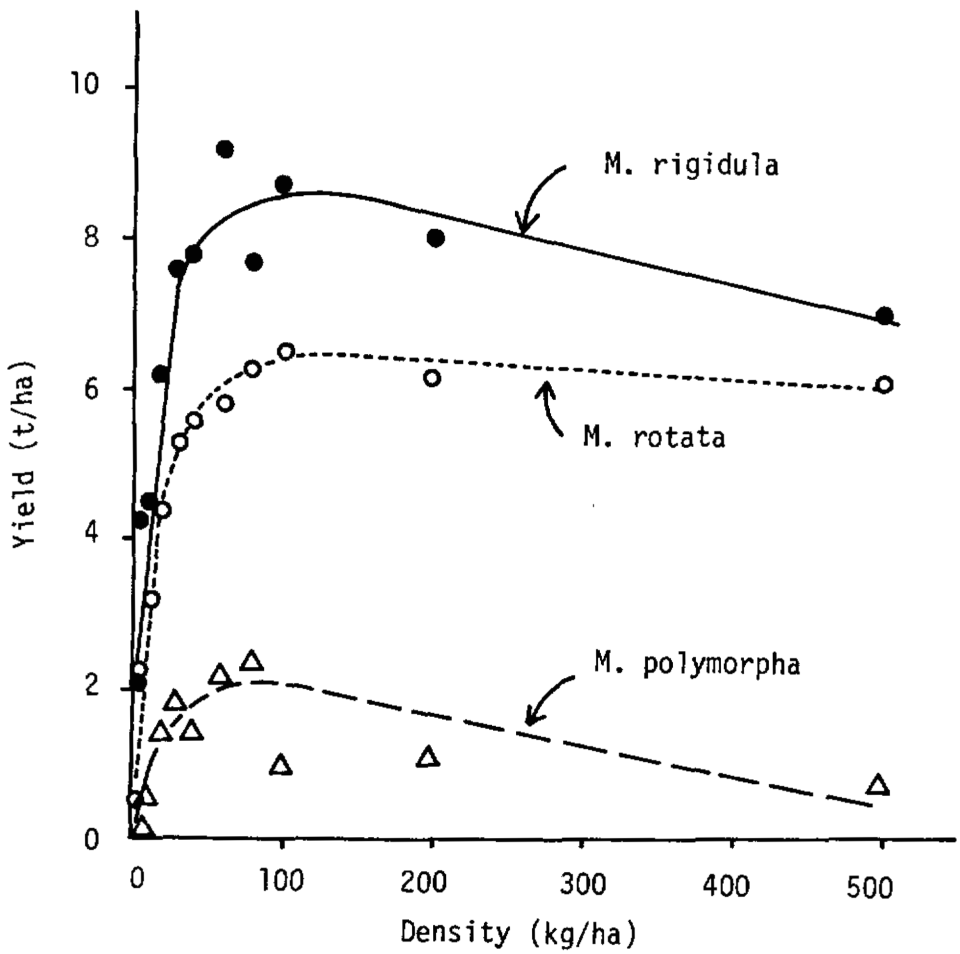
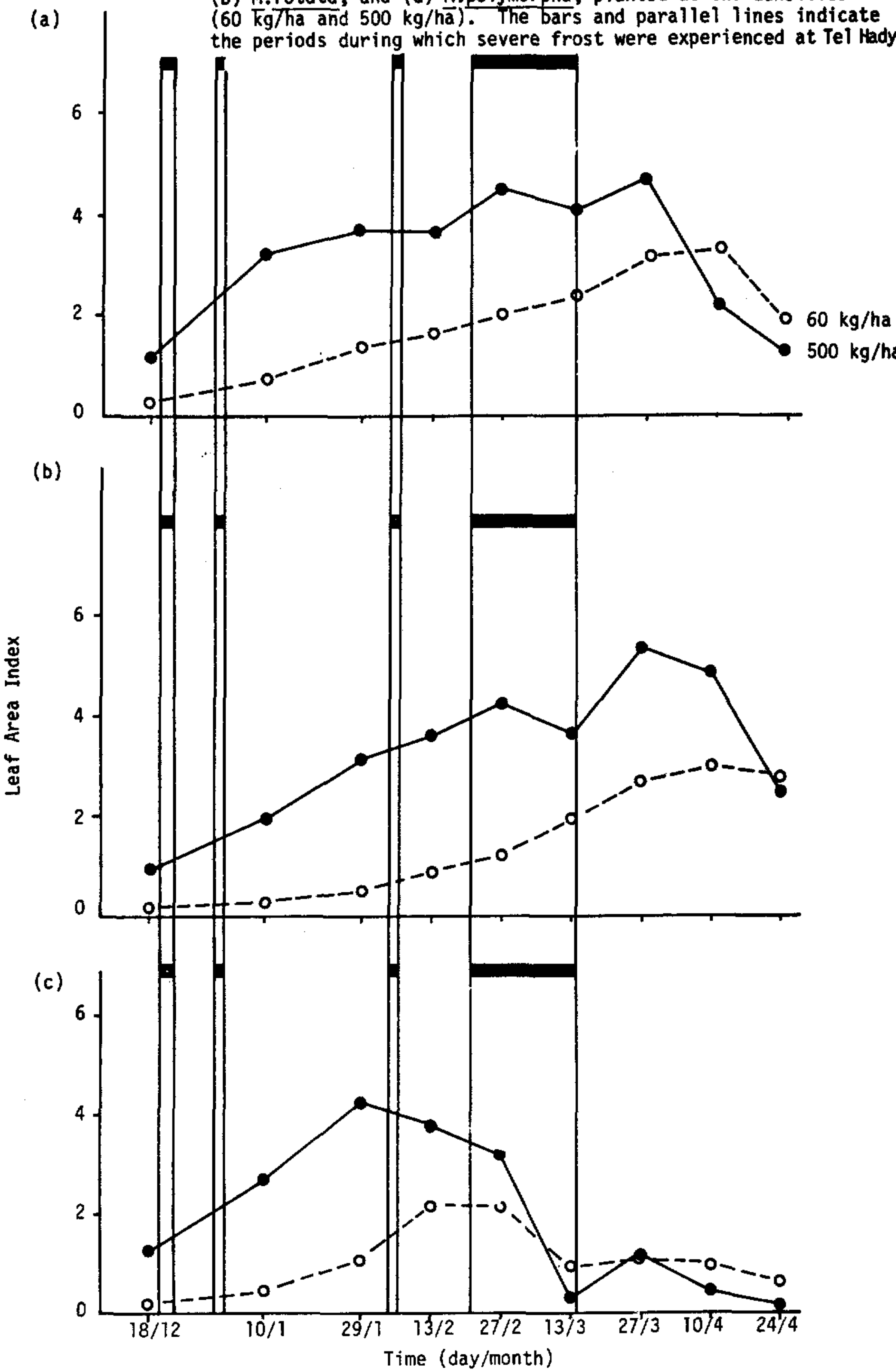


Fig. 4. The time course of leaf area index (LAI) of (a) M.rigidula, (b) M.rotata, and (c) M.polymorpha, planted at two densities (60 kg/ha and 500 kg/ha). The bars and parallel lines indicate the periods during which severe frost were experienced at Tel Hadya.



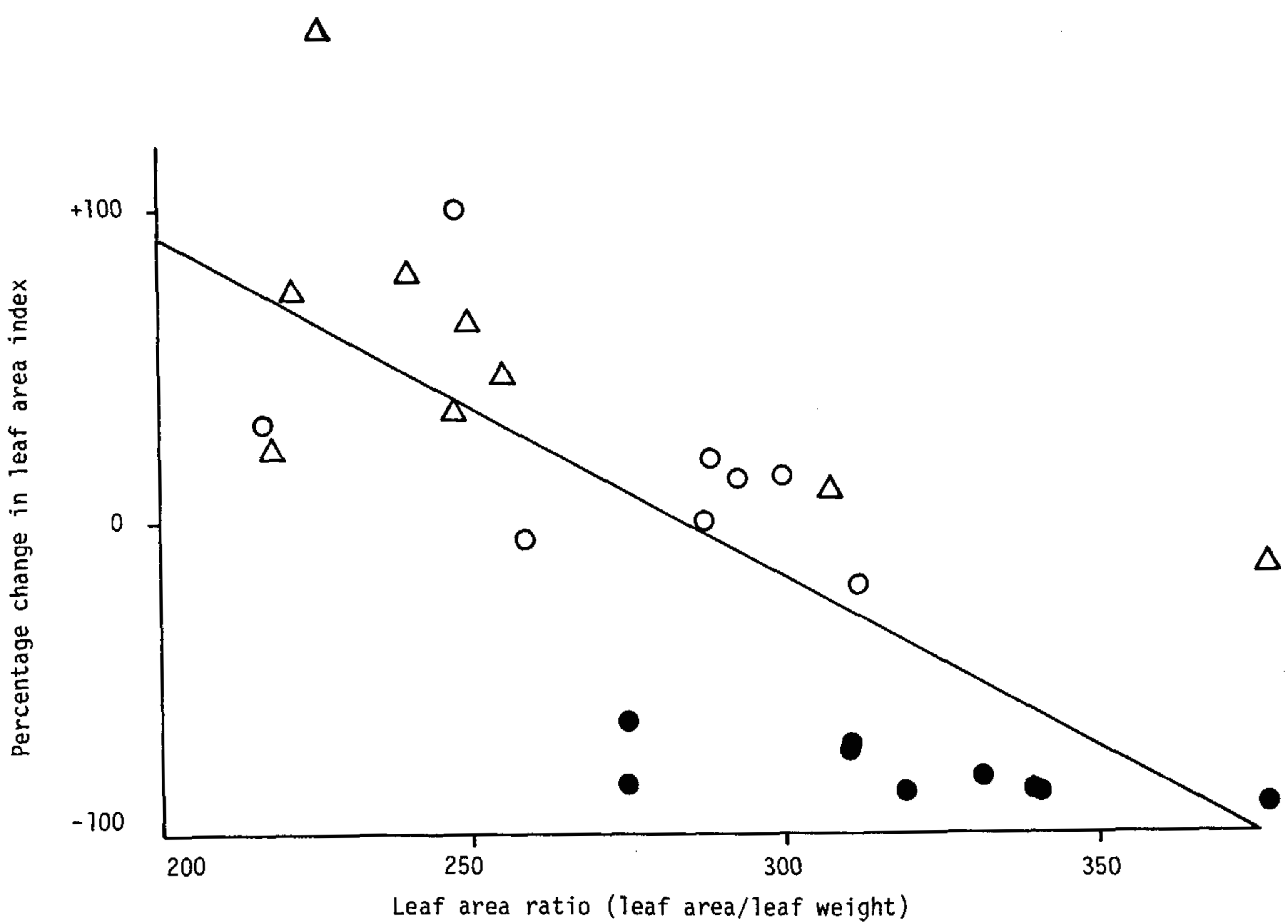


Fig. 5. The relationship between percentage change in leaf area index (27th February to 13 March) and leaf area ratio (leaf area in cm^2/leaf weight in g) after frosts in late February and early March. The triangles represent M. rotata, the open circles M. rigidula, and the closed circles M. polymorpha.

area ratio of $275cm^2/g$ there was no change in LAI between the two dates, and presumably the level at which no frost damage occured was a little below this figure. The relationship probably differs between species since M. polymorpha suffered damage at all leaf area ratios, but it is significant that this species clearly had a higher ratio than either M. rigidula or M. rotata in all treatments. While not providing an explanation for all of the variation in frost damage, low leaf area ratio is clearly an important attribute in a plant's ability to resist frost.

The time course in leaf area ratio for each species is shown in Fig. 6, and the effect of density in Fig. 7. The leaf area ratio of all species was least early in the season, increased until the end of January, decreased during February, increased for a short period in the spring before declining again in late spring. Fig. 6 is of interest for two reasons: firstly, if leaf area ratio is important then all three species were likely to be most susceptible to frost in January, and secondly M. polymorpha was clearly the most vulnerable species at all times except late spring when frosts are unlikely. The data certainly suggest that if frosts of equal severity to those experienced in late February had occured in January then damage would have been even more severe. It also explains why the frost which occurred in December (Fig. 1) had so little effect: at this stage of the growing season leaf area ratio was at its lowest.

In earlier results (Table 1) we referred to the differential survival of individual seedlings among native and introduced medics. It is also of great interest to analyse the impact of plant density on seedling survival, but, since self-thinning occurs at high density

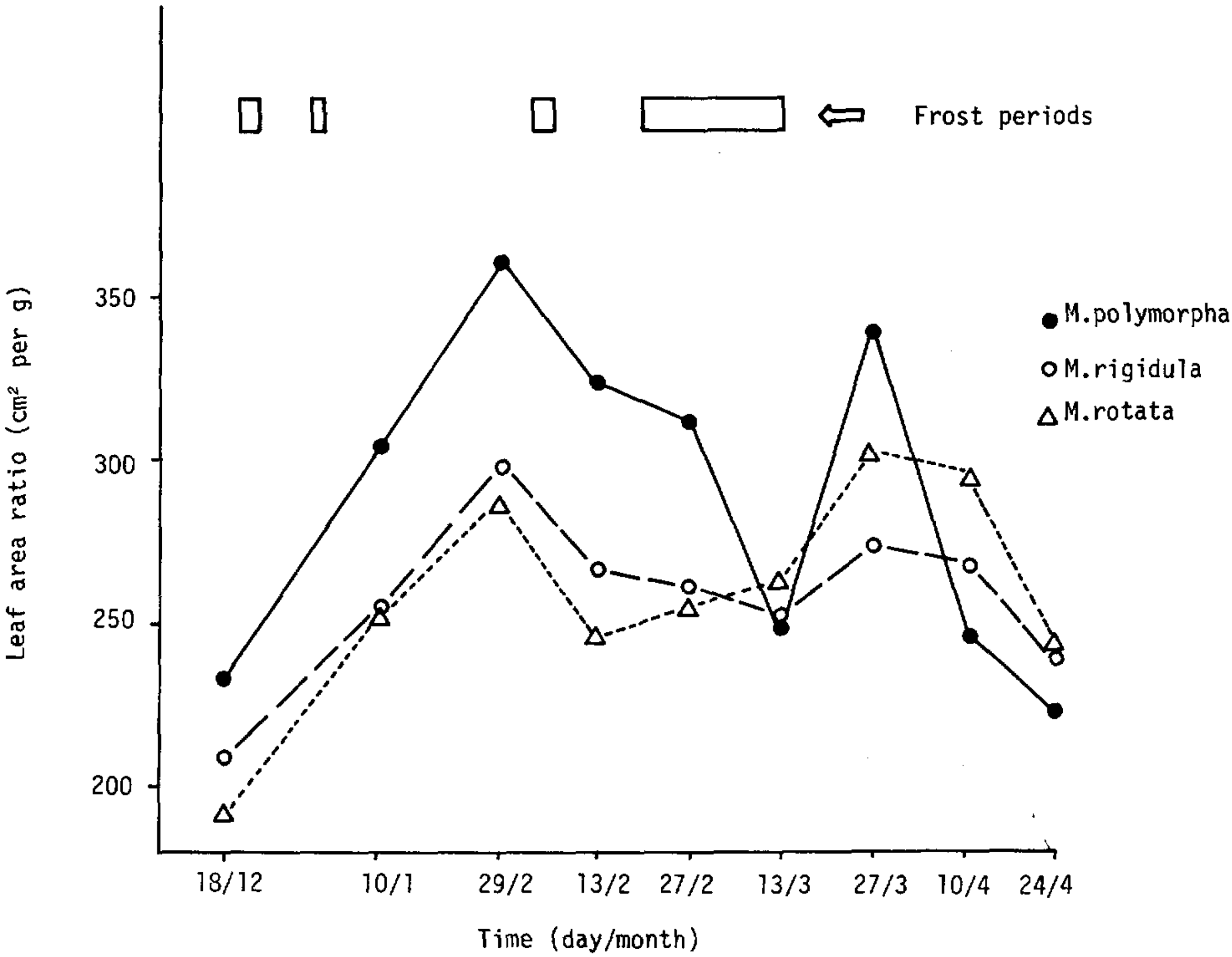


Fig. 6. The time course of leaf area ratio (cm²/g) of M.polymorpha, M. rigidula, and M.rotata (mean of 11 densities). Frost periods are indicated by the bars at the top of the Fig.

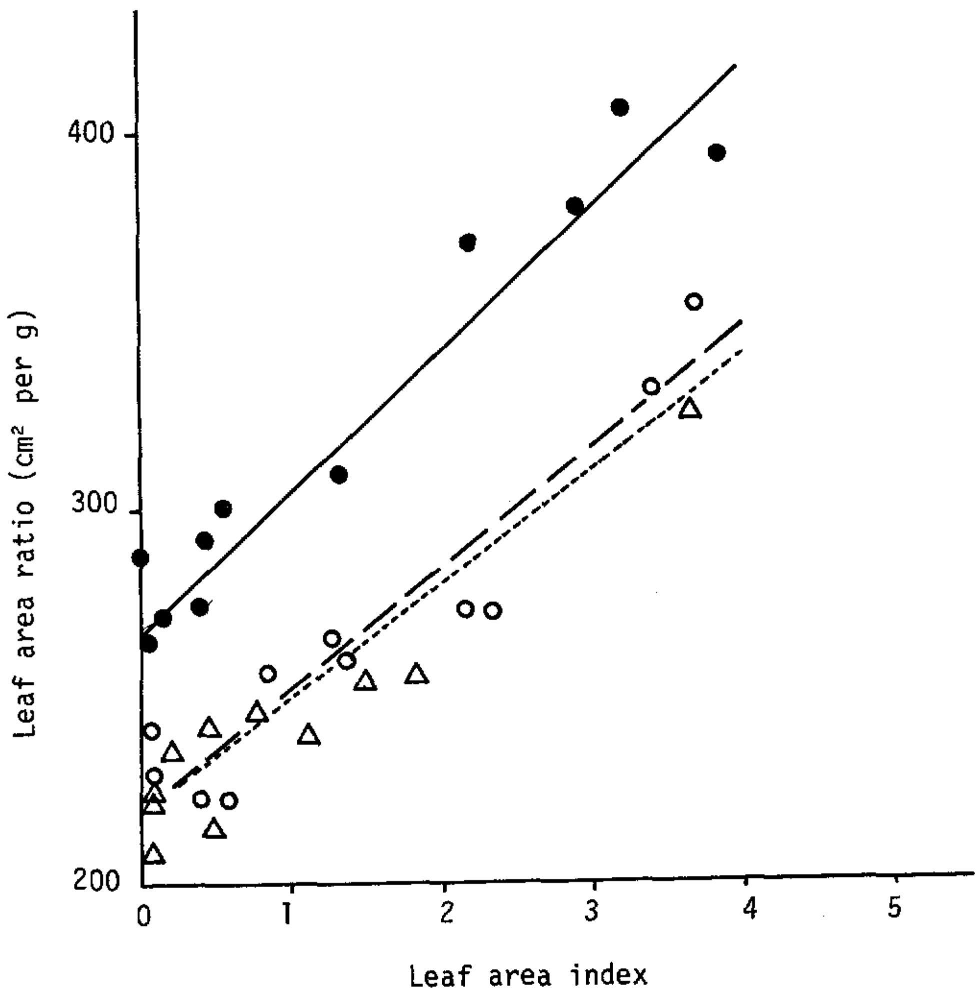


Fig. 7. The relationship between leaf area ratio and leaf area index of M. polymorpha (closed circles), M. rotata (triangles) and M. rigidula (open circles). The lines are fitted regressions all of which were significant at $P<0.001$.

it is not always easy to separate the impact of frost from other factors causing plant death. One method is to use the 3/2 thinning law which states that once self-thinning begins the graph of the relationship between the mean plant weight (log 10) and the number of plants ($\log_{10}$) has a slope of 3/2. The law has generality over all plant communities, including grasses, herbs and trees* and is therefore an excellent description of self-thinning in dense plant communities. In our case any deviation from the law is likely to be due to the effect of frost.

The law applied to M. rigidula and M. polymorpha is shown in Fig 8. The line on the right of each graph has a slope of 3/2 and, in the case of M. rigidula, it is clear that the change in plant numbers is in accordance with the law. In the case of M. polymorpha however, plant loss in all densities was greater than predicted. Any changes in plant numbers observed in M. polymorpha are therefore likely to be due to frost, while there was no plant death caused by frost in either M. rigidula or M. rotata (not shown).

Fig. 9 shows that there is a highly significant relationship between plant death and density in M. polymorpha, the relationship accounting for 83% of variation in plant death (the two lowest densities have been excluded from this relationship because random errors in plant counts in the $0.5m^2$ quadrats is such that the calculation of percentage death is unreliable). Note that the

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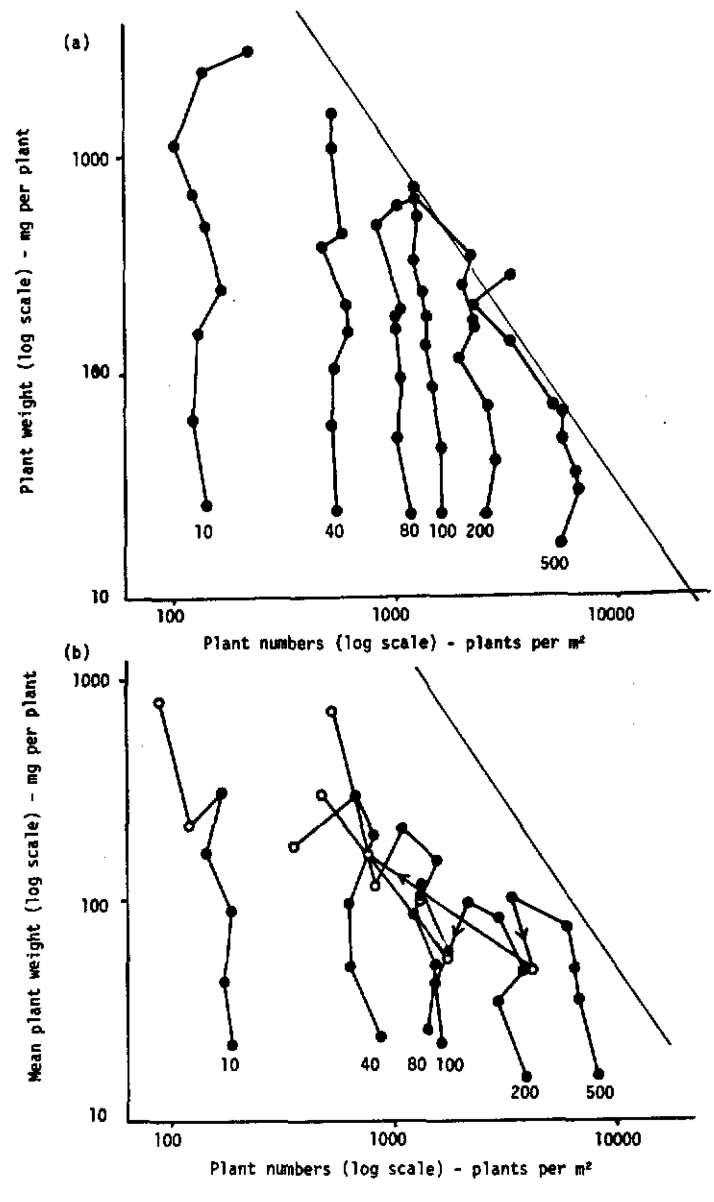
(1) White, J., and Harper, J.L. (1970). J. Ecol. 58, 467.

Fig. 8. The relationship between actual density of plants of (a) M. rigidula and (b) M. polymorpha and the mean weight per plant at nine harvests from 18 December to 24 April. There are six sowing densities (from left to right 10, 40, 80, 100, 200, and 500 kg/ha) and the points joined by continuous lines represent changes of actual density and plant weight with time during the course of the experiment. The straight line at the right has a slope of 3/2. The open circles in (b) represent harvests after the severe frosts in early March.



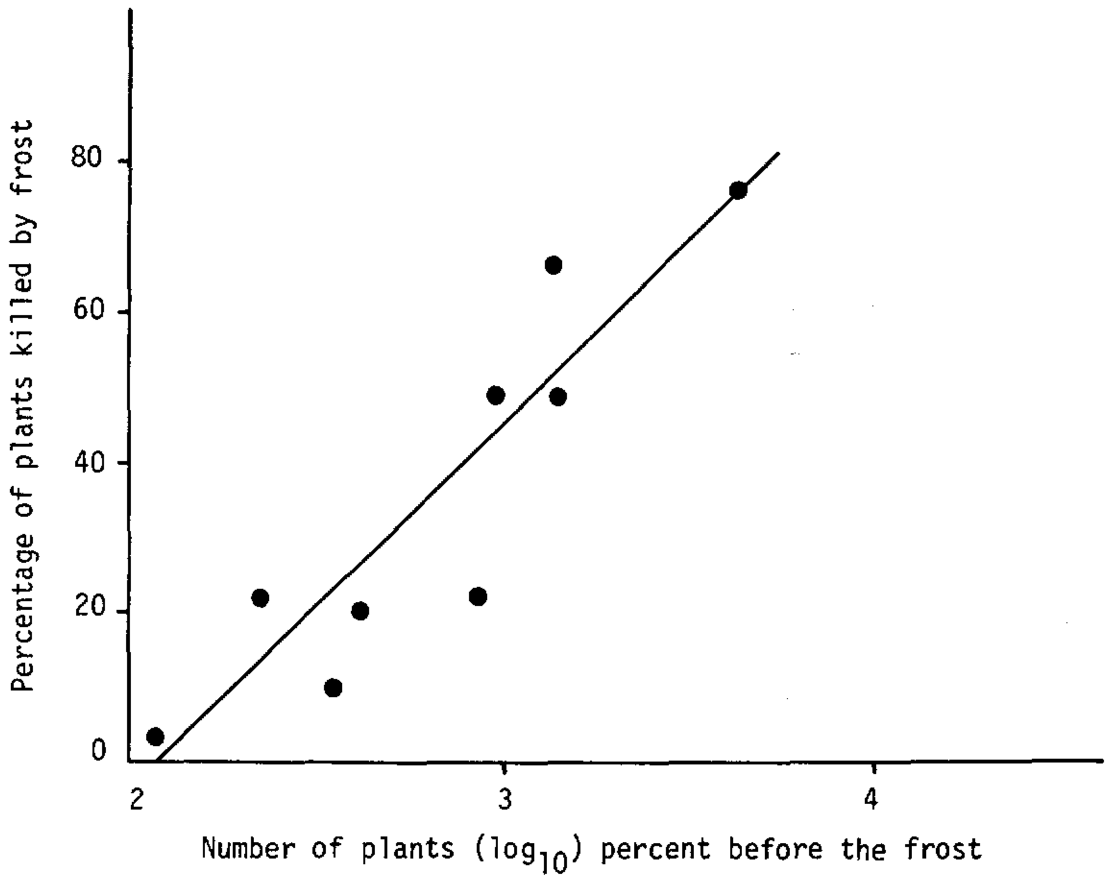


Fig. 9. The relationship between the percentage of *M. polymorpha* plants killed by frosts and the actual plant density before the frosts. The relationship is significant ($P<0.001$) and accounts for 83% of variance in plant death.

percentage of plants killed when density was 500 - 800 plants/m^2 agrees closely with the percentage of plants killed in Experiment 1 (Table 1) where the same cultivar of M. polymorpha was used.

The results of this study can be summarized as follows:

- native medics are more resistant to frost than the Australian cultivars.
- the advanced selections of M. rigidula and M. rotata are very resistant to frost.
- frost resistance in native populations of annual legumes is related to frost frequency in their native habitats
- herbage and seed yield of susceptible species is greatly reduced by frost
- resistance to frost is affected by plant density, and much of the variation in frost resistance with different densities and species is associated with variation in leaf area ratio
- annual legumes were most susceptible to frost in January
- if plant death occurs, the percentage of plants dying is closely related to density. - **P.S. Cocks**

Adaptation of native medics to pasture/cereal rotations

Prior to 1984 the evaluation of *M. rigidula* had been confined (largely) to tested small plots with the further restriction of their being sown and harvested in the same year. Although the species has shown great promise so far, before it can be used by farmers it must be examined under conditions similar to those occurring on farms where, in Syria, we expect it to be used in rotation with cereals and to be grazed by sheep. The next step towards commercial evaluation is therefore to test regeneration in the third year of a pasture/cereal rotation. This has been done in an experiment where the natural regeneration and herbage yield of 25 promising medics was measured in 1984/5, their initial establishment two years ago being followed by wheat last year.

Experiment 4

The treatments comprised 23 entries of *M. rigidula* and one each of *M. rotata* and *M. noeana*. The entries were selected after two y⁻ars measurement of herbage and seed yield from 343 accessions of 14 species in nursery rows, and 124 selections of 9 species in small plots, in 1980/1 and 1981/2 respectively. The selections of *M. rigidula* originated from Turkey (13 selections), Syria (5), Algeria (2), Libya, Jordan and Lebanon; *M. noeana* came from Siirt, Turkey, and *M. rotata* from Kazanli, Turkey (Table 3).

A randomized block design was chosen with six replicates and plot size of 4.8 x 5m. Three replicates were used to measure 1982/3 herbage yields, while the remainder were for seed yields. The experiment was sown on November 27, 1982, at 15 kg/ha, and 18 kg/ha of phosphorus was applied as triple superphosphate. Herbage was harvested to ground level when plants reached the stage of 50% flowering, which varied, among selections, between March 30 and April 19. Seed was harvested in July 1983, when pods were fully mature. Both herbage and seed yields were measured in 1 x 4m quadrats: subsamples of herbage were dried at 85°C for 24 hours and weighed, while mature pods were threshed and the seeds cleaned and weighed.

In the replicates used for seed harvest the un-harvested pods were spread evenly over each plot. Following cultivation to a depth of 10cm, wheat (cv Senator Cappelli) was sown on December 15, 1983 over the whole experimental area 100 kg/ha and fertilized with 18 kg/ha of phosphorus as in the previous year. In February each plot was split: half was sprayed with Brominil Plus at 1 kg/ha to control broad-leaved weeds. Each half was harvested separately and its yield recorded.

In autumn 1984 the medics were allowed to regenerate naturally. In December the number of regenerating seedlings was counted in 0.5 m^2 quadrats placed randomly in each plot. Herbage yield was measured in 1985 on January 1, February 7, March 12, and April 14 by cutting it to ground level in 0.5m^2 quadrats. Subplots (sprayed and unsprayed) were sampled separately. Herbage was weighed after drying at 85°C for 24 hours.

The amount of residual seed (that from previous years) was measured on April 19. Some seed had been buried during the cultivation and sowing of wheat in the previous year while some remained on the surface. The two fractions were harvested separately: that on the surface by removing herbage in $0.5m^2$ quadrats and carefully collecting all pods, that buried by removing five cores with a total surface area of $336cm^2$ to a depth of 10cm. The cores were collected in the quadrats from which the surface pods had previously been removed. Both above and below ground samples were sieved to remove soil, washed in water, and dried. The pods were threshed and cleaned by hand. Viability of both fractions was determined by placing four replicates of 100 scarified seeds of each selection on moist filter paper. Germination was assessed seven days later.

Yield of new seed in 1985 was determined by measuring the total amount on the surface on June 16, and subtracting the amount present on April 19: buried seed was left undisturbed. Quadrats of $0.5m^2$ were harvested, threshed, and cleaned as before. Since there was no response of herbage yield to spraying, final seed yield was measured only on unsprayed half-plots.

Total rainfall was 322mm, 228mm, and369 mm in the 1982/3, 1983/4, and 1984/5 seasons respectively. Rainfall was evenly distributed in 1982/3, in 1983/4 it was exceptionally dry from January onwards, and the wet winter of 1984/5 was followed by a dry spring. There were 52, 25, and 41 days of frost in the three seasons respectively.

Production and survival of seed

Seed yields of M. rigidula in 1982/3 varied from 463 kg/ha (sel. 1893) to 792 kg/ha (sel. 1919) with a mean of 634 kg/ha. The single selections of M. rotata and M. noeana produced 489 and 681 kg/ha respectively (Table 3). In terms of seed number M. rigidula varied from 9900/m^2 to 23100/m^2 (mean 15600/m^2) while there were 21300 seeds/m^2 of M. noeana and 6000 seeds/m^2 of M. rotata. Although seed yield and seed number were correlated ($P<0.001$), the number accounted for only 55% of variation in yield, indicating considerable variation in seed size among the selections.

Of the 634 hg/ha of seed produced by M. rigidula in 1982/3, 458 kg/ha was present in April 1985, or 72% of the original population (Table 3). If the amount harvested in 1982/3 (4m^2 or 17% of the plot area) is taken into account 87% of the original population was still present. Most had been buried by the previous year's cultivation: only 9% of seed remained on the surface. There was precisely double this amount of both M. rotata and M. noeana but since these figures are from single genotypes only, the difference is within the range of experimental error. Residual seed yields of selections 1856 and 1893 are apparently anomalous since both represent considerably more than the original population. Twenty-seven percent (32% taking into account the 1982/3 harvest) of M. noeana, 45% of M. rotata, and from 38% to 187% of M. rigidula seed 'survived'.

Table 3 also shows the weight of germinating seed, calculated from number of plants present in December 1984, and weight of

Table 3. Origin,of the 25 Medicago selections used in Experiment 4,their first year yield of seed (kg/ha), weight of germinating seed in the third year (kg/ha), time to 50% flowering (days), residual seed in the third year (kg/ha), and yield of new seed in the third year (kg/ha).

Selection number (1)	Origin	Flowering time	First year seed	Germinating seed	Residual seed	New seed
716	Jisr Al Shagour, Syria	127	779	45	590	346
1304	Mardin, Turkey	141	547	41	301	102
1531	Bergana, Turkey	141	613	64	350	333
1569	Siirt, Turkey	140	672	60	342	355
1850	Vadda, Libya	131	698	56	513	279
1851	Setif, Algeria	143	475	71	267	83
1852	Saida, Algeria	131	641	38	501	219
1856	Turkey (2)	130	603	25	938	285
1861	Urfa, Turkey	132	648	58	422	133
1865	Hankendi, Turkey	143	603	167	308	112
1868	Elazig, Turkey	142	665	126	484	208
1878	Diar Baker, Turkey	140	473	38	346	99
1881	Jerash, Jordan	123	770	48	765	274
1891	Urfa, Turkey	140	559	32	531	213
1893	Diar Baker, Turkey	140	463	53	635	124
1894	Mardin, Turkey	134	574	61	253	234
1900	Kahranan Marash, Turkey	132	738	106	231	217
1902	Elazig, Turkey	142	721	133	351	243
1913	Aleppo, Syria	133	717	80	404	147
1915	Rago, Syria	133	571	63	427	284
1917	Rago, Syria	131	731	50	449	355
1919	Terbol, Lebanon	126	792	83	570	225
1938	Siirt, Turkey	146	681	68	191	132
1943	Kazanli, Turkey	143	489	57	218	28
1963	Safita, Syria	137	536	53	482	172
Mean		136	630	67	435	208
SE			16.7	8.0	154.9	98.6

(1) All selections except 1938 and 1943 are *M. rigidula*: sel. 1938 is *M. noeana* and sel. 1943 is *M. rotata*.

(2) Exact origin of this selectionis not known.

individual seeds. The results show that from 25 to 167 kg/ha of *M. rigidula* germinated in 1984/5, compared with the 15 kg/ha sown in 1982/3. If the mean weight of germinating seed is added to the mean weight of residual seed a total of 525 kg/ha of *M. rigidula* seed, or 99% of the original population survived through the wheat crop of 1983/4. Survival of the other species was markedly less, 44% of *M. noeana*, and 65% of *M. rotata*. These results are summarized in Fig. 10 which shows the number of seeds present in various phases of the rotation.

The residual seed remained viable, and there were no significant differences in viability: germination was more than 99%, regardless of selection, species, and whether or not the seeds had been buried.

Herbage production

First year (1982/83) herbage yield of *M. rigidula* varied from 1.27 t/ha (sel. 1856) to 4.06 t/ha (sel. 1868) with a mean of 2.65 ± 0.39 t/ha. Yield of *M. noeana* was 3.63 t/ha, ranking third of the 25 selections, and that of *M. rotata* was 1.81 t/ha, ranked 21st.

Herbage yields in the regenerating year were considerably higher than those of the first year: the mean yield of all selections was 4.37 ± 0.254 t/ha on April 14, and the highest was 6.14 t/ha (*M. rigidula* sel. 1963). Early winter yields (January 1,) reached 1.92 t/ha (*M. rigidula* sel. 1865) although the mean was only 0.84 ± 0.352 t/ha. By February 7 selection 1963 had produced 2.97 ±

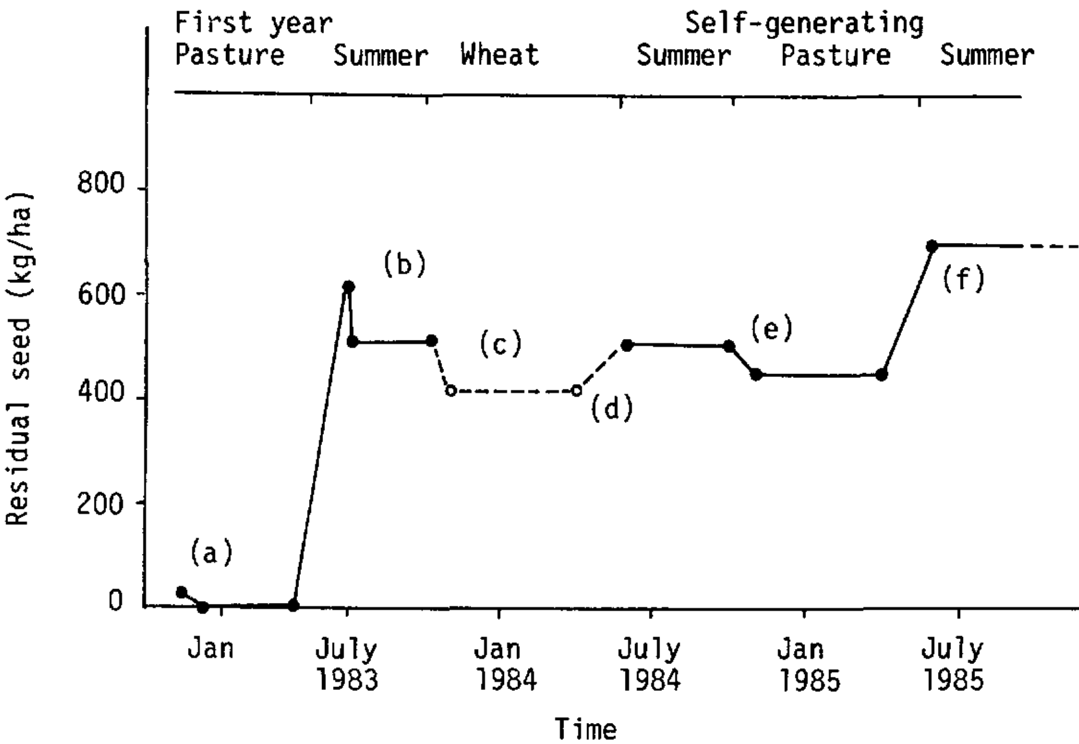


Fig. 10. Changes in seed population over three years in a medic/cereal rotation where M. rigidula was the most important medic. The point (a) is the weight of seed orginally sown, (b) is the yield of seed at the end of the first year (the fall is caused by the sample harvested), the fall at (c) is the amount germinated in the year of crop, the increase at (d) is the amount set under the crop, the fall at (e) is the amount which germinated to form pasture in the third year, and the increase at (f) is the amount of seed set in the third year. The dashed lines and open circles in the second year are estimates based on the level of seed dormancy at point (c).

0.659 t/ha, and its growth was 33 kg/ha/day. Indeed between January 1 and February 7 the average growth rate of all selections was 29 kg/ha/day. In February and early March growth virtually stopped: some selections showed signs of severe frost damage although, with one exception (M. rotata), plants were not killed. Mean growth rate before the final harvest was 69 kg/ha/day, selection 1963 reaching 101 kg/ha/day.

The inter-relationships between regenerating herbage yield (1984/85) and seed size, percentage of impermeable seeds, first year (1982/3) herbage and seed yields, days to flowering, and number of regenerating seedlings are shown in Table 4. The number of regenerating seedlings accounted for 92% of variation in early winter yield but its importance declined such that, while on February 7 it still accounted for nearly 80% of yield variation, by April 14 it accounted for only 20%. Indeed none of the independent variables in Table 4 accounted for more than 24% of variation in final yield.

The relationship between plant number (plant density) and herbage yield is shown in Fig. 11. On January 1 the relationship was linear (Fig. 11a) but by February 7 significant curvilinearity was apparent (Fig. 11b). This remained true on March 7 (Fig. 11c), but the relationship reverted to linearity on April 14 (not shown) though only weakly so ($P<0.05$).

The percentage of impermeable seed was not related to any other variable, not even the amount of residual or germinating seed. First year seed yield was also unrelated to all other variables,

Table 4. Correlation matrix of the 10 variables recorded in experiment 4.

	(1)	(2)	(3)	(4)	(5)	(6)
(1) seed size (mg)						
(2) impermeable seeds (%)	0.30					
(3) plant number 1984/5 (per m²)	-0.47*	0.13				
(4) herbage yield 1982/3 (t/ha)	-0.56**	-0.02	0.70			
(5) seed yield 1982/3 (kg/ha)	0.15	0.10	0.19	-0.07		
(6) days to flowering	-0.43*	0.13	0.39*	0.51**	-0.59**	
(7) herbage yield Jan 1, 1985 (kg/ha)	-0.43*	0.08	0.96***	0.68***	0.28	0.38
(8) herbage yield Feb 7, 1985 (kg/ha)	-0.47*	-0.02	0.89***	0.72***	0.25	0.44*
(9) herbage yield Mar 7, 1985 (kg/ha)	-0.57**	-0.27	0.72***	0.69***	0.09	0.44*
(10) herbage yield April 14,1985 (kg/ha)	-0.49*	-0.27	0.45*	0.45*	0.07	0.24

* $P < 0.05$
** $P < 0.01$
*** $P < 0.001$

Table 5. Statistical parameters for the relationships between pod number and seed yield in M. rigidula, M. rotata, and M. polymorpha

	$100r^2$	a	b
M. rigidula	95***	54	0.2966
M. rotata	99***	-4.6	0.2716
M. polymorpha	99***	-2.0	0.1404

*** $P < 0.001$

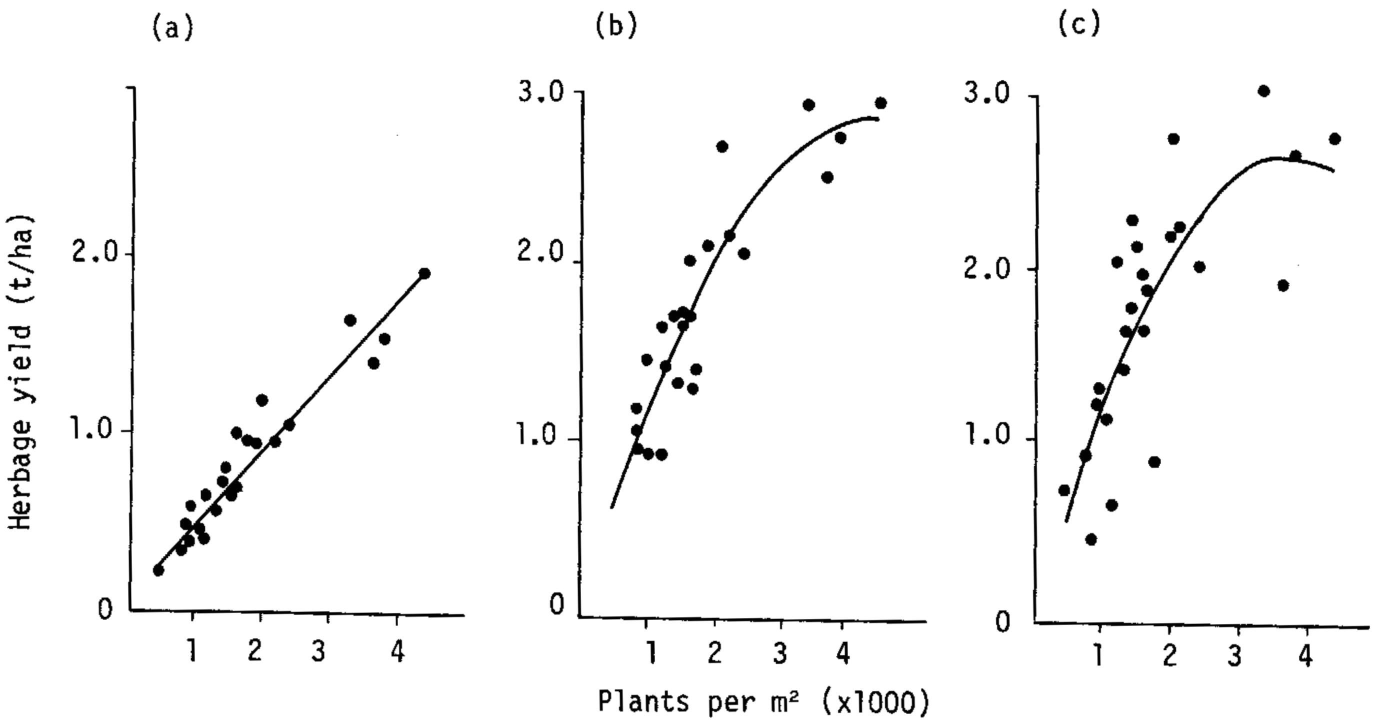


Fig. 11. The relationship between herbage yield of regenerating pastures and actual plant number in (a) early winter (1 January), (b) mid winter (7 February), and (c) early spring (7 March). Points represent 23 selections of _M. rigidula_, one of _M. rotata_, and one of _M. noeana_.

including residual seed. The other variables - seed size, first year herbage yield, regenerating plants number, days to flowering, and regenerating herbage yields - were significantly inter-related (Table 4).

Wheat yields

The average yield of wheat (416 kg/ha) reflected the poor season of 1983/4. There were no significant effects of the previously grown medic selection on yield, but spraying the plots with Brominil Plus increased grain yield from 383 kg/ha to 449 kg/ha (SE ± 20.1, $P<0.01$).

Conclusions

The data clearly show that M. rigidula can regenerate naturally and form productive pastures in rotation with wheat. This experiment, and the selection work which preceded it, have resolved one of the important problems preventing the introduction of ley farming: the need to identify a suitable annual legume adapted both to the soils and climate of north Syria and to the ley farming system itself.

As a result of this work several selections of M. rigidula are now being included in grazing experiments and on-farm trials. On the basis of number of regenerating seedlings, selections 1965, 1902, 1868, and 1900 will advance in this way, while selections 716 and 1919 are being further tested because of their high seed yields. Seed multiplication of these selections has commenced.

Of course many other questions remain, including 'what is the response of M. rigidula to grazing'? Management systems will need to be developed which maximise livestock production while maintaining an adequate seed population. Social and economic problems will need to be carefully defined before ley farming can be successfully introduced. These problems are discussed in the following sections. - **P.S. Cocks**

Seed production and survival in pastures

Annual pastures depend upon effective production and survival of large quantities of seeds, and it is important to improve our understanding of these processes. In addition to its influence on persistence from year to year, a high density of seed also results in a high yield of herbage (Fig. 11). A reserve of seed is also needed to guard against seed losses through germination in the cropping phase and in poor seasons. Furthermore large quantities of seed are eaten by livestock and are a nutritious component of their diet. For these reasons experiments were designed to study factors affecting seed production and survival in the presence and absence of grazing animals.

Ungrazed pastures

Experiment 3

This experiment was described in detail earlier. Three medic species (M. rigidula sel. 1919, M. rotata sel. 2123, and M. polymorpha cv. Circle Valley) were sown at 11 rates (1 to 500 kg/ha) on two dates (31 October and 6 December). There were two replicates. The number of flowers and immature pods was counted in subsamples taken when measuring herbage yield on 27 March, 10 April, and 24 April. Seed yield was measured later in the season by harvesting 2m x 1m quadrats: the dried herbage and attached seed was removed first and the remaining seed carefully swept from the surface of the soil. After sieving to remove soil the sample was threshed by machine, winnowed, and finally cleaned by hand. A random sample of 100 intact pods was retained and weighed, threshed by hand, and the number and weight of seeds were recorded. The following components of seed yield were thus obtained: seed yield, pod number per m^2, pod weight, individual seed weight, and number of seeds per pod.

Seed yield

The seed yield of all species depended on sowing density (Fig. 12). Yields of M. rotata and M. rigidula were not significantly different reaching, for the earlier sowing date, over 1 t/ha at densities of 40 - 50 kg/ha: yield at higher densities was much less falling to below 0.5 t/ha at a density of 500 kg/ha. M. polymorpha

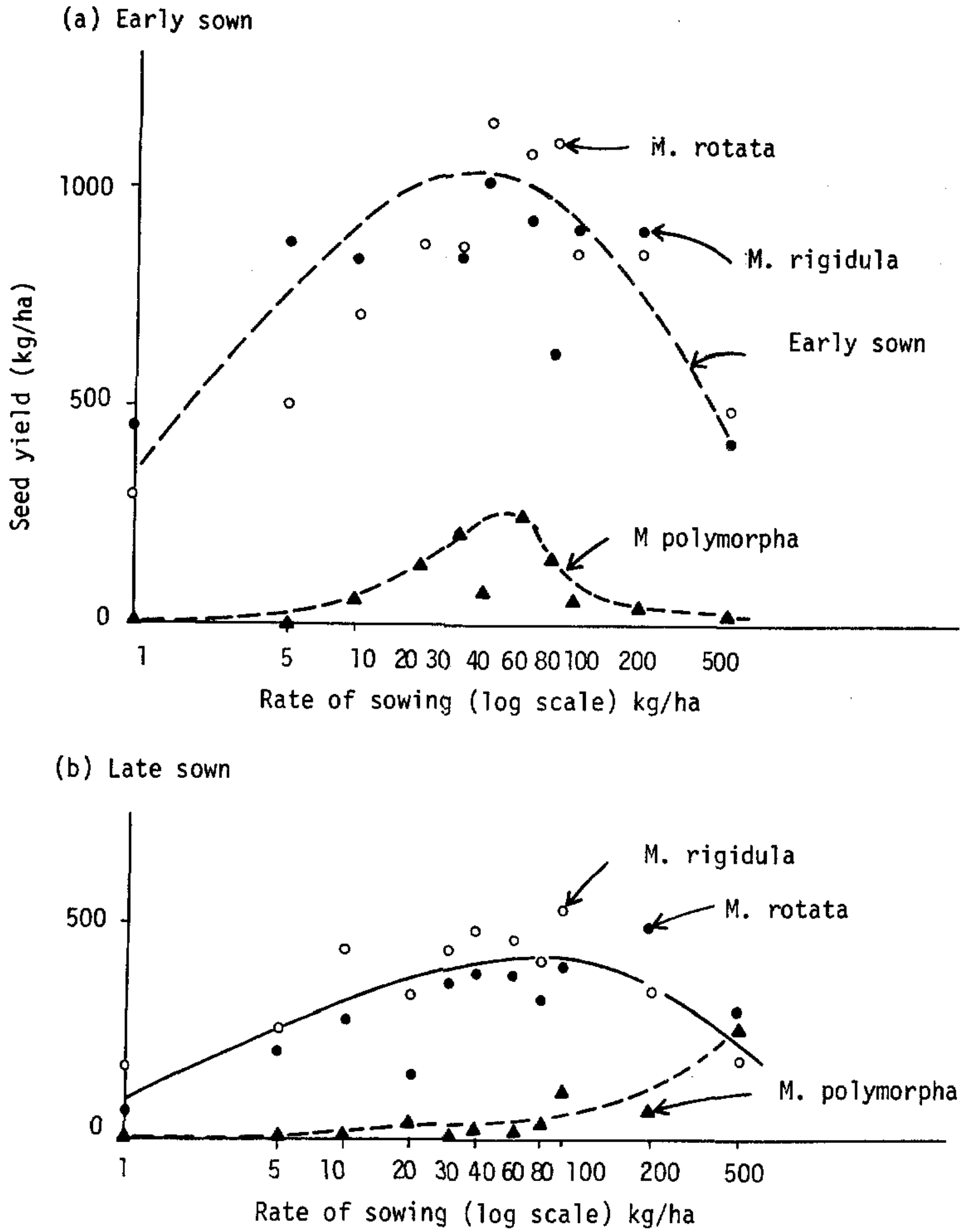


Fig. 12. The influence of rate of sowing on seed yield of M. rigidula (closed circles), M. rotata (open circles), and M. polymorpha (triangles) sown early (31 October) and late (6 December).

yielded much less at all densities probably reflecting the impact of frost.

Seed yield was much lower following the later sowing date, for which the highest yield was obtained at the higher densities: that is, at sowing rates of about 80 kg/ha for M. rigidula and M. rotata, and 500 kg/ha for M. polymorpha. Again there were no significant differences between seed yields of M. rotata and M. rigidula. The highest yield for these two species was less than half of that for the earlier sowing date.

Components of seed yield

Of the three components of seed yield - number of pods per m^2, seed size, and seeds per pod - number of pods per m^2 accounted for almost all of the variance caused by sowing density and date. In M. rotata and M. polymorpha, 99% of the variance was accounted for by pod number, while for M. rigidula 95% was accounted in this way. This is illustrated in Fig. 13, the actual points for M. polymorpha not being shown in the interest of clarity, while the statistical parameters of all three relationships are shown in Table 5.

Given that pod numbers dictate seed yield it is of great interest to monitor the fate of flowers in the early sown treatment (the effect was similar in the late sown treatment which therefore is not reported). The highest number of living flowers of M. rotata and M. rigidula were recorded on 10 April when 39000 flowers per m^2 of the former and 57000 of the latter were present (the average of all

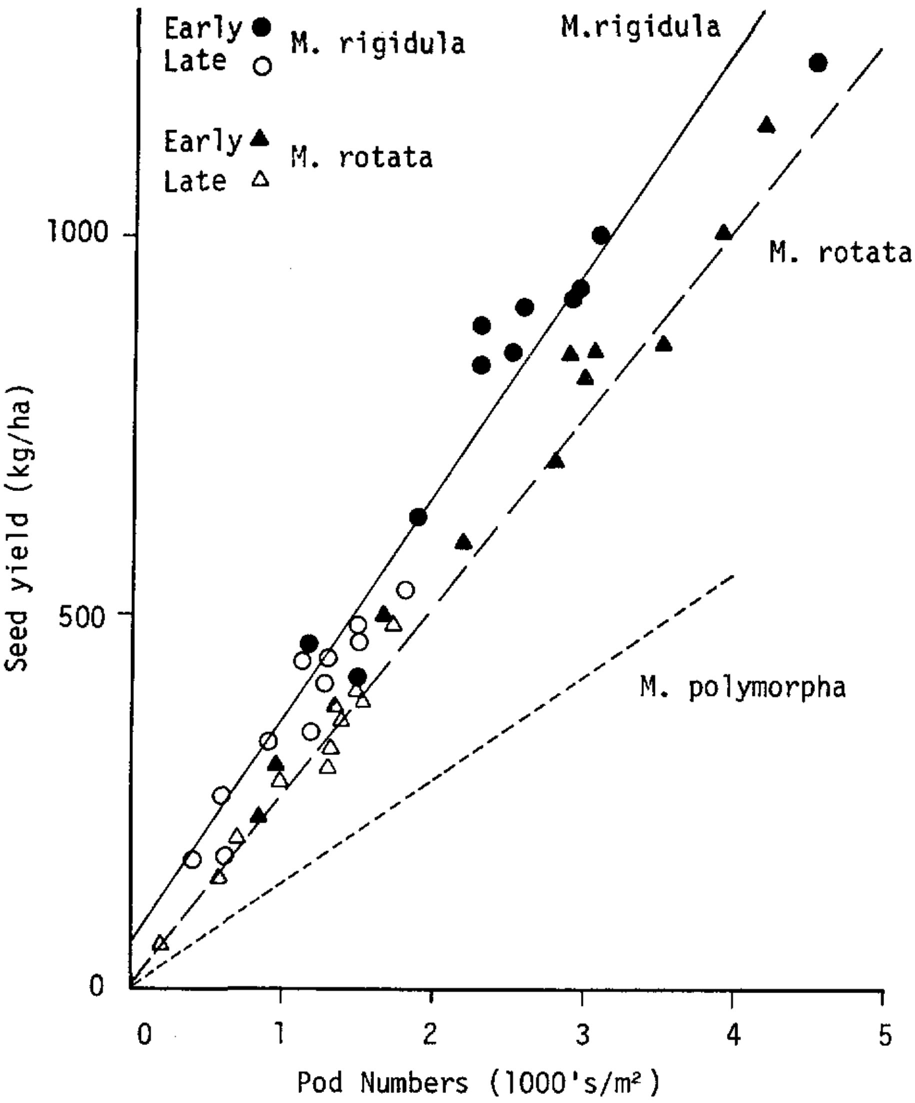


Fig. 13. The relationship between seed yield and pod numbers in early and late sown swards of M. rigidula, M. rotata, and M. polymorpha (in the intrests of clarity individual points are not shown for M. polymorpha). The fitted regression lines account for 95%, 99%, and 99% of variance in seed yield of the three species respectively (all significant at $P<0.001$).

sowing densities). These figures compare with final pod numbers of 2600 for M. rotata (or 6.8% of those present on 10 April) and 2500 for M. rigidula (or 4.4% of these present earlier). The highest number of M. polymorpha flowers was recorded on 24 April (3500), and 670 pods were present at harvest (19% of the earlier numbers). It should be noted that M. rigidula flowered first, and that the low density treatments flowered for the longest period. Of the three species the number of living flowers of M. rigidula fell most rapidly, the number present on 28 April representing only 16% of those present on 10 April, while the number of M. rotata flowers was still 52% of those present at the earlier date. Because a higher proportion of flower loss in M. rotata occurred after 24 April the effect of density is best illustrated in that species.

The effect of actual plant density on flower production and pod survival is shown in Fig. 14, where the number of flowers and pods present on 24 April and the percentage surviving until pod harvest are plotted against plant numbers. ('survival' is a valid concept because very few new flowers were produced after this date). Clearly flower production was higher at low plant densities and the number of flowers per plant was greatest at the lowest density (1035 flowers/plant at a sowing rate of 1 kg/ha). However survival of flowers was greatest at highest plant density reaching nearly 45% (of flowers present on 24 April) at the highest density. These two components of pod number - flower production and percentage survival - account for the shape of the relationships in Fig. 12: that is though survival is high at high plant density production is low and vice versa resulting in the highest seed yield at intermediate densities.

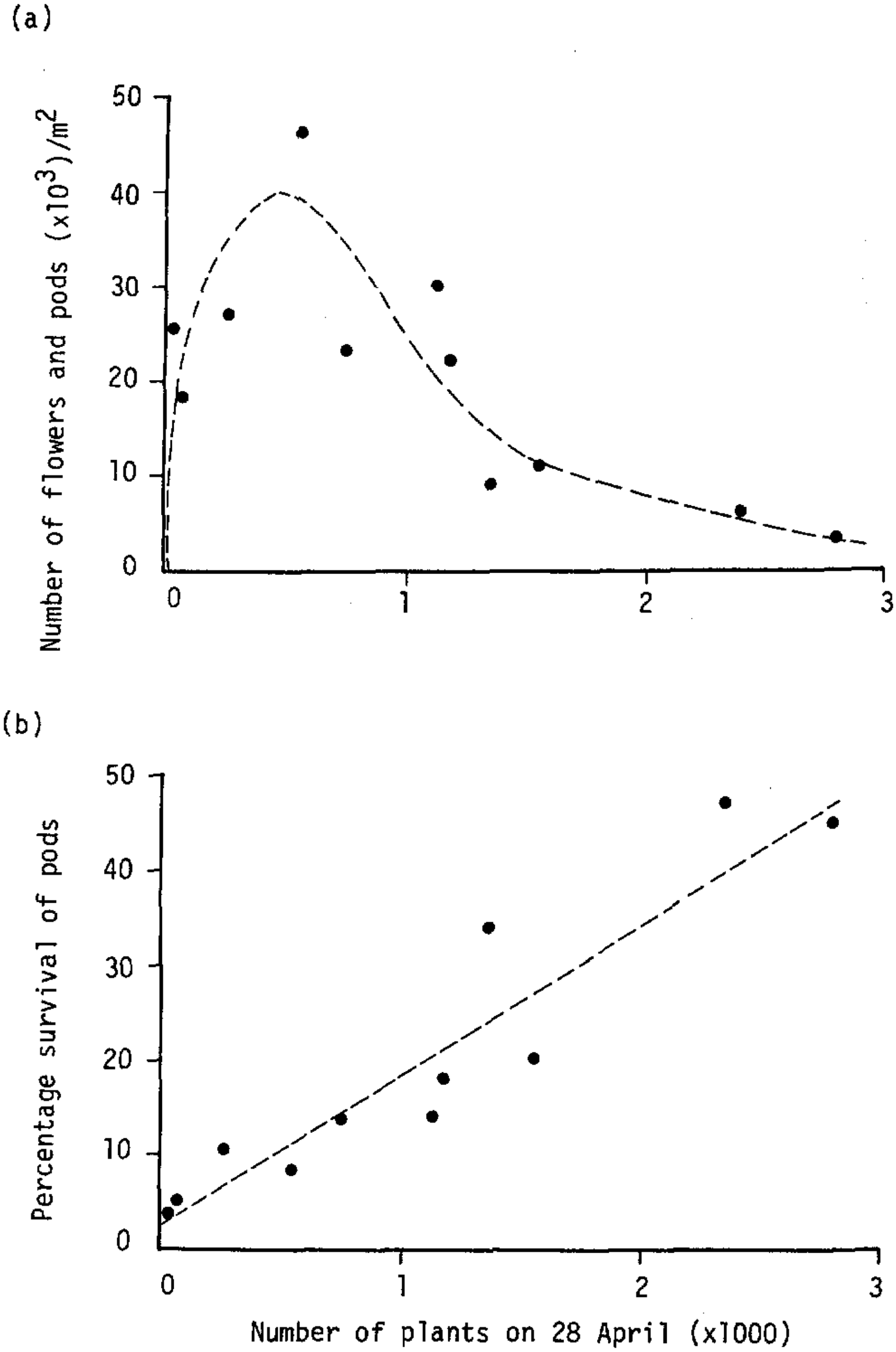


Fig. 14. The relationship of (a) number of flowers and pods present on 28 April, and (b) the percentage of those present surviving until maturity, to the numbers of plants present on 28 April. The curve in (a) was fitted by hand, and the straight line in (b) was fitted by linear regression ($P<0.001$).

The relationships for M. rigidula and M. polymorpha were less clear, probably because of the earlier flowering of the former, and the effect of frost on the latter.

Early sowing resulted in slightly smaller seeds than late sowing and slightly more seeds per pod, the two effects producing the same seed yield (Table 6). Note that M. rotata had slightly larger seeds than M. rigidula, and M. polymorpha had the smallest seeds. Seed size and number per pod of M. rotata and M. polymorpha were not affected by sowing density, but density had a strong negative effect on seed size of M. rigidula, especially at late sowing (Fig. 15): both relationships were significant, that at late sowing accounting for 92% of variation in seed size ($P<0.001$), and that at early sowing for 57% ($P<0.01$). - **P.S. Cocks**

Grazed pastures

Experiment 1

The design of this experiment was outlined earlier (in the frost section): it is described more fully below.

There were three rates of stocking, low (5.3 sheep/ha), medium (10.7 sheep/ha) and high (16 sheep/ha). Flock size was common to all treatments (12 ewes), stocking rate being determined by plot size. There were two stocking rate replicates.

Table 6. Seed size (mg) and number of seeds per pod of *M. rigidula*, *M. rotata*, and *M. polymorpha* sown early (31 October) and late (6 December).

	Seed size		Seeds per pod	
	Early	Late	Early	Late
M. rigidula	5.03 ± 0.51	5.64 ± 0.84	6.7 ± 0.35	6.0 ± 0.32
M. rotata	6.11 ± 0.52	6.29 ± 0.44	4.4 ± 0.26	4.2 ± 0.40
M. polymorpha	3.02 ± 0.16	3.39 ± 0.25	4.3 ± 0.41	3.7 ± 0.50

Table 7. Seed yield of four medic species after grazing during spring at three rates of stocking (5.3, 10.7, and 16 sheep/ha).

	Low	Medium	High	Mean
M. polymorpha	119	103	27	83
M. rigidula sel. 716	596	480	225	444
M. rigidula sel. 1919	601	457	319	459
M. rotata sel. 2123	572	356	378	435
Mean	472	349	245	355

Least significant difference ($P < 0.05$) between stocking rates = 144, between species = 166.

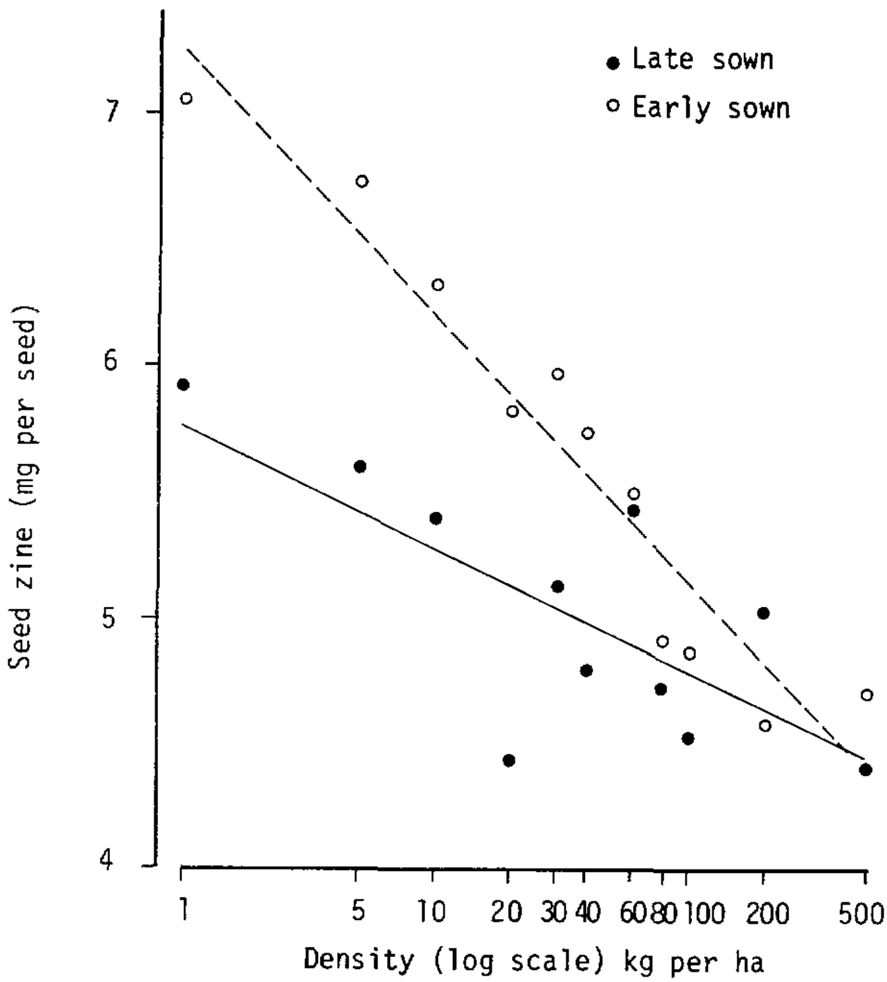


Fig. 15. The relationship between size and sowing rate of early (closed circles) and late (open circles) sown M. rigidula. Both straight lines were fitted by linear regression, that sown early significant at $P<0.01$, and that sown late at $P<0.001$.

Within each main plot the following 7 medic accessions were sown as subplots:

M. polymorpha cv. Circle Valley (small, smooth pods)
M. rigidula sel. 716 (the most promising ICARDA selection)
M. rigidula sel. 1919 (high seed yield)
M. truncatula cv. Jemalong (the Australian cultivar usually recommended for the region)
M. truncatula cv. Cyprus (very early flowering)
M. rotata sel. 2123 (likely to be selected for basaltic soils in the region)
M. scutellata cv. Robinson (upright growth, smooth pods)

Each subplot for a species was 15 x 14m, the total area of subplots (including replicates) being less than 12% of the main plot area. Each medic treatment was replicated twice within each main plot.

Subplots were sown on 3 December at 100 kg/ha to give rapid early growth. A fine seed bed was prepared, seeds were broadcast on the surface, and covered by hand raking. All seed was inoculated with *Rhizobium* strain WSM244, except *M. scutellata* which is known to be nodulated better by strain CC169.

The remaining area of the main plots was sown at 30 kg/ha with a mixture of medics as follows: *M. rigidula* sels. 716, and 1919, *M. rotata* sel. 2123, *M. polymorpha* cv. Circle Valley, and *M. truncatula* cv. Jemalong. The main plots were sown by hand broadcasting, the seed being covered by spike harrows, and rolled. The whole area, main plots and subplots, received triple superphosphate at a rate of 16 kg P_2O_5/ha, and weeds in subplots were controlled chemically (grassy weeds) or by hand (broad-leaved weeds).

Because of reduced plant growth following frosts the introduction of livestock was deferred until 30 March, when 5 sheep and their lambs were admitted to each plot. A further 3 ewes entered the experiment on 9 April and 4 ewes on 23 April to give the final stocking rates. The ewes remained in the experiment until August 21 (high stocking rate), September 9 (medium stocking rate), and September 16 (low stocking rate).

From 30 March until the end of the growing season (14 May) the quantity of pasture available was measured at intervals of no longer than 14 days, and usually 7 days. In the main plots 10 'open' quadrats of size 0.5 x 0.5m were used, while in the subplots there were two similar quadrats. Herbage yield was also measured for protected quadrats ('closed'), enclosed by metal cages to estimate growth and flower production in the absence of sheep. The cages were relocated after each harvest. The number of flowers and pods were counted, and total yield of herbage was measured after drying at 85^{o}C. M. truncatula cvs. Cyprus and Jemalong, and M. scutellata cv. Robinson were excluded from the experiment because of frost. Seed yield was measured on 9 June, in cages protected from 14 May.

The yield of 'residual' seed (seed lying on the ground) was measured at two week intervals beginning on 9 June and ending when the sheep were removed from the plots. At each harvest, dead herbage was also measured. These measurements were all taken in open quadrats and were limited to the main plots.

Data on herbage yields are not presented in this Report.

Flower and seed production

Seed production is shown in Table 7. M. polymorpha produced less seed than the other species (probably because of frost) and all other differences between species were not significant. All species produced less seed at high stocking rate compared with low stocking rate. There was no significant stocking rate x species interaction. The average yield of 355 kg/ha was disappointing, and probably reflects the effect of frost and the dry spring.

The number of flowers and pods are shown in Fig. 16. The Fig. shows only the effect of stocking rate: differences between species were not significant (except for M. polymorpha) although both accessions of M. rigidula commenced flowering before M. rotata. The effect of stocking rate was less than expected and even on 23 April differences were no more than 30%. However the number of flowers on that date was sufficient to produce 2.3 t seed/ha, (assuming average seed weight and number of seeds per pod), nearly 500% more than was eventually obtained. The results therefore agree with those of Experiment 3 where, even in the absence of grazing, seed yield was well below potential.

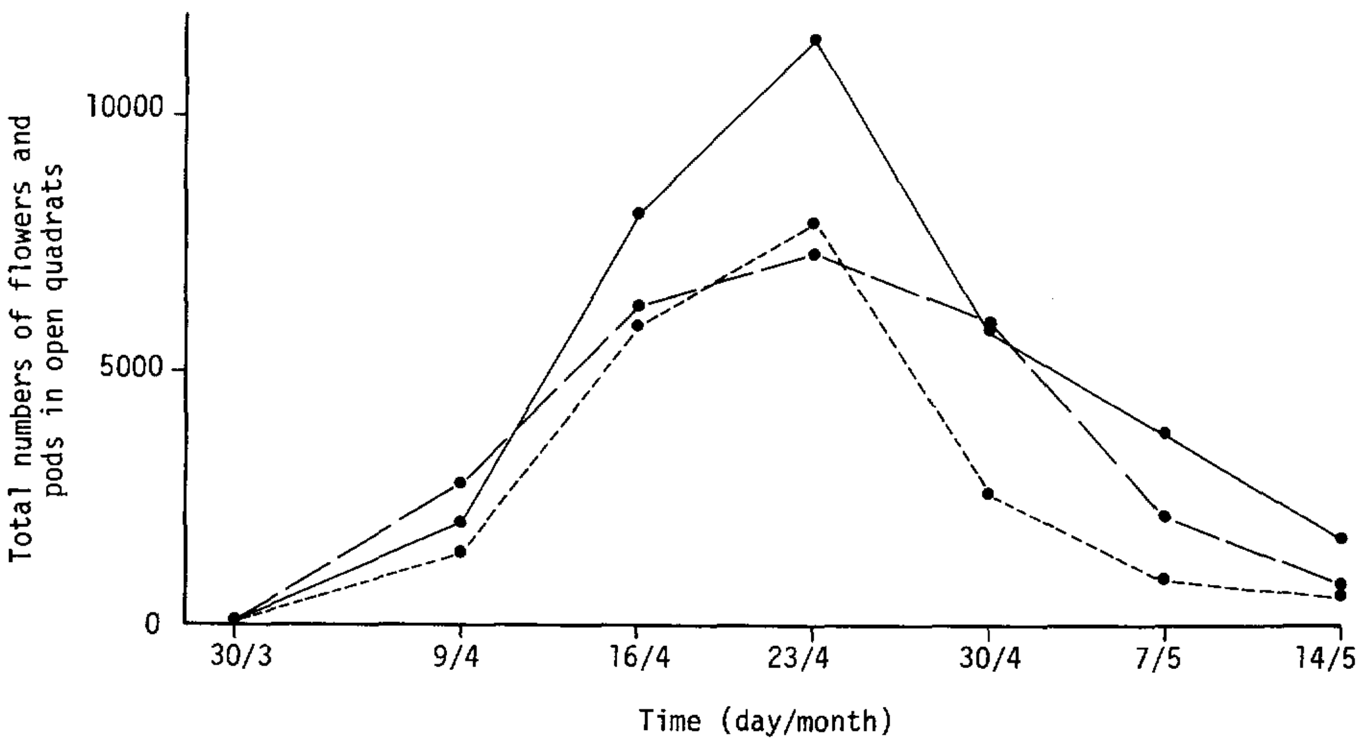


Fig. 16. Changes in the combined number of flowers and pods with time at three stocking rates: 5.3 ewes/ha (solid line), 10.7 ewes/ha (broken line) and 16.0 ewes/ha (dotted line). The number of flrowers and pods were counted in pasture exposed to grazing.

In this experiment the effect of grazing can be separated from other sources of flower loss. This has been done in Fig. 17 where changes in pod numbers not attributed to grazing were calculated from differences in protected quadrats between harvests, while those due to grazing were calculated by differences between closed and open quadrats at each harvest. The Figure shows that maximum flower number occured on 16 April, which was also the time at which the animals consumed the greatest number of flowers.

Seed eaten by sheep

Fig. 18 illustrates the effect of two of the stocking rates on sheep liveweight. The slight fall during May was due to an outbreak of foot and mouth disease which was quickly controlled. Note that at the low stocking rate the sheep increased weight throughout the summer and were still doing so when they were removed from the plots on September 16. At the high stocking rate liveweight fell from July 9. From the end of May the sheep lived on plant debris and seed pods.

Liveweight changes were closely reflected in the amount of seed. The latter is illustrated in Fig. 19. At the low stocking rate seed weight fell at a constant rate throughout the period of grazing, and 34 kg/ha remained when the sheep were removed. At the highest stocking rate residual seed fell more rapidly until only 10 kg/ha remained: thereafter, while amount of seed continued to fall slowly, the sheep obviously found it difficult to find and eat the remaining seeds. Note that the day on which amount of residual seed fell to 10

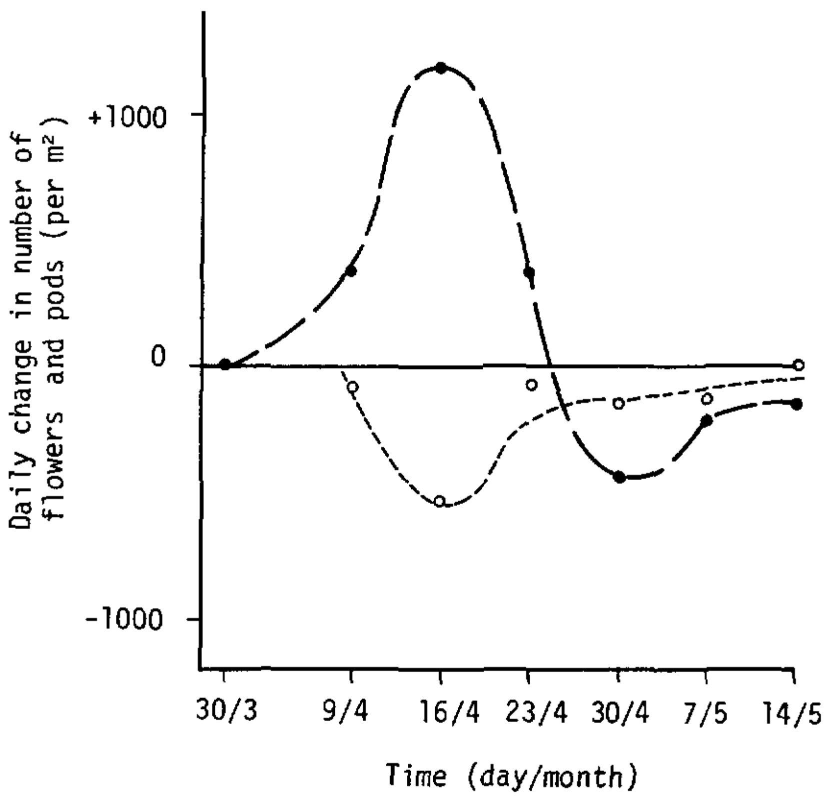


Fig. 17. The daily changes in number of flowers and pods in closed (closed circle, solid line) and open (open circles, broken line) quadrats. The change in closed quadrats represents the net effect of flower production and flower loss, while that in open quadrats includes the effect of grazing.

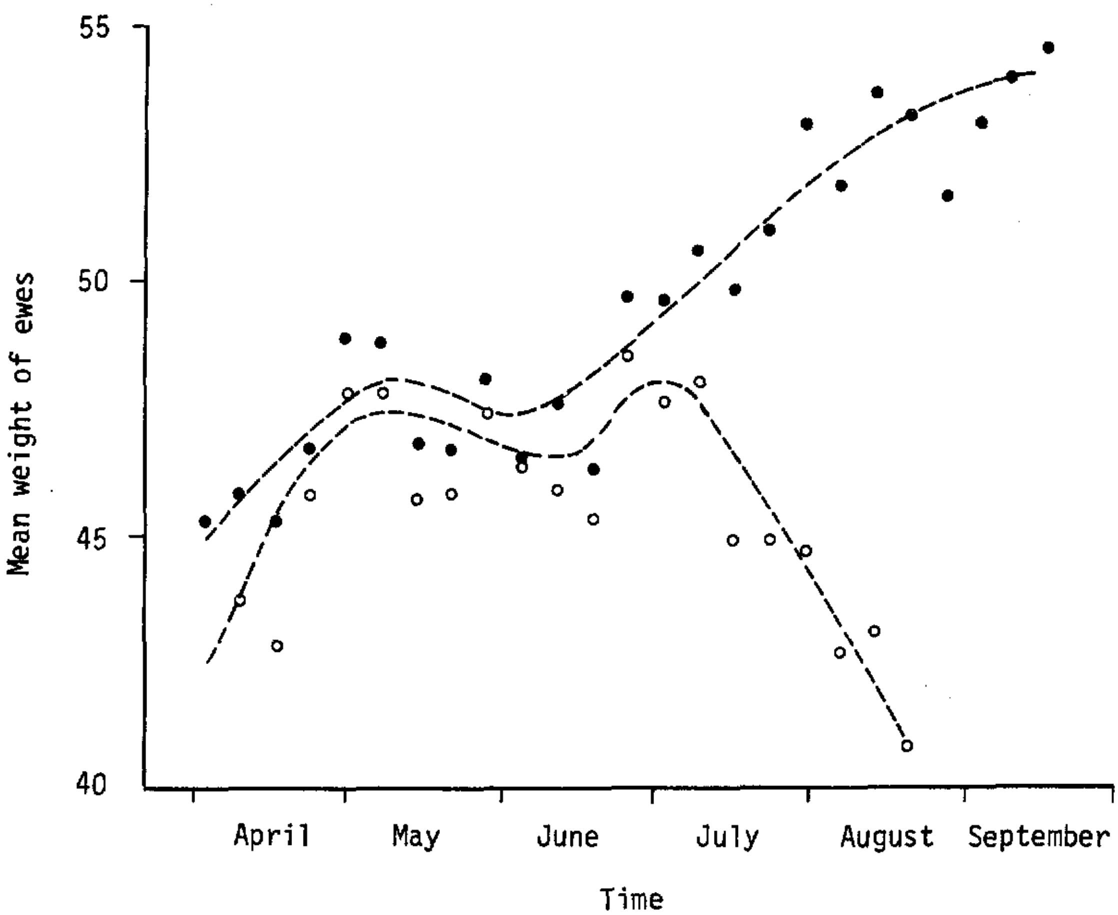


Fig. 18. The change in weight of ewes grazing medic pastures and residues from April until September. The closed circles represent ewes grazing at 5.3/ha, and the open circles ewes grazing at 16/ha.

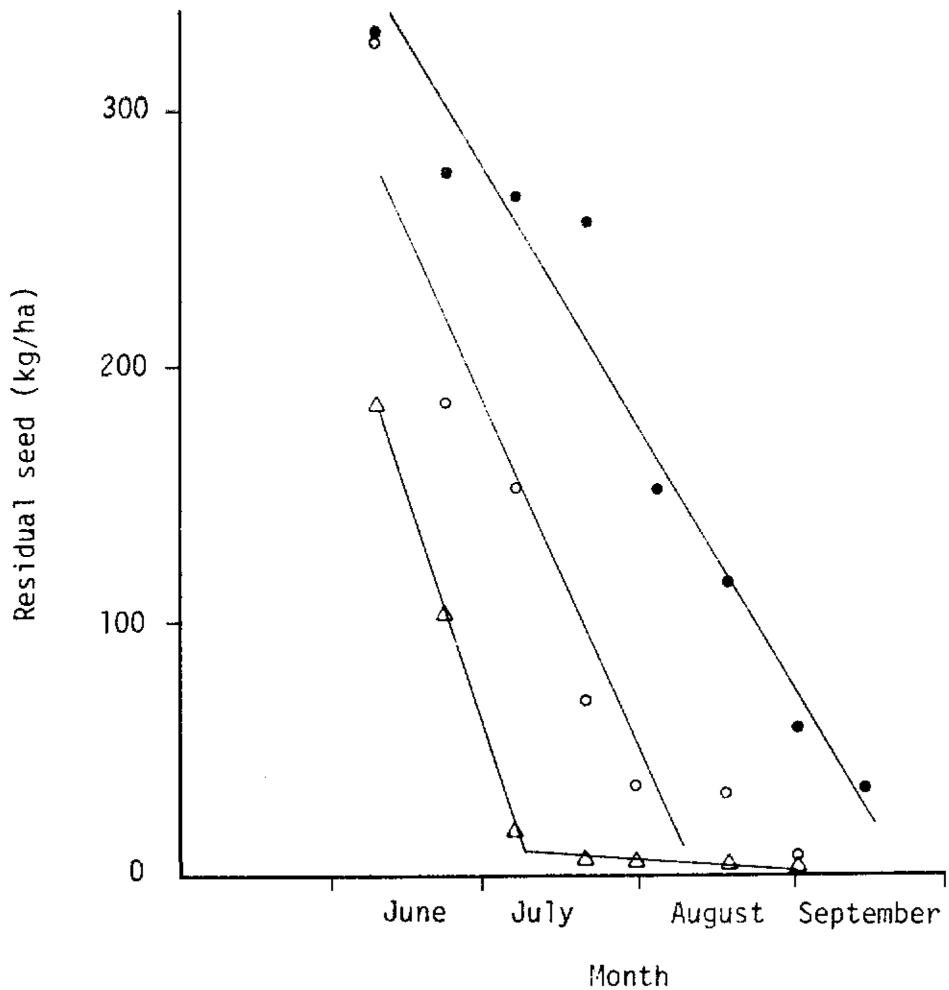


Fig. 19. The change in amount of seed present in grazed medic pastures during summer. The pastures were grazed at 5.3 ewes/ha (closed circles), 10.7 ewes/ha (open circles), and 16.0 ewes/ha (triangles). The straight lines were fitted by linear regression ($P<0.001$ in all cases), but at high stocking rate only data until 9 July was used in the calculations.

kg/ha (July 9) was the same day on which liveweight started falling. Over the three stocking rates, and as long as seed remained above 10 kg/ha, the sheep consumed it at a rate of 450 g/head/day. There was a tendency for sheep to choose the large pods of M. rigidula in preference to the small pods of M. polymorpha. For example at the medium stocking rate only 3% of the pods were M. polymorpha on 9 June, but by 1 September M. polymorpha comprised nearly 40% of the total number of pods: in the same period M. rigidula sel. 716 fell from 61% to 37%. However as the pod supply dwindled the effect was reversed. There appeared to be no selection for large pods within species, mean pod size of each species remaining constant throughout the summer.

Naturally the sheep also consumed plant debris and the rate at which this disappeared is shown in Fig. 20. Again there was a linear relationship between amount of herbage and time, but the rate of disappearance was less closely related to stocking rate. It is worth noting also that the linear decline at high stocking rate extended well beyond the day on which liveweight began to fall.

The results of Experiments 1 and 3 can be summarized as follows:

- Seed yield is strongly dependent on plant density and falls at high densities.

- Variation in seed yield can be accounted for by variation in pod number.

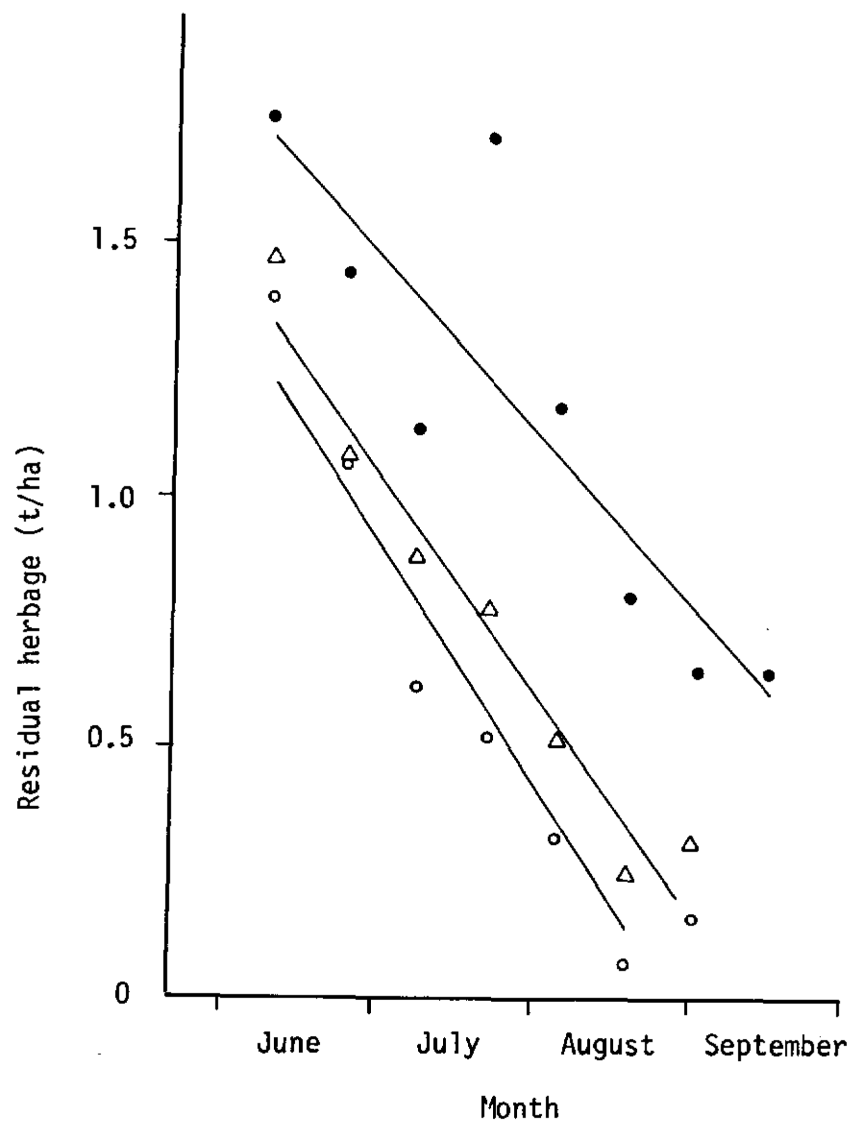


Fig. 20. The change in amount of residual herbage in grazed medic pastures during summer. The pastures were grazed at 5.3 ewes/ha, (closed circles), 10.7 ewes/ha (open circles), and 16.0 ewes/ha (triangles). The straight lines were fitted by linear regression ($P<0.001$ in all cases).

- *M. rigidula* seeds are larger when produced at low plant density and as a result of late sowing. Seed sizes of *M. rotata* and *M. polymorpha* are apparently independent of these factors.

- There is a very large loss of potential seed yield due to natural flower loss. In *M. rotata* flower loss is least at high plant density, but this does not compensate for the low number of flowers produced.

- Flower loss in grazed pasture is due both to grazing and to other causes. The results suggest that at the stocking rates used grazing is of less importance.

- There was a tendency for sheep to choose the large pods of *M. rigidula* in preference to the small pods of *M. polymorpha*. - **P.S. Cocks**

Development of a methodology for selecting new pasture cultivars

Cultivars for annual pastures must posses attributes which ensure efficient reproduction and seed survival while at the same time are so well adapted to soils and climate that they have a good agronomic performance. They contrast sharply with other crops in which farmers control the reproduction and establishment phases: seed storage, time and method of sowing, seed bed preparation, banded fertilizer application, and so on. For pasture cultivars selection with emphasis solely on herbage yield, or even seed yield, may be a poor indicator of adaptation to the conditions which they will inevitably have to face. By contrast, in crops where seed is economically the most important component, high seed yield is the logical indicator of adaptation.

Until recently ICARDA has selected its pasture cultivars mainly on the basis of herbage and seed yield. In evaluation of this kind, M. truncatula and other commercial species failed, and M. rigidula was selected as most successful, although it is not used commercially. Future selection must take into account variation in the soils and climate of farms in the region, and in the farming systems in which annual pastures will be used. To meet these requirements a new methodology is being developed in which the ecology of agriculturally promising species is being studied in their native habitats, and in which natural selection among adapted species will be allowed to occur in the farming systems which will use them. In this way we will rapidly screen species as suitable for difficult environments and select from them accessions (or breeding lines) adapted to pasture farming systems. - **P.S. Cocks**

Ecogeographic survey of indigenous annual legumes

Experiment 2

The objectives of this experiment were firstly to sample genetic diversity of natural populations with a view to conservation, and secondly to relate distribution of species and genes to soils and climates. Details of the experiment are given in the section on frosts (page 13).

Ninety five sites were sampled: the populations, in terms of species and weight of legumes, are illustrated in Table 8 and Fig. 21. The size of the seed populations varied from less than 1 kg/ha to 24 kg/ha with an average over all sites of 6 kg/ha. 1229 accessions representing 79 species in 19 genera were collected, the most frequent being Trifolium and Medicago. It is interesting to note that subterranean clover (T. subterraneum), a species of great world-wide importance but not usually associated with Syria, was collected at 12 sites.

It is important to consider the implication of the results on the necessity to store genetic resources. It is often argued that many potentially important species, including the medics and clovers, are in danger of genetic erosion. The survey suggests that, far from being in danger, many of the species are widespread and present in large numbers. The point is important because it affects the kind of plant collecting which should take place: there

Table 8. Genera, and the number of species and accessions within each genus, collected at 95 sites in western Syria (summer of 1984).

Genus	No. of species	Number of accessions
Astragalus	2	26
Biserrula	1	5
Coronilla	2	15
Hippocrepis	1	16
Hymenocarpus	1	50
Lathyrus	2	20
Lens	1	2
Lotus	2	9
Lupinus	1	3
Medicago	22	365
Onobrychis	4	49
Ornithopus	1	6
Physanthylus	1	8
Pisum	1	2
Scorpiurus	2	29
Securigera	1	7
Trifolium	26	528
Trigonella	6	50
Vicia	2	39
Totals	79	1229

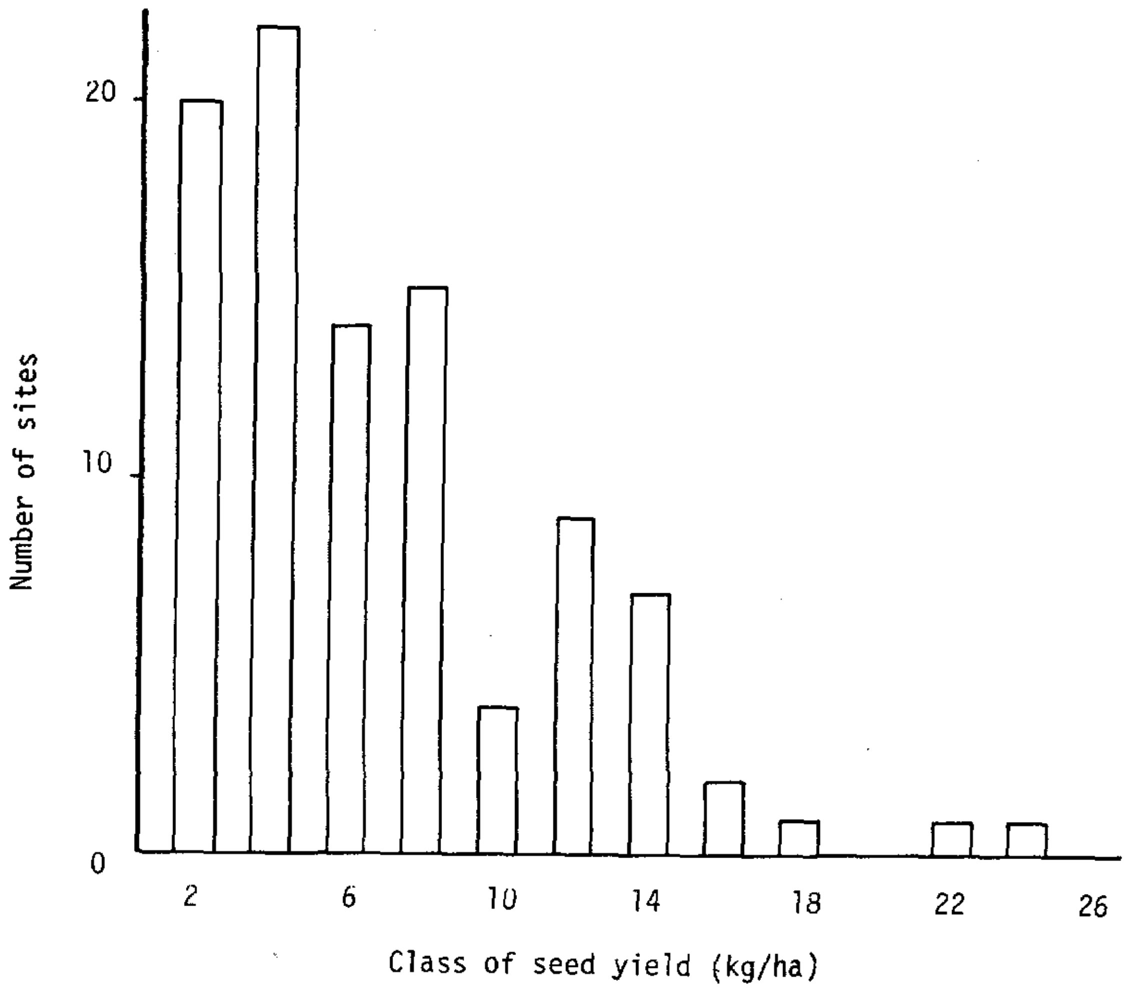


Fig. 21. Distribution of seed yields at 95 rangeland sites in Western Syria. The average population of seeds was 6 kg per ha (120 seeds per m^2).

does not seem to be a need simply to collect for conservation alone, and collectors should therefore set objectives associated more closely with the development of adapted cultivars.

Relationship of distribution of species to soils and climate

The detailed soil and climatic data collected from western Syria were related to species distribution using modal block classification, a clustering method first used in numerical taxonomy (Hartigan 1976*). The classification comprises a non-exclusive clustering technique in which 'cases' (i.e. genotypes, species or, in this survey, sites) are clustered in blocks so that each variable in each block is constant. This value is the 'modal value' for that block.

The aim of the technique is to select subsets of the variables which best define subsets of the total data. The data set is then arranged so that both cases and variables are as nearly contiguous as possible, and reveal clusters defined by inter-related variables. The method only operates on 'coarse data' (binary as opposed to continuous data), and is therefore best suited to large-scale as opposed to detailed ecological investigation. In addition to its value in defining groups the classification is also of use in

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* Hartigan, J.A. (1976). Systematic Zoology, 25, 149. Dixon, L.J. (1985) ed. BMDP Statistical Software, Univ. of California, Berkeley, USA.

investigating those variables which contribute most highly in differentiating between previously defined groups (e.g. plant species). Details of the algorithms employed are in Dixon (1985).

The following climatic data were used in the analysis: number of days with minimum temperature less than 5^{o}C, number of days with maximum temperature over 35^{o}C, relative humidity in winter, and total rainfall. All data were obtained from the Climatic Atlas of Syria, published by the Ministry of Defense in Damascus. Soil data used were percentage of silt and clay, total nitrogen (Kjeldahl extraction), available phosphorus (Olsen method), calcium carbonate ($CaCO_3$), and pH. As a result of the classification the 95 sites were reduced to six soil groups and six climatic groups, which together defined a 2-way table of 36 climate/soil cells, 28 of which were occupied by at least one site.

Descriptions of the six climatic groups, and an indication of their distribution are as follows:

(1) coastal plain - high rainfall (>800 mm per year), and mild winters (<15 days under 5^{o}C).

(2) Foothills of the Jebel Al-Ansariye and Amanus ranges - high rainfall (>800 mm per year), cool winters (between 20 and 90 days under 5^{o}C), and mild summers (<35 days over 35^{o}C).

(3) plateaux west of Aleppo, Hama, and Homs, and the valley of the Orontes River - moderate rainfall (>300 mm per year), and cool winters (between 50 and 100 days under 5^{o}C).

(4) the dry part of the cereal zone - low rainfall (between 200 and 300 mm per year), cool winters (between 65 and 90 days under $5^{o}C$) and hot summers (>50 days over $35^{o}C$).

(5) the Anti-Lebanon ranges - low rainfall (<300 mm per year), cold winters (>100 days under $5^{o}C$), and cool summers (<30 days over $35^{o}C$).

(6) sub-alpine zone - moderate to high rainfall (>600 mm per year), cold winters (>100 days under $5^{o}C$) and cool summers (<10 days with temperatures more than $35^{o}C$).

The six soil groups were not closely related to the six climatic groups nor is it possible to describe their geographical distribution in simple terms. All groups had variable levels of phosphorus and are described as follows:

(1) sandy, coarse - textured soils with moderate to high levels of $CaCO_3$ (10 - 70%), and alkaline reaction (pH>7.4). Nitrogen levels were variable.

(2) moderate to fine - textured, silty soils with moderate to high levels of $CaCO_3$ (10 - 70%), and alkaline reaction (pH>7.4). Nitrogen levels were variable.

(3) moderate to fine - textured, red soils overlying lime with low levels of $CaCO_3$ (<10%) and alkaline reaction (pH>7.4). These soils were usually shallow with poor water - holding

capacity. Nitrogen levels were moderate to high (>1500 ppm).

(4) deep, medium to coarse - textured brown soils with low to moderate levels of silt (<35%) and variable amounts of $CaCO_3$, and nitrogen. These soils were mildly alkaline to alkaline (pH>7.2).

(5) brown, moderate to coarse - textured soils overlying marl, basalt, and lime. Low levels of $CaCO_3$ and neutral to mildly alkaline reaction (pH<7.4). These soils were often highly eroded. Nitrogen levels were variable.

(6) moderate to fine - textured black soils, overlying basalt, often with high levels of silt (>35%). Low levels of $CaCO_3$ and neutral reaction (pH<7.2). These soils were often poorly drained and usually had moderate to high levels of nitrogen (>1500 ppm).

The frequency of each medic species was classified as absent, rare, or common, and is presented for each site under the six soil and climatic classifications in Table 9. In the Table, absent is denoted by a period, rare by numeral 1 and common by numeral 2. The six climates are at the top of the Table, (the numbers 1 to 6 representing the text descriptions), immediately above the six soils (the numbers also described in the text). The Table shows that the most widely distributed species are M. polymorpha, M. orbicularis, M. minima and M. rigidula, white most of the other species were common at only a few sites.

Table 9. The distribution of 21 medics native to western Syria in relation to climate and soil.

Climatic type (1)	1						2						3						4			5		6				
Soil type (2)	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	1	4	1	2	3	5	6
M. polymorpha (3)	.211	112	.	2	1	.2	11	2.122	12.11.	2222	1222	112.	1211	12212122	..1122211111	2	2	222	.	.1...1.21	.	..	.	1	12	11.2.	1.	.....
M. orbicularis	.111	121	1	1	.	..	2.	2112.	12.11.	1..2	.1..	1.1.	2211	.2121222	..1111212.11	.	.	...	.	11...1111	1	..	1	1	21	11112	1.	1....
M. minima	211.	11.	1	.	1	..	..	1211.	121..2	1.11	1...	.111	1111	2.1..11.	..1.1.1...11	.	.	...	.	21.12.112	2	..	.	2	22	1..11	.2	.1...
M. rigidula	.11.	.1.	.	.	.	..	..	.111.	1	.2.1	1.2.	.1..	21..	2.11..1.	1121221..111	1	.	...	2	1.11212..	.	.1	1	1	..	..2..	.1	.....
M. radiata	....	...	.	.	.	..	..	.....	......	....	....	....	....	....	.........1..	.	1	...	.	....	.	22	1	.	..	1....	..	.....
M. murex	....	...	.	1	2	.2	..	.....	......	....	....	..1.	....	....	....	.	.	11.	.	....	.	..	.	.	..	.....	..	.....
M. praecox	....	...	.	.	.	..	..	.....	......	....	....	1.11	....	....	....	.	.	.1.	.	....	.	..	.	.	..	.....	..	.....
M. granadensis	....	...	.	1	2	..	..	1....	......	....	....	....	....	....	....	.	.	..1	.	....	.	..	.	.	..	.....	..	.....
M. rotata	....	...	.	.	.	..	..	.....	1.2.1.	1...	....	1.1.	...1	....	....1.......	.	2	111	.	....	.	..	.	.	..	.....	..	.....
M. blancheana	....	...	.	1	.	..	1.	1.1..	1.11..	.22.	.2..	....	....	...1....	....21......	.	2	..1	.	....	.	..	.	.	1.	..1.2	1.	.....
M. constricta	.1..	1..	.	.	.	..	..	...1.	1.....	1...	....	.121	111.	1.1.....	11..........	.	.	...	.	....	.	..	.	.	.1	.....	..	.....
M. turbinata	..1.	1..	1	2	.	..	1.	...1.	.11.1.	1.1.	....	1.1.	1...	..1122.2	..1.........	.	.	...	.	....	.	..	.	.	1.	...12	..	.....
M. coronata	.1..	...	1	.	.	..	..	..1..	1...1.	....	....	....	111.	....	1.11...1..11	.	1	...	.	....1.1..	.	..	.	.	..	.1...	..	.....
M. arabica	....	...	.	.	.	..	..	.....	......	...1	1..2	....	....	.1......	....	.	.	...	.	....	.	..	.	1	.1	.....	..	.....
M. aculeata	....	...	.	.	.	..	..	.....	1.....	....	....	....	....	.11.....	.....1......	.	.	.1.	.	....	.	..	.	.	..	.....	..	.....
M. scutellata	.12.	1.1	.	.	.	1.	2.	.....	1.1.2.	..1.	....	....	....	...1....	....	.	.	...	.	....	.	..	.	.	..	.....	..	.....
M. rugosa	.2..	.2.	.	.	.	..	..	...2.	...1..	1...	....	....	....	....	....	.	.	...	.	....	.	..	.	.	..	.....	..	.....
M. intertexta	....	..2	.	.	.	..	1.	.....	......	..1.	....	....	....	....	....	.	.	...	.	....	.	..	.	.	..	.....	..	.....
M. truncatula	....	...	.	.	.	..	..	.....	.1....	....	....	..1.	....	....	....	.	.	...	.	11	.	..	.	.	..	.....	..	.....
M. littoralis	2...	...	.	.	.	..	.2	.....	......	....	....	....	....	....	....	.	.	...	.	....	.	..	.	.	..	.....	..	.....
M. disciformis	....	...	.	.	.	..	..	.....	......	....	....	....	....	....	..2.........	.	.	...	.	....	.	..	.	.	..	.....	..	.....

(1) For description of the climatic types see text.

(2) For description of soil types see text. In climatic zones 4, 5 and 6, not all soil groups are present.

(3) A period denotes that the species is absent, 1, that it is rare, and 2, that it is common at a site.

An interpretation of Table 9, which describes the distribution of the species is as follows.

M. polymorpha is an extremely common species found at high frequency in all soil groups where rainfall is moderate to high and winter temperature is mild to cool. It often achieves high densities. The data suggest that M. polymorpha is particularly well adapted to soils of neutral to slightly alkaline reaction and those with high percentage silt.

M. orbicularis and M. minima appear to occupy similar habitats. Both are widely distributed, the data suggesting that M. minima is especially common in dry or cold environments. Both species prefer alkaline soils to those which are neutral.

While M. rigidula is widely adapted in western Syria it is most common in climatic zones 2, 3, and 4, that is the mountains, and the plateaux immediately to the east of the mountains. It is infrequent in the zone of mild winters, and also in the sub-alpine zone. It is widely distributed on the various soil types, especially on red soils over lime and some of the other very alkaline soils.

M. murex, M. praecox, and M. granadensis are all rare in Syria, probably because they cannot tolerate severe winters. All appear to be limited to neutral soils, and M. praecox only to soil group 6, that is black soils overlying basalt. The effect of rainfall is difficult to determine because the soils on which these species occur are limited to areas of high rainfall.

M. blancheana and M. rotata are considered by some authors (e.g. Lesins and Lesins 1979*) to be closely related species with similar ecological requirements, and this appears to be so in western Syria. Both are common on soils derived from basalt and marl (groups 5 and 6), but also occur widely on red soils over limestone (soil group 3). M. blancheana appears to be less soil - specific than M. rotata, and, in contrast to M. rotata, its distribution extends to the sub-alpine zone.

M. constricta and M. turbinata have similar distribution, being absent from dry environments and occupying a broad range of soil types, especially on the western slopes of the mountains. Where they occur on the drier eastern slopes they occupy the more alkaline soils, where M. trubinata, in particular occurs with high frequency on silty, calcareous soils.

M. coronata is a widely distributed species though never common, possibly because it has minute hard-to-find seed pods. It is usually found on alkaline soils and tends to avoid silty soils.

M. radiata, though rare in this survey, is known to be common in the dry areas (climatic group 4). It is worth mentioning that

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* Lesins, K.A., and Lesins, I. (1979). Genus Medicago (Leguminosae): A taxogenetic study, Dr W. Junk, Nehterlands, The Hague.

its position in the genus Medicago is uncertain, often being included in Trigonella to which it shows strong morphological and ecological affinities (especially T. arabica and T. schlumbergeri). In Syria it is restricted to areas away from the sea, a characteristic which no other medic (except perhaps M. noeana) possesses.

M. arabica is usually restricted to high rainfall areas and brown 'woodland' soils over marl. Nevertheless, as Table 17 indicates, it does occur rarely in other environments.

M. rugosa and M. intertexta are rare species occurring exclusively on alkaline soils in the coastal plain or adjacent foothills. Apparently M. rugosa has been found in Syria on only one previous occasion, by the French ecologist Pabot, who discovered it between Homs and Tell Kalakh, an area notably different to those in which we found it. M. intertexta is not mentioned in 'Nouvelle flore du Liban et de la Syrie' (Mouterde 1970*). In view of these facts our despription of the environment for these species should be treated with caution.

M. scutellata, though more frequent than M. rugosa and M. intertexta, shows a similar preference. In coastal areas it is prevalent en chalky, white, alkaline soils.

* Mouterde, P. (1970). Nouvelle Flore du Liban et de la Syrie, Dar El Mashreq, Lebanon, Beirut.

M. aculeata and *M. truncatula* are both rare species about which little can be said of their distribution in Syria.

M. littoralis, in Syria, is almost certainly restricted to sandy coastal environments, where it occured at high densities in the only two such sites sampled.

M. disciformis had not previously been recorded in Syria. It was found once, at high density on shallow, well drained, red soils in climatic zone 4.

The data will give a sound ecological basis for the development of medic cultivars in the various soil and climatic types of western Syria. The study has been extended to the north east of Syria, and to the area south of Damascus, and when all results are taken into consideration a complete picture of the adaptation of the various medics will emerge. A similar analysis will be conducted on the distribution of other annual legumes found in the surveys. - T. Ehrman (Genetic Resources Unit) and P.S. Cocks

Natural selection of medics in a two-course rotation of wheat and pasture

Experiment 5

A two-course rotation experiment began at Tel Hadya in 1983 with three major objectives: (1) to compare economic returns from seven different rotations, (2) to monitor important variables associated with the rotations, and (3) to use the pasture/cereal treatment for the natural selection of medics adapted to the ley farming system. The experiment is jointly managed by three of ICARDA's scientific programs: the Farming Systems Program, the Pasture, Forage and Livestock Program, and the Food Legume Improvement Program. In this section early results on the natural selection of medics are presented.

Absence of an existing commercial case is a major obstacle to research on the development of a pasture/cereal system. For example, the best way to select adapted medics is by screening in farming systems in which they are or will be used, yet without adapted cultivars it is difficult to develop such systems. The two-course rotation experiment offers us an excellent opportunity to do this. As mentioned above, our approach is to use natural selection, and to this end a mixture of 113 accessions was sown in 1983, in the first phase of the rotation, and again in 1984 in the second phase. The composition of the mixture was described in last year's Annual Report: it included 12 species (ten of which are shown in Table 10, the other two being M. rugosa and M. scutellata) the most frequent being M. rigidula, M. aculeata, M. truncatula, and M. rotata. The seed population is sampled at least once each year, and surviving accessions will be identified by growing in nursery rows.

The pasture plots are grazed at 8 sheep/ha, and in 1984 the decision was made to leave the sheep in certain plots until the quantity of residual seed fell to 200 kg/ha. This occurred in early September.

The pasture, sown in November 1984, was sampled seven times during grazing in summer 1985, and the results, which include four samplings in 1984, are shown in Fig. 22. Also sampled in 1985 was the residual seed from the pastures established in November 1983, which was lying dormant in the wheat phase of the rotation. The seed yield was very much higher in 1985 than during the drought of 1984.

In 1986, seed harvested on dates indicated by circles in Fig. 22, will be grown in nursery rows for identification. Another category will also be included: seed recovered from droppings of the grazing sheep. The proportion of each species at these harvests has already been estimated on the basis of pod identification and the results are shown in Table 10. Figures in the Table are calculated by dividing the percentage composition at sampling time by the original percentage composition: where the result is greater than one it indicates that the species is increasing, and where it is less than one the species is decreasing. In the autumn of both years, M. rigidula and M. rotata increased, while M. noeana increased after the second sowing. M. blancheana increased in both spring samplings but fell at both autumn samplings as a result of grazing. The four 'commercial' species, M. truncatula, M. littoralis, M. scutellata, and M. rugosa failed badly, particularly in the second year, due to severe frosts. - **P.S. Cocks**

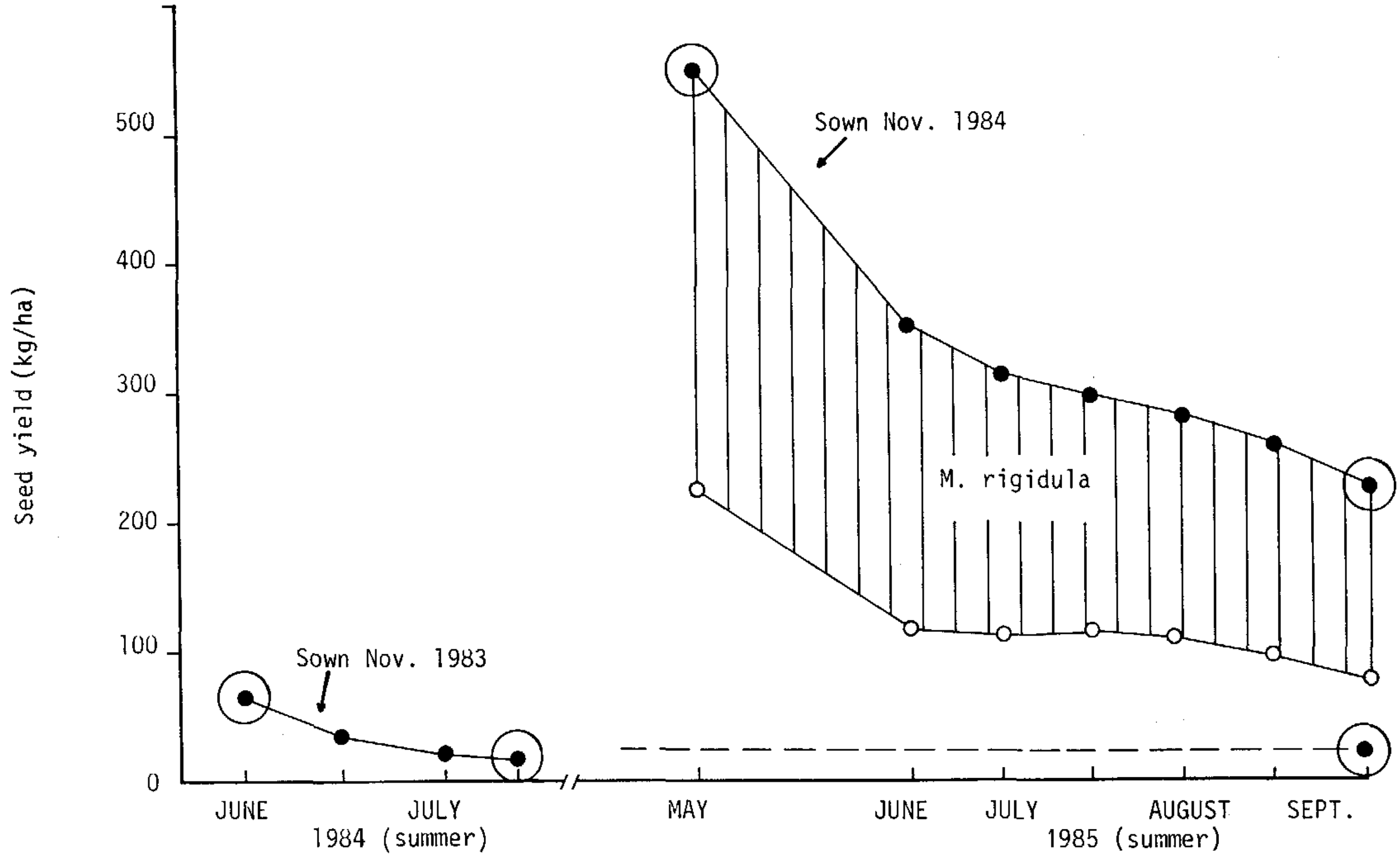

Fig. 22. The effect of grazing on residual seed yield of medic mixtures during the summers of 1984 and 1985. The hatched area in 1985 is that part of the mixture containing M. rigidula. The plots were grazed at 8 sheep/ha in both years. The circles represent the time at which seed was harvested for subsequent growing-on in nursery rows.

Table 10. Rate of increase in the proportion of 10 medic species sown in 1983/4 (first phase of the rotation) and 1984/5 (second phase) in pasture/crop rotations in which the pastures were grazed in summer.

Species	Year sown and time of sampling				
	Sown Nov. 1983, sampled 1984 and 1985			Sown Nov. 1984 and sampled 1985	
	Spring	Autumn	After Crop	Spring	Autumn
M. aculeata	0.31	0.15	0.26	0.32	0.29
M. blancheana	1.38	0.77	1.41	1.33	1.00
M. constricta	0.22	0.42	0.18	0.19	0.27
M. littoralis	0.30	0.39	0.39	0.11	0.10
M. noeana	0.62	0.79	0.89	1.61	1.89
M. polymorpha	1.23	0.45	0.27	0.04	0.13
M. rigidula	1.67	1.45	1.79	2.06	2.12
M. rotata	2.29	3.03	1.68	1.26	1.07
M. truncatula	0.45	0.28	0.65	0.10	0.09
M. turbinata	0.26	0.57	0.41	0.32	0.28

Natural selection of annual pasture legumes for northern Iraq

Experiment 6

Natural selection, as described in experiment 4, has been applied in northern Iraq, near Erbil, where the annual rainfall is 416 mm.

A complex mixture of legumes was assembled from the genetic resources of the South Australian Department of Agriculture, whose total collection exceeds 15000. On the basis of origin and overall diversity, 237 genotypes of 45 species in 5 genera were chosen for enter the mixture (Table 11). The seed population was sampled in June 1982 (the first pasture year of the rotation), June 1983 (the cereal year), and June 1984 (the second pasture year). Individual accessions were identified by growing as spaced plants and comparing with nursery rows derived from the original seed.

From each seed sampling about 1000 seeds were individually sown into 'jiffy' pots: small bio-degradable pots containing about 100ml of peat. The plants were allowed to grow until the 4-leaf stage when they were transplanted into the field in rows 1m apart, the plants being 25cm apart within the rows. The 237 control genotypes were germinated at the same time and ten plants from each genotype planted into the field at the same time and in the same manner as the unknowns.

Table 11. Composition of the mixture used in the program of natural selection* in northern Iraq.

Astragalus boeticus (1 genotype)	Scorpiuris muricatus (2)
A. conduplicatus (1)	Trifolium aintobense (1)
A. hamosus (1)	T. balansae (1)
Hymenocarpus circinnatus (2)	T. batmanicum (1)
Medicago aculeata (9)	T. cherleri (6)
M. arabica (4)	T. eriosphaerum (1)
M. blancheana (5)	T. globosum (2)
M. constricta (3)	T. hirtum (7)
M. granadensis (1)	T. isthmocarpum (1)
M. intertexta (7)	T. nigrescens (1)
M. littoralis (2)	T. pauciflorum (3)
M. murex (3)	T. pilulare (3)
M. noeana (5)	T. purpureum (4)
M. orbicularis (11)	T. resupinatum (3)
M. polymorpha (16)	T. spumosum (1)
M. radiata (1)	T. subterraneum (32)
M. rigidula (40)	Trigonella coelesyriaca (1)
M. rotata (5)	T. cylindracea (1)
M. rugosa (3)	T. grandiflora (1)
M. scutellata (9)	T. noeana (1)
M. soleirolii (1)	T. polycarta (1)
M. tornata (6)	
M. truncatula (26)	
M. turbinata (2)	

* The numbers in brackets are the number of genotypes of each species included in the mixture. For example there were 11 genotypes of Medicago orbicularis, and 32 genotypes of Trifolium subterraneum.

The flowering time of each accession was recorded and used in the identification. The unknowns were compared with the controls and identified using the following morphological attributes: leaf markers, stem hairiness and colour, plant habit, number of flowers per inflorescence, direction of whorling of pods, pod size, pod spininess, nature of spines, pod hairiness and seed colour. Apart from M. scutellata and M. noeana, where identification was difficult, it was easy to separate the genotypes within each species.

As a result of the first sampling a total of 1037 plants were grown and identified. The results (Table 12) indicate that in the year of sowing M. orbicularis was by far the most successful species. The four most frequent individual genotypes were all M. orbicularis, as were seven of the 20 most frequent. The most common accession of M. polymorpha was fifth, of M. truncatula seventh, of M. rotata thirteenth, and of M. rigidula fourteenth. None of the 11 cultivars in the comparison was in the top 20, and of cultivars registered in Australia (but not in commercial use), only Akbar and Sanza (both M. truncatula) was in the top 20.

In the second (cereal) year 554 plants were grown and identified. The results (Table 12) indicate a profound shift away from M. orbicularis to M. polymorpha, although the proportion of M. orbicularis remained slightly above that of its proportion when sown. Both M. blancheana and M. rotata increased their proportions to be well above that of the original population, as did M. scutellata. The frequency of most of the remaining species fell during the year, including M. truncatula which, however, remained slightly above its original proportion.

Table 12. Proportion of the the 10 best species in the mixture each year in relation to the proportion sown (percentage at harvest ÷ percentage in sowing mixture). A value greater than 1 indicates that the proportion in the mixture has increased and less than 1 indicates that the proportion in the mixture has decreased (experiment 6).

Species	1982	1983	1984
M. aculeata	.63	.32	.89
M. blancheana	.97	1.24	1.00
M. intertexta	.70	.04	.15
M. noeana	.70	.65	1.83
M. orbicularis	3.26	1.03	.16
M. *polymorpha*	1.07	4.45	.83
M. rigidula	.68	.27	.59
M. rotata	1.39	1.47	1.55
M. scutellata	.82	1.48	.69
M. truncatula	1.39	1.02	3.20

In the third year (the second pasture year) there was yet another change in botanical composition, this time resulting in dominance of M. truncatula (Table 12). However M. rotata remained a very abundant species, and M. noeana, a species native only to northern Iraq and south-east Turkey, markedly increased. In the third year the Australian cultivars performed very well, and cultivars Jemalong and Borung were the most successful. However there is some doubt as to whether they invaded from the surrounding pasture which was sown to Jemalong, Borung and Cyprus barrel medic in 1982. - **P.S. Cocks**

Experiment 7

To measure herbage and seed yield, seed of the seven most persistent accessions were sown at Tel Hadya in an experiment with four replicates. Plot size was 5m x 2m, the plots were sown at a rate of 25 kg/ha, and top-dressed with 16 kg/ha of phosphorus. The seed, inoculated with Rhizobium strain WSM244, was broadcast by hand, and incorporated into the soil by handraking. The experiment was sown as soon as possible after the autumn rains (5 December, 1984).

Quadrats of size 1m x 1m were harvested on March 23 and May 5. Seed was harvested in quadrats of the same size on 26 June, and the number of hard seeds was counted on 26 June and 12 October.

The results are shown in Table 13. In terms of herbage yield M. noeana, M. rotata, and M. rigidula were superior to the Australian cultivars. This is explained, of course, by the impact of frosts. The native species also produced far more seeds than the Australian cultivars, and tended to be later flowering.

As discussed earlier the frosts experienced at Tel Hadya in 1985 were of unusual severity, but such frosts are common in northern Iraq. For example, in 1983 the minimum temperature at Erbil was $-7^{o}C$, compared with $-11^{o}C$ at Tel Hadya in 1985, and the number of days when the temperature was below $0^{o}C$ was 35, compared with 43 days at Tel Hadya in 1985. The important point is that, at least in some years, frost resistance is an important characteristic for annual legumes in northern Iraq. Thus the susceptibility to frost of Jemalong and other genotypes of M. truncatula is an important reservation to its acceptance as the major cultivar. As in Syria, there is a very strong case for developing cultivars based on native species whose frost resistance evolved during centuries of adaptation. In this context it is worth pointing out that Jemalong failed in field sowings at Erbil as a result of the 1983 frosts.

One surprising aspect of the results has been the relatively poor performance of M. rigidula. It too is a native of Iraq so its failure is difficult to understand in view of its success in northern Syria. It may be worthwhile collecting Iraqi rhizobia specific to M. rigidula: some failures of this species in Jordan appear to be due to poor nodulation.

Table 13. Some agronomic characteristics of the most persistent species and genotypes when grown at Tel Hadya (experiment 7).

Species and genotype	Herbage yield (kg/ha) 23 March	5 May	Seed yield (kg/ha)	Frost[(1)] effect	Hard[(2)] seeds (%)	Flower-[(3)] ing time
M. truncatula						
cv. Jemalong	23	241	22	6.5	62	138
cv. Borung	3	202	12	7.8	56	126
acc. SA14839[(4)]	32	433	34	7.3	40	142
M. rotata						
acc. SA14126	159	1730	300	1.8	72	152
M. noeana						
acc. SA15497	511	5157	403	0	99	169
acc. SA15485	427	5234	589	0.8	86	149
M. blancheana						
acc. SA13767	39	1281	145	8.3	83	135

(1) Frost effect: 0 = no effect, 10 = completely killed.

(2) Hard seeds: measured after harvest on 10 October.

(3) Flowering time: days after sowing at Adelaide, South Australia.

(4) acc.: accession number allocated by the South Australian Department of Agriculture.

The outstanding success of *M. polymorpha* in the second year was due to its strong growth in the cereal. Its performance in the third year was disappointing, but the success of cv. Circle Valley in adjacent sowings indicates that the species is of value in Iraq, where it is a widespread native. Circle Valley itself is susceptible to frosts.

In conclusion the two cultivars of *M. truncatula* (cvs. Jemalong and Borung) should remain in pasture mixtures recommended for northern Iraq. Cultivars should be developed from *M. rotata* acc. SA14126 and *M. noeana* acc. SA15485. Pasture mixes for this part of Iraq should also include Circle Valley pending the development of frost-resistant cultivars of *M. polymorpha*.

ICARDA would like to acknowledge the contribution to this work of SAGRIC International* and the Iraqi Ministry of Agriculture and Agrarian Reform. - **P.S. Cocks**

Natural nodulation of annual pastures

Very little is known about the indigenous populations of *Rhizobium* which inhabit west Asian soils and which nodulate and

* Box 1671 GPO, Adelaide, South Australia.

fix nitrogen with agronomically important pasture legumes including the medics. The two main objectives of this research are: to investigate the nodulation response of several medic and clover species produced by the naturally occuring populations of soil Rhizobium; and to acquire information about its population size and symbiotic characteristics in order to determine inoculation strategies.

Uninoculated seed of 18 annual medics and 14 annual clovers were sown in $4m^2$ plots in non-arable land: the medics were also sown in arable land. The seed was not inoculated because natural populations of Rhizobium were being investigated. Each group of legumes was sown in a completely randomized block design and replicated three times. The plots were fertilized at sowing with 18 kg P/ha in the form of triple superphosphate.

M. noeana, M. rigidula (vars cinerascens, M. rigidula, and agrestis) and M. radiata produced functional (nitrogen-fixing) nodules. However, M. minima, M. rigidula var. submitis, M. orbicularis and M. sativa showed signs of ineffective nodulation. M. constricta was effectively nodulated in the arable land and ineffectively nodulated in the non-arable land. Plots were harvested when the plants reached the flowering stage. Herbage yields were greater in the plants that showed effective nodulation (Table 14).

Eight other medics were severely affected by frost in February and March. Nodulation characteristics were recorded at early stages of growth before the period of frost occurred. The medics included: M. rotata, M. blancheana, M. aculeata, M. intertexta, M. turbinata,

Table 14. Herbage yield (kg/ha) of annual medics grown in arable and non-arable soil at Tel Hadya.

Host species/variety	Cultivation site	
	Arable	Non-arable
Medicago noeana	3,914	2,340
M. rigidula var *cinarescens*	3,128	2,847
M. radiata	1,646	2,041
M. rigidula var *agrestis*	1,820	2,021
M. constricta	1,608	962
M. minima	889	819
M. rigidula var *submitis*	541	286
M. orbicularis	361	290
M. sativa	297	133
M. rotata	-	216
CV (%)	24.0	27.4
LSD (5%)	684	573

M. truncatula and two varieties of *M. polymorpha* (vars *polymorpha* and *vulgaris*). Of the clovers in the experiment *Trifolium alexandrinum*, *T. cherleri*, *T. purpureum*, *T. hirtum* and *T. lappaceum* were effectively nodulated and their herbage production ranged between 700 and 2,000 kg/ha. Seedlings of *T. campestre*, *T. tomentosum*, *T. subterraneum*, *T. scutatum*, *T. scabrum*. *T. argutum*, *T. resupinatum* and *T. spumosum* showed ineffective nodulation.

These preliminary observations indicate that further investigations are needed on the response of pasture legumes to indigenous *Rhizobium* in order to monitor their effectiveness and establish whether there is a need for inoculation. - **L.A. Materon**

Inoculation techniques for small-seeded legumes

For inoculation to be successful, the *Rhizobium* strain must be able to remain with, and survive on the seed surface long enough to colonize the developing root system, the primary target being the radicle. Materials used to aid in the adherence of peat-based inoculants to the seed increase the chances of *Rhizobium* survival, and also give some protection against adverse environmental factors which are lethal to the bacteria. The covering of inoculated seed with a coating in addition to the adhesive, gives extra protection.

Preliminary investigations have been made to determine the effect of various adhesives and coating materials on the effectiveness of inoculation of pasture legumes. Seed of *Medicago rigidula* selection 716 was inoculated with *Rhizobium meliloti* strains

WSM244 and CC169. Peat inoculants were attached to the seed by several adhesives (Table 15).

No differences in herbage yield were detected due to the alternative bacterial strains. However, herbage production of plots established using seed which had been treated with organic gums, sucrose, and local beet molasses, increased approximately 1.5 fold as compared to the uninoculated control (Table 15).

In another experiment to measure the effect of coating, a slurry made of peat and a solution of molasses (as the adhesive) was used to inoculate seed of M. rigidula sel. 716, followed by the coating treatments listed in Table 16. Lower yields obtained in this latter experiment are attributed to late planting. However, results clearly indicate a yield reponse associated with an additional benefit caused by coating the inoculated seed (Table 16). A broader investigation of seed inoculation techniques, using several other species of annual medics,will be conducted in the next growing season. - **L.A. Materon**

Medics on farmers' fields - adaptation of ley farming to northern Syria

Throughout the pasture section of the Annual Report certain assumptions are made about the way self-regenerating pastures will

Table 15. Response of *Medicago rigidula* to inoculation and the use of inoculant adhesives.

Treatment	Herbage DM yield[1] (kg/ha)	Increase due to inoculation (%)	Symbiotic effectiveness %[2]
Adhesive materials			
Gum cellulose	4,830	41.2	81.0
Sucrose	4,174	32.0	70.0
Molasses	4,031	29.6	67.6
Gum arabic	3,824	25.8	64.1
Water	3,815	25.6	64.0
Corn oil	3,557	20.2	59.6
Uninoculated controls			
Phosphorus (18 kg/ha)	2,838	-	47.6
P + Nitrogen (27.7 kg/ha)	5,963	-	100.0
LSD (5%)	1,062		
CV (%)	21.7		

[1]Planting date: November 27, 1984.

[2](DM yield of inoculated treatment ÷ DM yield of P + nitrogen control) x 100

Table 16. Yield response of *Medicago rigidula* to inoculation and seed coating.

Treatment	Herbage DM yield[1] (kg/ha)	Increase due to coating (%)	Symbiotic effectiveness %
Coating materials			
Sodium molybdate	3,278	16.9	81.7
Milk powder	3,175	13.3	79.2
Calcium carbonate	3,119	11.3	77.8
Charcoal	3,055	9.0	76.2
Uncoated	2,803	-	69.9
Uninoculated controls			
Phosphorus (18 kg/ha)	2,543	-	63.4
P + Nitrogen (27.7 kg/ha)	4,010	-	100.0
LSD (5%)	1,149		
CV (%)	25.0		

[1]Planting date: December 12, 1984.

be managed. Pastures are expected to be grown in a two-course rotation with cereals, grazed by sheep, the system of grazing being set stocking (the most appropriate system), and cultivation to establish the cereal phase being no deeper than 10 cm.

ICARDA believes that great progress will be made if a west Asian or north African version of ley farming evolves. The change will depend on many factors, but very importantly on the efforts of farmers. There will inevitably be problems, if only because the assumptions are based on farming practice in southern Australia where a great many socio-economic factors differ from west Asia and north Africa. However, we believe that the role of ICARDA is to introduce concepts to farmers and, by working closely with them, to help solve problems associated with the implementation of the concepts. An approach such as this is especially important in introducing ley farming because it differs in many ways from current livestock practice. Accordingly a three-way collaborative project involving ICARDA, Syrian Ministry officials, and local farmers has been established and is described below.

On 25 March 1984 Program staff visited Tah, a village a few km east of Ma'aret on the main Aleppo - Hama road. Tah, typical of many villages producing livestock, has an average of about 350 mm of rain. One of the farmers has land which, until 1982, had been used in the traditional way but had spontaneously become dominated by medics. At the time of the visit the pasture was extremely productive and, we thought, demonstrated the great value of medics in the region. As a result we decided to invite local Ministry officials and farmers to a field day at the farms. The field day attracted a great deal of interest and it was decided to use the farm as a focal point for developing the medic system. We hoped that by using the awareness and enthusiasm of farmers at Tah, and the experience and local knowledge of Ministry of Agriculture officials, we could establish working models of the ley farming system. Subsequently we measured herbage and seed yield of the pasture and found that it produced 4.5 t/ha of herbage and 500 kg/ha (ungrazed) or 150 kg/ha (grazed) of seed. The pasture species were *M. polymorpha*, *M. minima*, *Onobrychis crista galli*, wild vetches, and several annual grasses.

In 1985 we established a project in which we conducted a survey of farmers with the objective of establishing a socio-economic basis for the project, and sowed one ha of medic pastures (*M. rigidula*, *M. polymorpha* and *M. truncatula*) on each of six fields. Local machinery was used, and subsequent grazing was carefully monitored. The productivity of sheep on the original farm was measured, and careful assessment was again made of herbage and seed production. Several small experiments were established to test which of the various medic species was best adapted, measure their response to superphosphate, and to determine the need for inoculation with *Rhizobium*. - **P.S. Cocks and H. Sawmy, Y. Swedan (Ministry of Agriculture and Agrarian Reform), and Dibo Dadesh (MAAR)**

Results of the survey

Forty-eight farmers, including the six at Tah, were questioned on various aspects of their farming systems. Information was gathered on the way in which livestock are fed, prices of the various livestock foodstuffs, the kind of rotations which are used, and the profitability of the various crops and rotations. Much of this information awaits analysis but some preliminary results are presented here.

When the farmers were asked how they fed their livestock they answered by estimating the proportion of the animals' diet which comes from 13 'hand-fed' and 10 'grazing' sources. Examples of the former (in order of farm usage) are: barley grain, lentil straw, barley straw, wheat bran, cotton seed cake, and cotton seed hulls, and of the latter are: grazing of cereal stubble, grazing of marginal land, grazing of mature cereal crops, grazing of cotton residues, and steppe grazing (where farmers send their animals to the Syrian interior for several weeks). Results are given in Fig. 23 for the various sources of feed divided into three categories: hand feeding of concentrates and straw, range and steppe grazing, and grazing of mature crops and crop residues. The distribution of the three categories is plotted on a monthly basis in Fig. 23. From October to March sheep rely heavily, and, in December and January exclusively, on hand-fed concentrates and straw. This pattern continues until grazing on marginal land and in the steppe becomes available in spring. Various sources of grazing (chiefly cereal stubbles) are used through the summer. The cycle is completed by grazing of cotton and sugar beet residues in late summer and autumn.

The survey also produced valuable information on crop rotations. The survey area was divided into three zones: a zone wetter than Tah, (up to 400 mm), an intermediate rainfall zone which includes Tah, and a drier zone (down to 250 mm). In the wetter zone the predominant

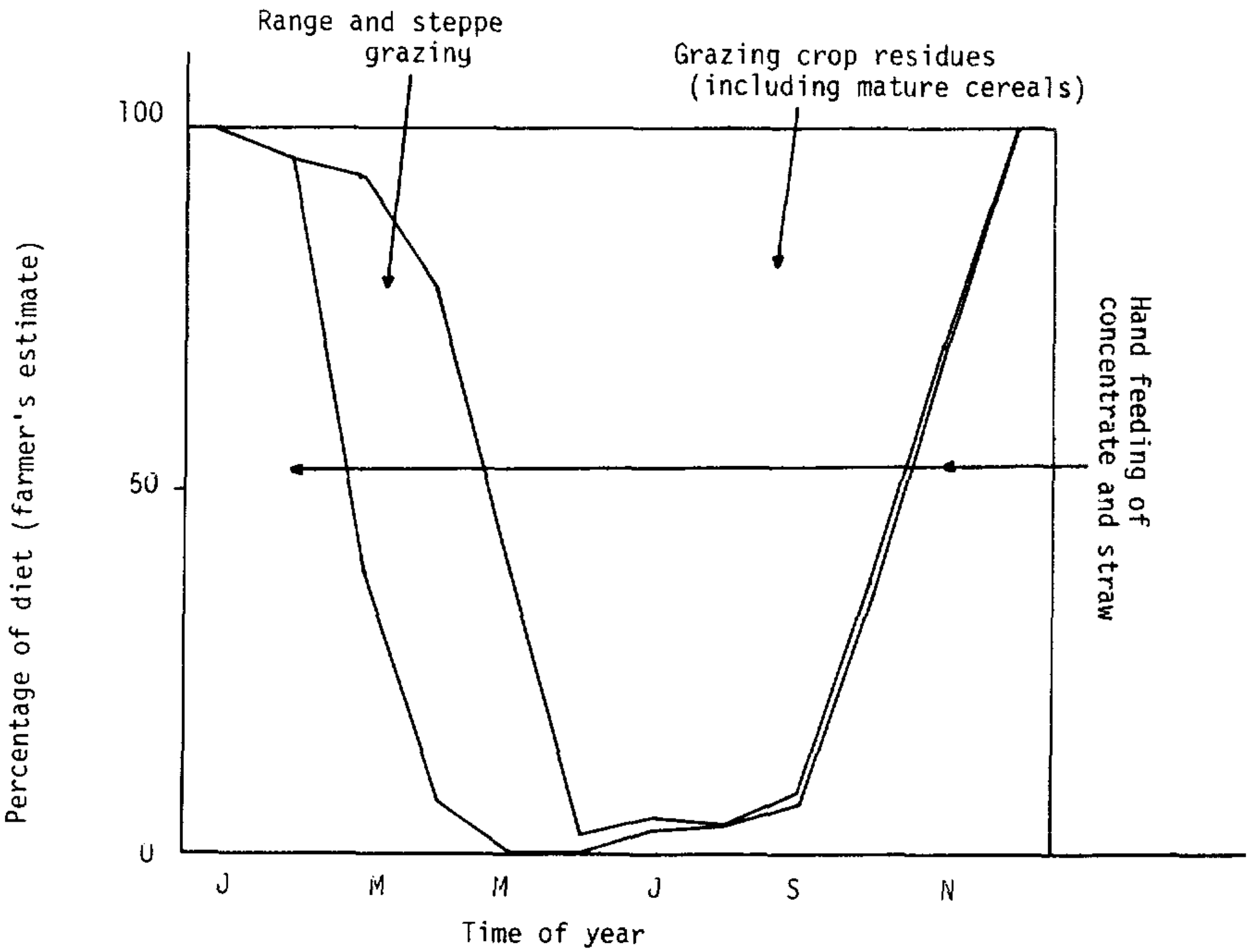

Fig. 23. Sources of feed for sheep on a seasonal basis: in winter sheep are hand fed using concentrates and straw, in spring they are grazed on the steppe and on marginal land, while in summer they graze cereal stubbles and mature crops. The percentages are based on farmers estimates in a survey centred on the village of Tah, south of Aleppo.

rotations were wheat/chickpeas, wheat or barley/fallow, and wheat/forage legume. In the Tah zone 3-course rotations were common, about half being wheat/lentil/summer crop, and the other half barley/lentil/summer crop. Rotations involving fallow were rare. In contrast nearly all of the rotations in the drier zone were wheat or barley in rotation with fallow. The results indicate that if medics are to be used in the Tah region the farmers may change from a 3-course rotation to a 2-course rotation, and adopt pastures at the expense of lentils and summer crops (sesame or watermelons).

The farmers' costs and returns (averaged over all zones) are shown in Table 17. It is interesting to note that cereals are far more profitable than other crops in the area. Table 14 also shows that harvesting costs are a strong disincentive to growing lentils, and that if pastures are to be introduced the best point in the rotation may be the beginning of the lentil year. The data in Table 14 are of great value because they indicate the levels of profitability which will have to be achieved if pastures are to be introduced. - **H. Sawmy, T.L. Nordblom (Farming Systems Program), Y. Swedan, D. Dadesh (MAAR) and P.S. Cocks**

Productivity of pastures

A very early indication of gross returns from pastures was obtained from the original medic field where the milk yield of grazing ewes was monitored during the 5 months of lactation. Records of milk weight were made at approximately two-week intervals from 10 of the 100 ewes grazing the 4 ha of medic, and another 10 ewes fed at

Table 17. Costs, returns and profit of various crops grown in the Tah region during 1985 (Syrian pounds/ha).

	Costs		Returns	Profit
	Establishment	Harvest*		
Wheat	654	267	2791	1870
Barley	801	388	3037	1848
Lentils	542	1154	2200	504
Sesame	400	209	1323	714
Water melons	527	368	1869	974

* Includes mid-season (sprays etc) costs.

Table 18. Herbage D.M. and seed yield (kg/ha), and number of grazing days for six medic fields sown on farms in the Tah district.

Field	Herbage yield		Seed yield		Grazing days
	Winter	Spring	Before grazing (5)	After grazing (6)	(per ha)
1	2.2 (1)	4.4 (4)	457	167	450
2	- (2)	3.8	410	279	100
3	-	1.7	133	76	150
4	-	2.8	423	- (2)	120
5	-	1.7	170	-	- (7)
6	1.6 (3)	3.4	368	-	900

(1) Measured 11 April

(2) Not measured in winter

(3) Measured 20 March

(4) All spring yield measured 3 May: farms 1 and 6 are regrowth after winter grazing.

(5) Measured 29 May before summer grazing

(6) Measured 1 August

(7) No grazing

the discretion of the farmer. Over the whole period, ewes grazing medic only (without supplements) produced almost 1 kg/ewe more milk than those in the control flock despite the fact that the latter were fed concentrates and shepherded to pastures in at least two villages (Fig. 24). The medic carried 20 ewes/ha for the five month period and resulted in a yield of 1470 kg of milk/ha. If the milk was sold for 3 Syrian pounds/kg (a conservative estimate of price) the gross return from medic would be 4400 Syrian pounds, more than 40% higher than that from wheat or barley. Although this figure takes no account of the relative skills of the one medic farmer compared with average farmers, and does not include an estimate of costs, it does suggest that a cereal/pasture rotation would be economically attractive to farmers in the Tah area. Further economic analysis of medic pastures is planned for the 1985/86 season.

Herbage production from the indigenous medic at Tah was similar to that obtained at Tel Hadya. By 11 January, 1.3 t/ha of herbage was available and this increased to between 6 and 8 t/ha (depending on which part of the field was sampled) by 2 May. It is interesting to learn that the annual stocking rate was 8.3 ewes/ha/year. This figure agrees closely with recent estimates in New Zealand of* the appropriate stocking rate for pastures giving a similar yield of harbage.

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* Baslow, N.D. (1985). New Zealand J. Exp. Agric., 13, 5-12.

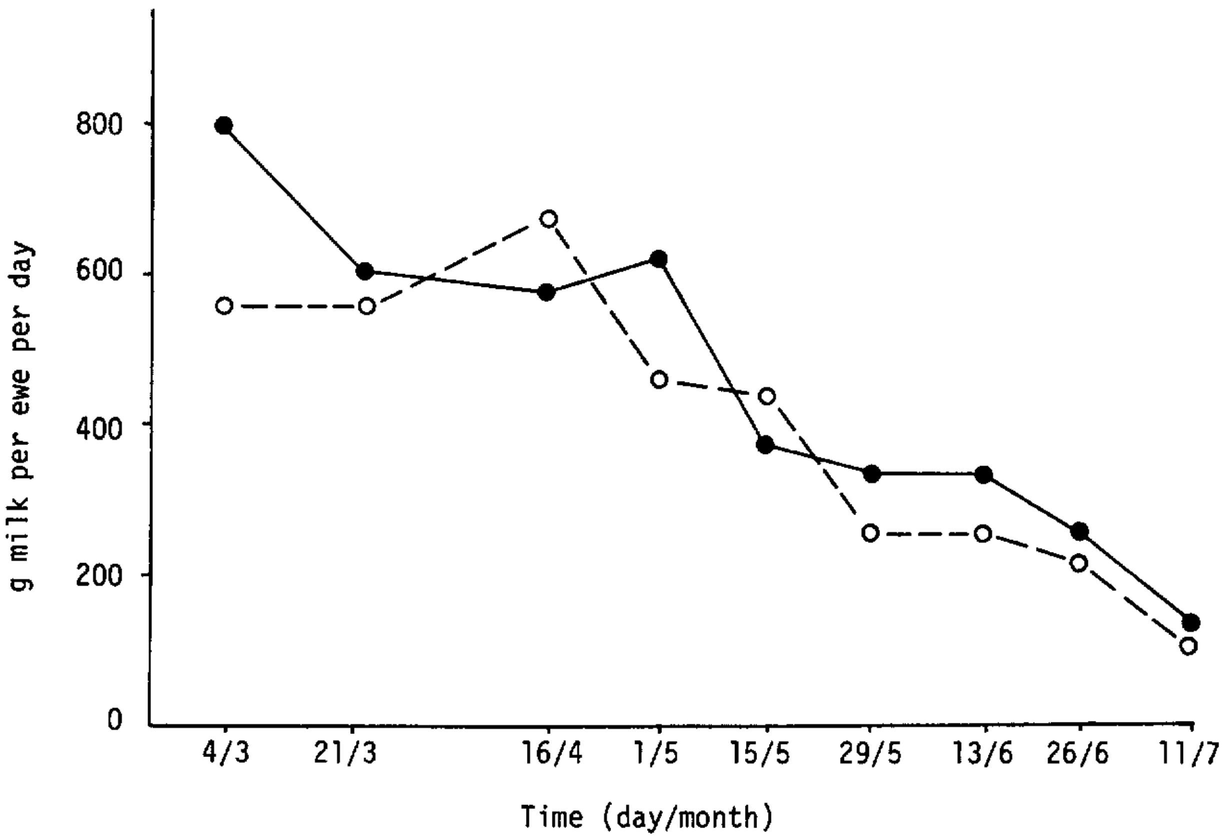

Fig. 24. Milk production from farmers ewes grazing medic pasture *without* supplementation (closed circles), or marginal land with supplementation (open circles) at Tah, a village near Aleppo.

The newly sown pastures were less productive than the indigenous pasture (Table 18). However seed yields (75 - 400 kg/ha) after grazing are of the same order indicating that future herbage yields are likely to be comparable. Indeed it is normal for medic pastures to be less productive in the first year than in later years.

At Tah there was no response to phosphorus either in indigenous or in new pastures, nor was there a response to inoculation. Of the medic accessions *M. rigidula* sel. 716, *M. rotata* sel. 1943, and *M. blancheana* sel 2099 produced most seed, and these accessions, with *M. aculeata* sel. 2008 were most frost resistant (Table 19). In general the results support our findings at Tel Hadya. - **H. Sawmy and P.S. Cocks**

FORAGE BREEDING

Forage crops are one of the alternatives being studied to replace fallow in cereal/fallow rotations. They are defined as leguminous species sown and harvested in a single year as hay or straw and which can also be grazed. They are not managed for self-seeding, and are not expected to regenerate spontaneously as would be the case for annual pastures. Forages are not used extensively: in Syria about 8% of zone 1, and about 5% of zone 2 is used for forage crops. Forage crops may be sown in mixture with a cereal and harvested as above.

Table 19. Effect of frost and seed production (kg/ha) of nine *Medicago* selections at Tah.

	Frost effect (percentage plants killed)	Seed yield
M. rigidula sel.716	3	510
M. rotata sel. 1943	3	467
M. blancheana sel.2099	1	429
M. truncatula cv. Cyprus	49	306
M. aculeata sel.2008	4	301
M. truncatula cv. Jemalong	37	259
M. scutellata cv. Robinson	45	245
M. polymorpha cv. Circle Valley	37	183
M. littoralis cv. Harbinger	70	67
LSD ($P < 0.05$).	13	151

In view of the huge diversity of legumes in the Mediterranean region surprisingly few have been used specifically as forage crops. Kernick (1978)* notes that three species of Lathyrus and nine species of Vicia (vetch) are potentially important, but of these probably only nine have been tested and still fewer used. In Syria only chickling (Lathyrus sativus), where rainfall is < 300 mm, bitter vetch (Vicia ervilia), where rainfall is > 400 mm, and common vetch (V. sativa), where rainfall is 300-500 mm, are actually grown. There are only very small areas of chickling. Several other species have been tried, most notably forage pea (Pisum sativum), and possibly Scorpiurus muricatus, some annual clovers (Trifolium spp), and snail medic (Medicago scutellata).

Three forage taxa are being evaluated by ICARDA: in order of resource allocation vetches, forage pea and chickling. Only in vetch has more than one species been studied: as well as common vetch, there has been exploratory work on narbon vetch (V. narbonensis), woollypod vetch (V. villosa subsp. dasycarpa) and bitter vetch (V. ervilia). As a result of recent work the role of forage pea is being questioned, and more emphasis is being placed on vetch and chickling.

Until recently research on forage crops was conducted under two headings: forage breeding, and forage agronomy. In 1984/85 emphasis

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* Kernick, M.D. (1978). Ecological Management of Arid and Semi-Arid Rangelands in Africa and the Near and Middle East. Rome, FAO.

has shifted to forage breeding, while agronomic work is continued in the Farming Systems Program. The breeding work has several objectives: to select cultivars of wide adaptation to ensure their success in contrasting environments, to select for non-shattering seed pods in common vetch, and to select for resistance to several foliar (bacterial blight, and downy and powdery mildew) and root (root knot and cyst nematode) diseases in common vetch and forage pea. Selection of improved narbon vetch, woollypod vetch and chickling expanded in 1984/85 and will be expanded further in 1985/86.

Selection for wide adaptation

Selection for wide adaptation involves the following steps: preliminary screening and seed multiplication in nursery rows, evaluation in microplots at Tel Hadya, evaluation in advanced yield trials at Tel Hadya (during this step the number of entries is reduced and plot size increased), and finally multilocation (regional) testing at five sites in Syria and Lebanon. Disease screening occurs at all stages, and an evaluation of the palatability of the most promising accessions is also undertaken. The latter step is discussed in the Livestock Management and Nutrition section of this Report.

In 1984/85 only forage peas were screened in nursery rows. Strains of common vetch and forage pea were included in micro-plots, and these species plus narbon vetch and woollypod vetch were included in advanced yield trials and multilocation testing.

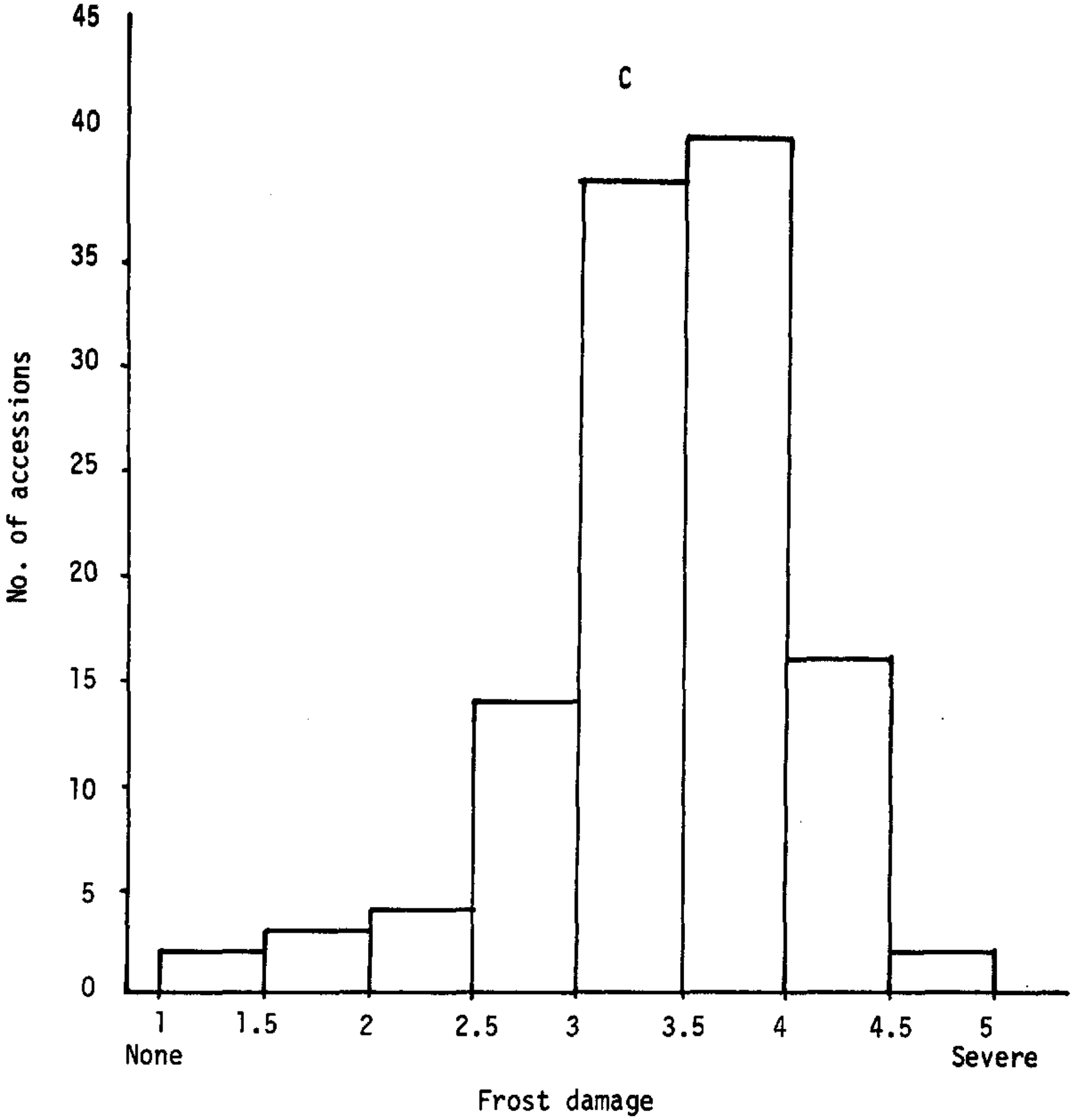


Fig. 25. Variability in frost damage of 121 forage pea accessions grown in nursery rows at Tel Hadya in 1984/1985. Frost damage is based on a visual score, recorded on a 1 to 5 scale where 1 = no damage and 5 = all plants killed. C indicates the score achieved by the local strain

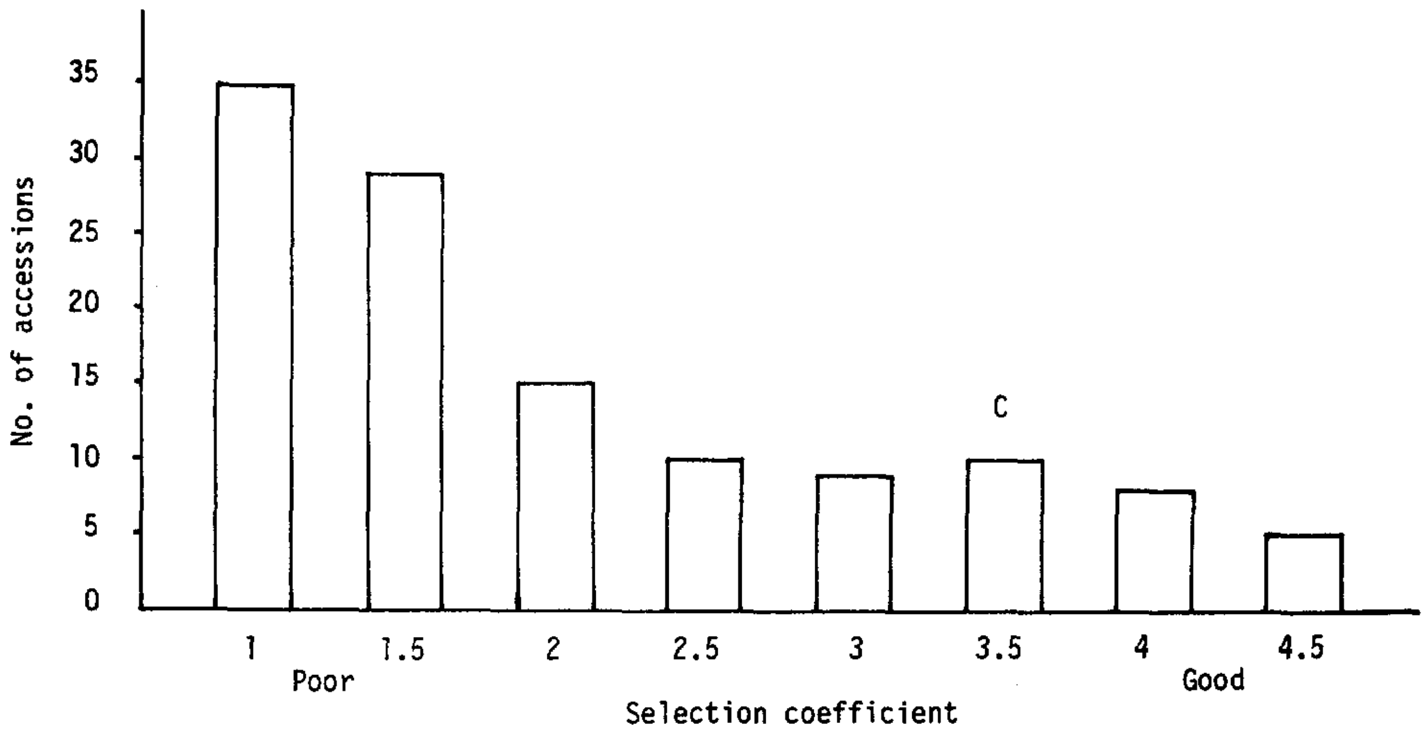


Fig. 26. Variability in selection coefficent (1, very poor; 5, very good) of 121 forage pea accessions grown in nursery observation rows at Tel Hadya in 1984/85.
C indicates the score achieved by the local strain.

Preliminary screening in nursery rows

Forage pea accessions of different origins were screened in nursery rows in a cubic lattice design with three replicates. In this preliminary screening, 121 accessions were visually scored, on a 1-5 scale, for establishment, seedling vigour, frost-tolerance, winter and spring growth, leafiness, growth habit, plant vigour, time to flowering and maturity, and susceptibility to diseases.

A period of severe frost during February and March, 1985, when temperatures were below zero for 42 days gave a good opportunity for screening for frost-tolerance. Frost drastically affected the growth of most peas: five strains showed tolerance (Fig. 25), whereas the rest were damaged by frost to various extents.

There was a wide range of variability, illustrated in Fig. 26 using the mean score for all characters (the 'selection coefficient') which has been fully documented for reference and future exploitation. Twenty-three strains were identified as promising, and ten were superior to the local control, which itself was one of the best, with a coefficient of 3.5.

Evaluation in microplots

The study of variation in agronomic characters helps the breeder to establish a suitable program which may result in the development of improved cultivars. Selection for desirable traits such as high herbage production and seed yield, and early flowering, begins in microplots in a year after nursery row evaluation, and leads on to more critical evaluation in advanced yield trials at Tel Hadya before the stage of multilocation testing of selected cultivars.

Vetches and peas were planted in 3.5 m^2 microplots arranged in a triple lattice design. A seed rate of 80 kg/ha and fertilizer application of 16 kg P/ha was used for both crops. The whole trial was duplicated: one was harvested at the 100% flowering stage for the determination of herbage yield and the other allowed to mature to measure seed yield.

Forty-nine selections of common vetch were tested in microplots for two seasons, 1983/84 and 1984/85. There were large differences in herbage production, seed yield and days to 100% flowering between strains and between years. Fifteen strains, which combined both high herbage and seed yield with frost-tolerance and early flowering, were identified for advanced yield trials.

An analysis of variance for the two years combined revealed highly significant interactions between strains and years. This indicates that the rank-order of selections is not the same for yield in each of the two years of testing. The selections which will advance are therefore ones which are highly productive despite environmental fluctuations from year to year. Results for them are given in Table 20.

Differences between the 49 strains in the average yield in the two years were as follows: sel. 2097 had the lowest dry-matter

Table 20. Mean herbage and seed yield, number of days to 100% flowering, and frost damage for selected strains of common vetch (*Vicia sativa* L.) grown in 1983/84 and 1984/85.

Selection No.	Dry matter yield (kg/ha)	Seed yield (kg/ha)	Days to flowering	Frost* damage
2027	4153	1272	131	1.35
2020	4152	1491	132	1.04
2021	4057	1401	132	0.99
2032	3959	1631	125	2.41
2025	3618	1636	133	0.97
2024	3274	1468	131	1.35
2023	4194	1192	130	1.42
2003	3468	1983	126	2.10
2068	3818	2066	131	1.25
Acc # 2541	3221	2638	123	2.30
2040	3040	2151	125	1.61
1429	3427	2000	123	2.93
Acc# 713	3466	2067	122	2.07
2100	3798	1360	130	2.34
2073	3522	2353	123	2.27
Mean	3266	1328	131	2.99
LSD (5%)	1143	374	1.09	0.70

*On the basis of a visual scale where 1 = no damage; 5 = all plants killed by frost.

#Strain which was promising and sufficiently uniform to be tested as a complete accession, hence no selection number.

yield, 2292 kg/ha (not in Table 1), while sel. 2023 had the highest, 4194 kg/ha. The yield of the local strain (accession 2541) was exceeded by 13 selections but was not significantly different from them: its lower yield was because it was more affected by frost. Seed yield ranged from 303 kg/ha (sel. 2011, not in Table 1) to 2638 kg/ha (acc. 2541), the control yielding significantly more seed ($P<0.05$) than the other selected strains except sel. 2073.

Differences in growth between the two years were as follows: the mean seed yields were 1584 and 1072 kg/ha in 1983/84 and 1984/85, respectively, while herbage yield was 4682 and 1849 kg/ha in the two seasons. The highest yields were thus obtained in 1983/84 in spite of drought, whereas relatively poor yields were obtained in 1984/85, which had a high rainfall (372 mm). The distribution of rainfall during the growing season, irrespective of the total amount, probably caused the differences although it cannot be separated from the effect of frost in 1984/85.

Thirty-six pea selections were also evaluated in microplots. Significant differences occurred in herbage yield, seed yield, days to 100% flowering, and damage inflicted by frost. Herbage yield varied from 41 kg/ha (sel. 702) to 1118 kg/ha (sel. 640). The control, (acc. 205) yielded 524 kg/ha, which was exceeded significantly by 6 selections. Seed yield ranged from 76 kg/ha (sel. 572) to 909 kg/ha (sel. 692). The control yielded 382 kg/ha which was exceeded by 14 selections, three being significant. None of the selections tested showed complete frost-tolerance: five had moderate tolerance, while the others were severely damaged by frost.

Seed and dry matter yields were closely related ($r=0.90$, $P<0.01$). This was due to their association with frost-tolerance, as indicated by significant negative correlations between DM yield and frost damage ($r = -0.679$, $P<0.01$) as well as seed yield and frost damage ($r = -0.699$, $P<0.01$).

The results also show clearly that forage peas generally produce less dry matter and seed than vetches (489 vs 3265 kg/ha and 325 vs 1328 kg/ha, respectively). The superior yield of vetch occurred similarly in 1982/83 and 1983/84, but in 1984/85 the difference was more marked due to the effect of frost.

Advanced yield trials

Two experiments were carried out to evaluate promising lines of forage vetch and pea. In the first, 23 lines of common vetch, one of woollypod vetch, and one of narbon vetch were included. Thirty-six lines of forage pea were included in the second experiment. Both legumes were sown and managed as for microplots, but in this case the plot size was larger (28 m^2).

Herbage yield of vetch varied from 838 kg/ha (sel. 2063) to 3130 kg/ha, (narbon vetch acc. 67). The yield of the local common vetch was exceeded by woollypod vetch (NS) and narbon vetch ($P<0.05$) but not by other selections of common vetch.

Seed yield ranged from 257 kg/ha (sel. 874) to 1435 kg/ha, (sel. 2003). The local control (acc. 2541) and narbon vetch produced high seed yields of 1415 and 1372 kg/ha, respectively. The days to 100% flowering varied from 122 (narbon vetch) to 145 (sel. 972). The high herbage and seed yield of narbon vetch was attributed to early flowering and frost-tolerance. The effect of frost on common vetch was less than that on forage pea. In vetch five selections were severely affected, 13 showed moderate frost-tolerance, while the remaining 7, including woollypod vetch and the local common vetch were tolerant.

Dry-matter and seed yields were closely related ($r=0.64$, $P<0.01$), and are illustrated in Fig. 27. The major factors which affected herbage production and seed yield were frost average and number of days to 100% flowering. This was indicated by significant correlations between frost damage and DM and seed yields ($r= -0.62$. $P<0.01$) and 0.43 $P<0.05$, respectively) (Figs. 28,29). A significant correlation also occurred between number of days to 100% flowering and both DM and seed yields ($r= -0.51$, $P<0.05$ and -0.75, $P<0.01$), respectively (Fig.s 30 and 31).

The results for forage peas in the advanced yield trials were similar to those in the microplot trials. Herbage yield varied from 18 kg/ha (sel. 550) to 1269 kg/ha (sel. 536), while seed yield varied from 15 kg/ha (sel. 550) to 487 kg/ha (sel. 541). Three selections produced a significantly ($P<0.05$) higher seed yield than the control. Only two strains, selections 541 and 324 showed reasonable frost-tolerance while the remaining selections were severely damaged.

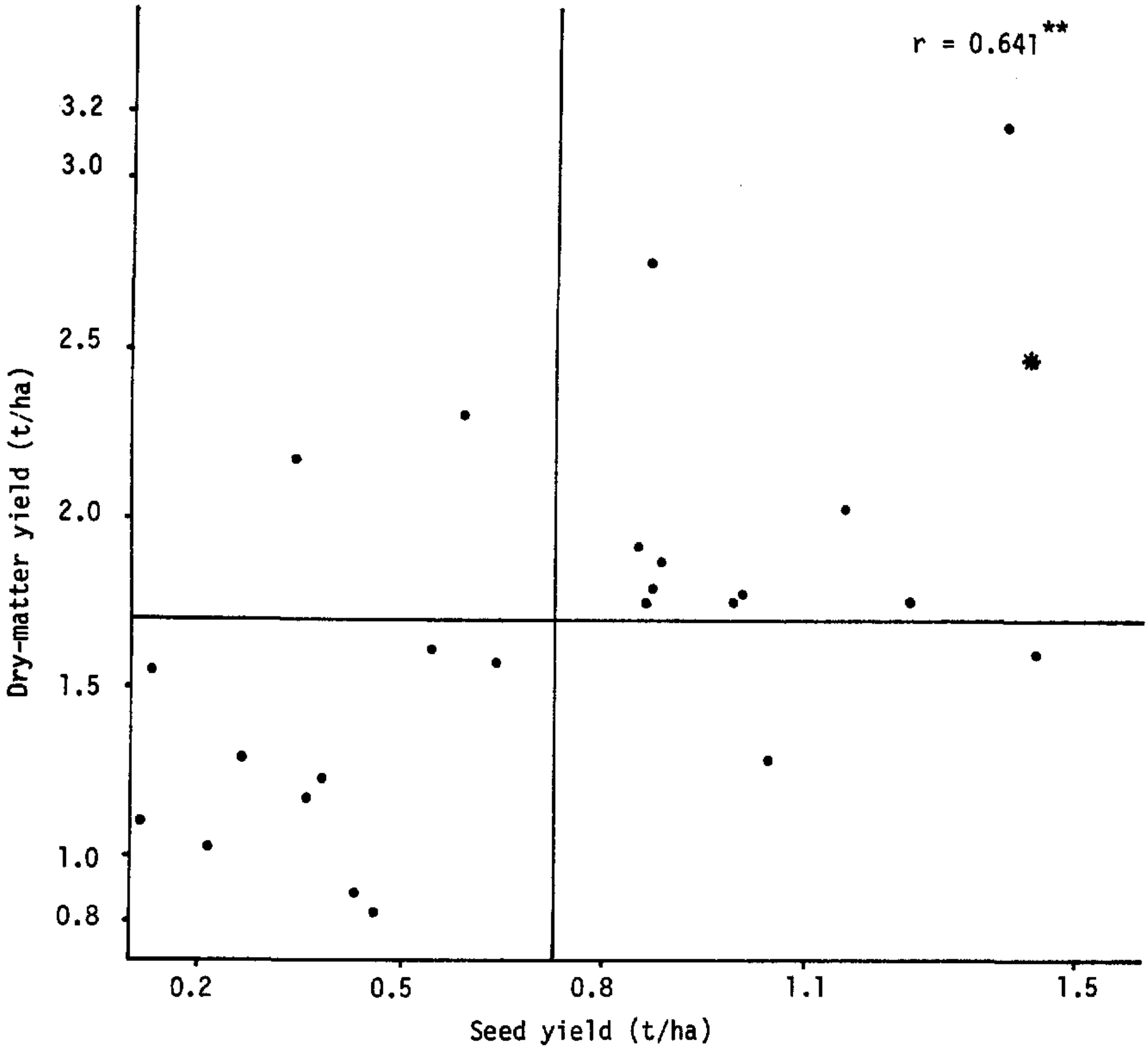


Fig. 27. Relationship between herbage DM and seed yield for 25 strains of vetch at Tel Hadya in 1984/85. The asterisk (*) indicates the performance of the local strain, and the vertical and horizontal lines indicate the mean performance of all strains illustrated.

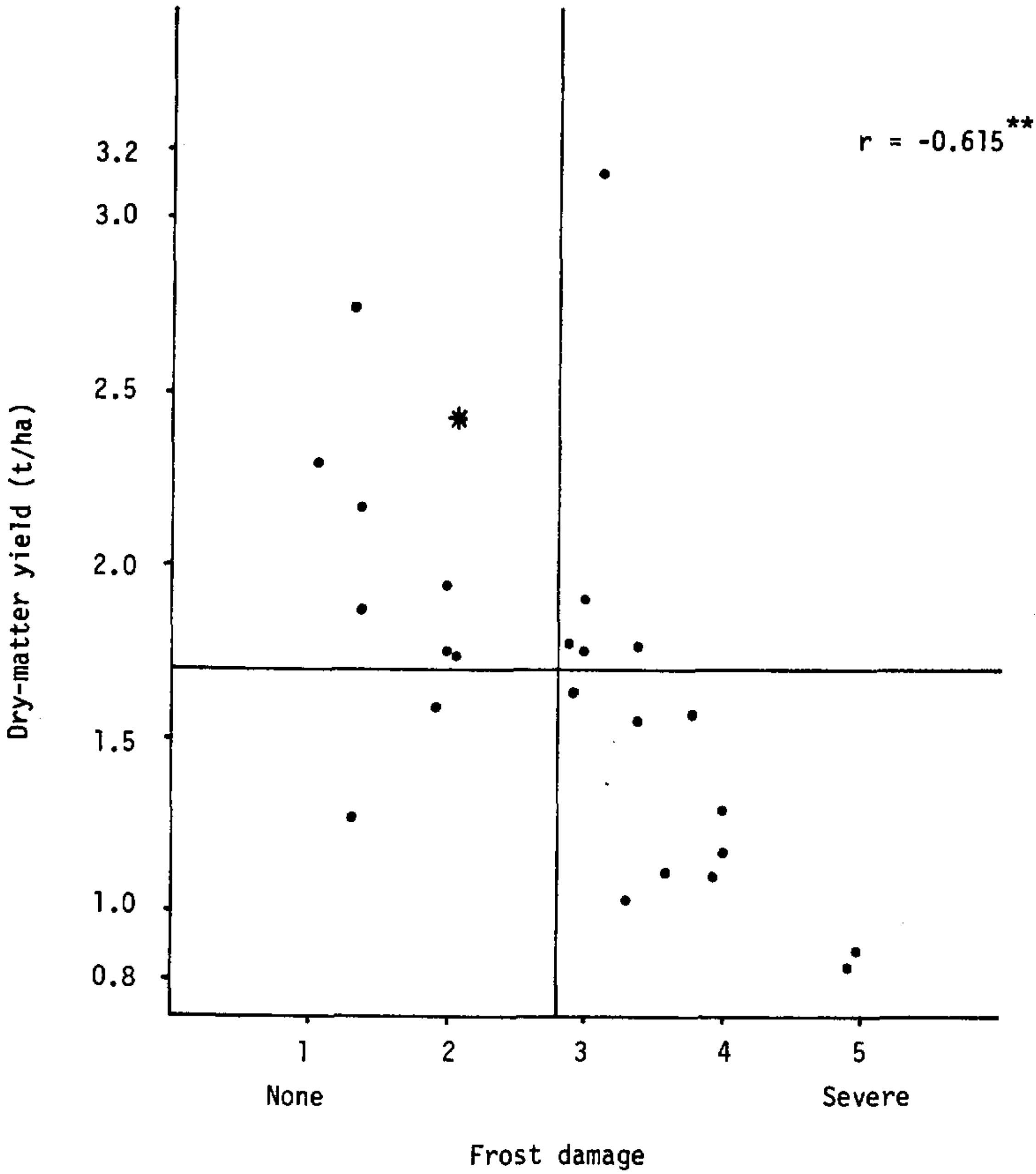


Fig. 28. Relationship between herbage DM yield and frost damage for 25 strains of vetch at Tel Hadya in 1984/85 (frost damage assessments are given in Fig. 25, other details in Fig. 27).

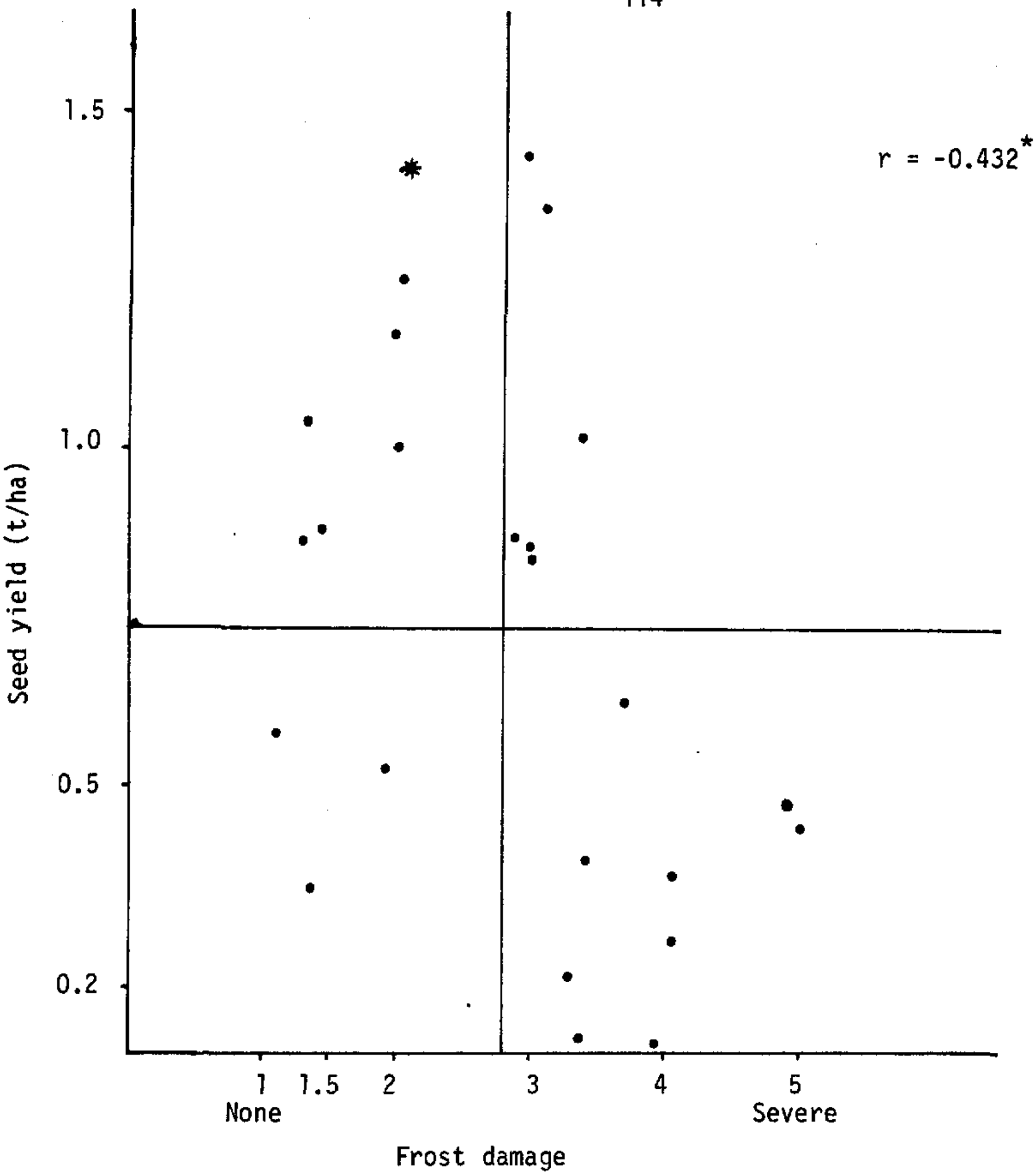


Fig. 29. Relationship between seed yield and frost damage in 25 strains of vetch at Tel Hadya in 1984/85 (other details as for Figs 25 and 27).

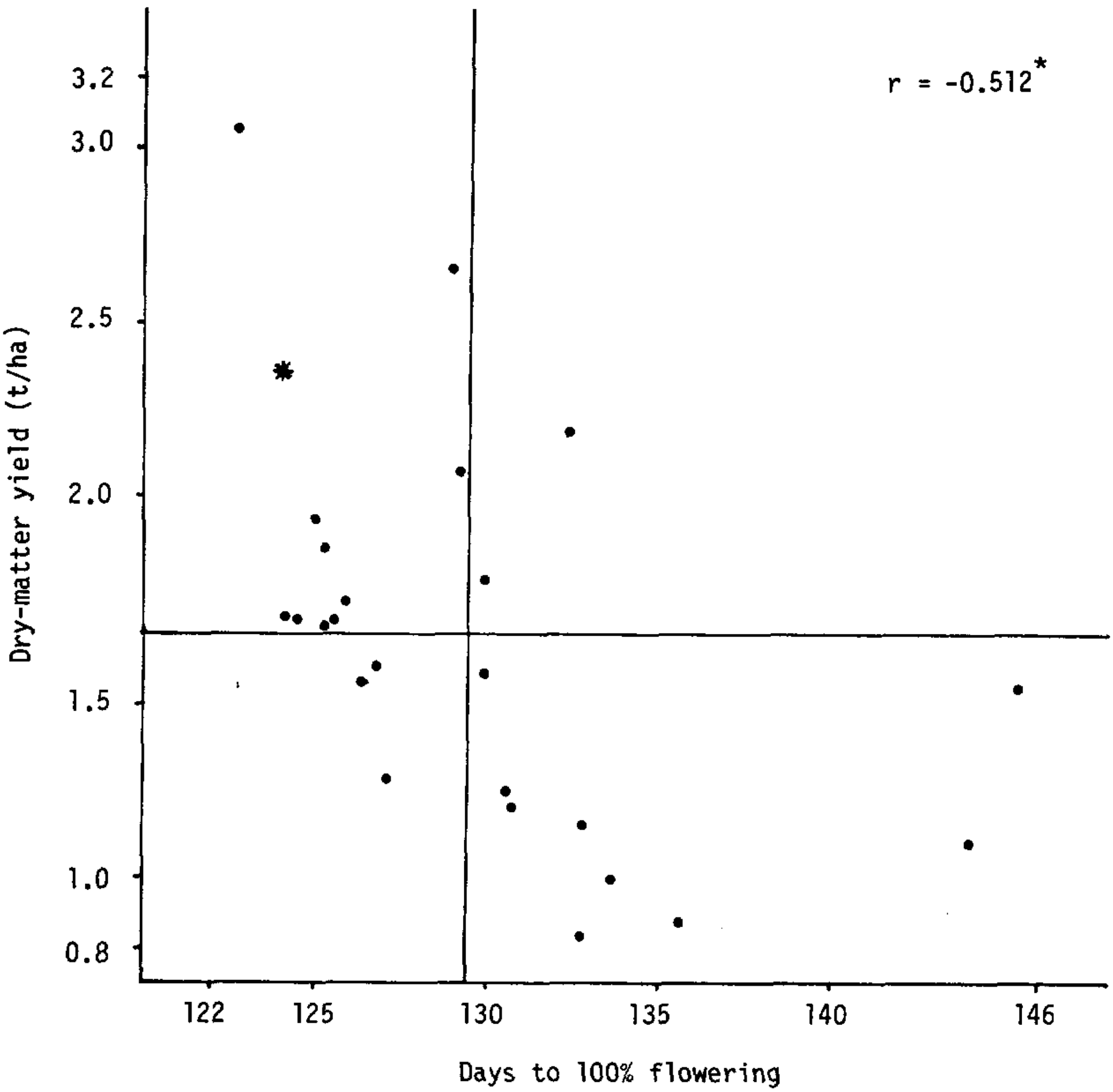


Fig. 30. Relationship between herbage DM yield and days to 100% flowering for 25 strains of vetch at Tel Hadya in 1984/85 (other details as for Fig. 27).

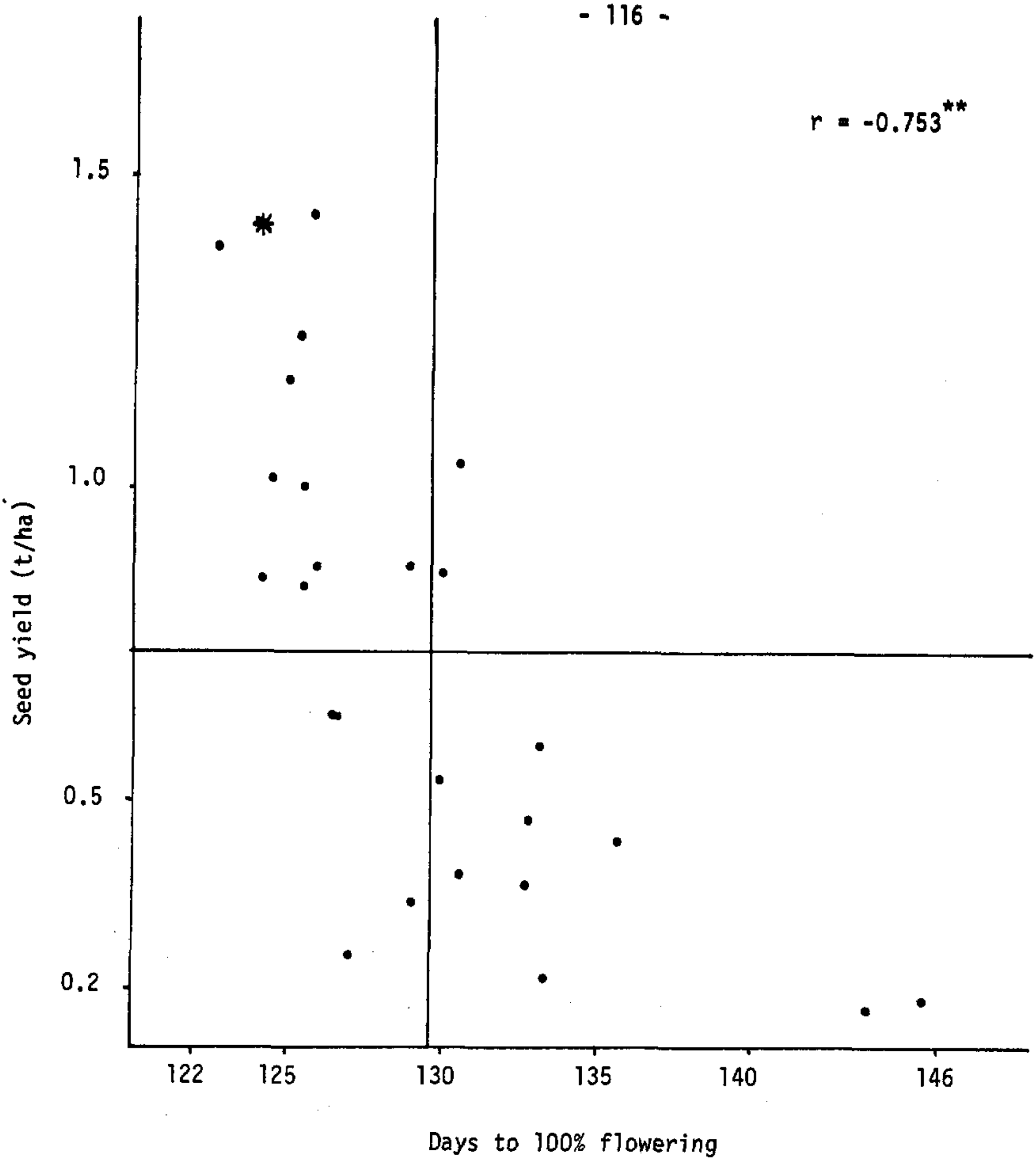


Fig. 31. Relationship between seed yield and days to 100% flowering for 25 strains of vetch at Tel Hadya in 1984/85 (other details as for Fig. 27).

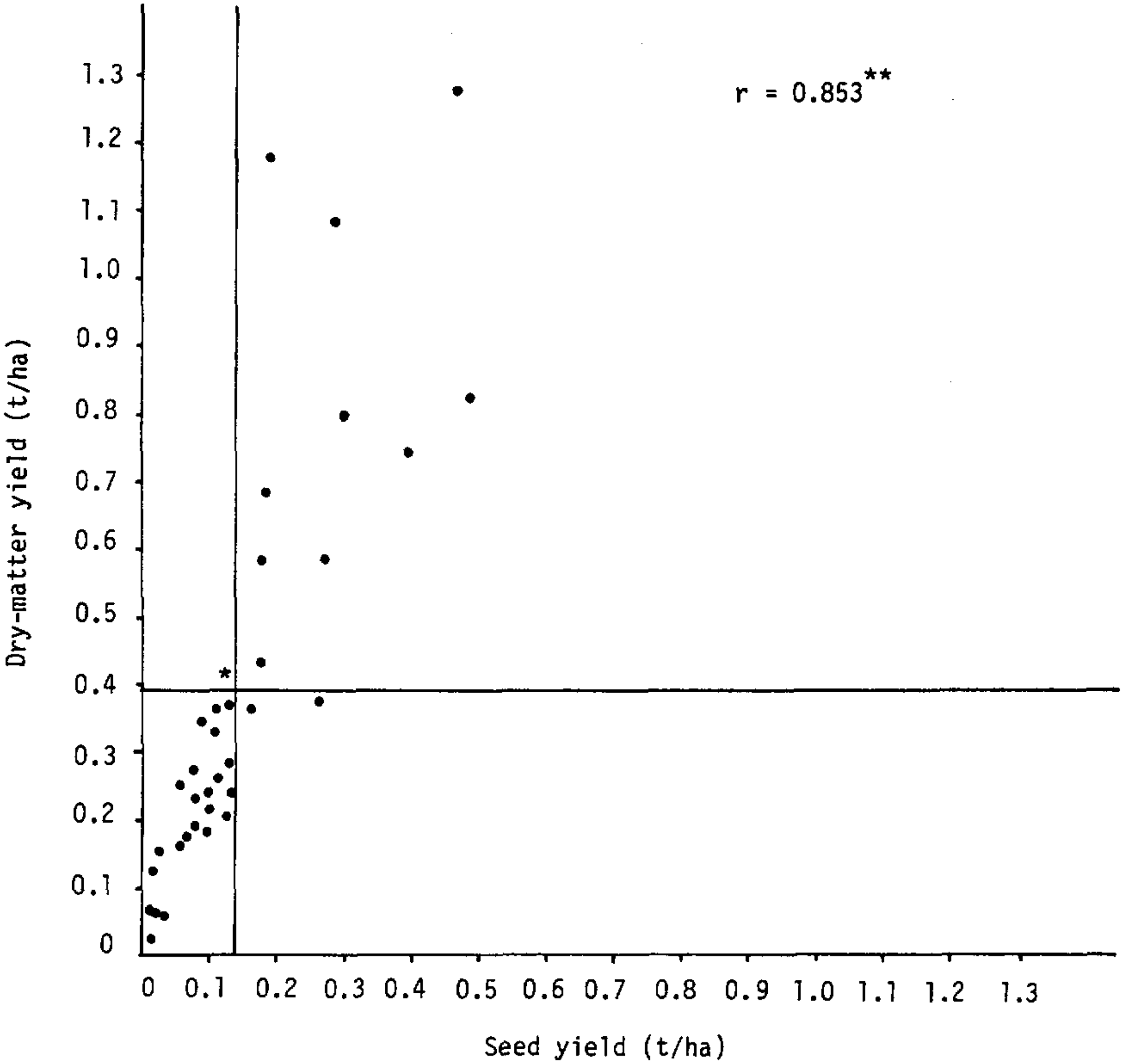


Fig. 32. Relationship between herbage DM and seed yield for 36 strains of forage pea at Tel Hadya in 1984/85 (other details as for Fig. 27).

Dry-matter and seed yields were closely related ($r=0.85$, $P<0.01$; Fig. 32). Both characters were correlated with frost damage, ($r= -0.658$, $P<0.01$ and -0.674, $P<0.01$ respectively, (Figs. 33, 34). However, the number of days to flowering was not associated with DM and seed yields ($r= -0.244$, N.S., and -0.248 N.S., respectively), in contrast to the results for vetch.

Multilocation testing

Twenty-five promising vetches and 25 promising forage peas were tested at sites in Syria (Tel Hadya, Kamishly, Homs, Izraa) and Lebanon (Terbol). The sites were chosen to represent the range of environmental conditions present in these countries and to obtain information on the response of strains to different environmental conditions. Meteorological data for and exact location of, the sites are given in Table 21.

At each site both peas and vetches were planted in $28m^2$ plots and managed in the same way as for microplot evaluation. In vetch, the mean herbage yield was 2792 kg/ha, varying between sites from 885 kg/ha in Kamishly to 4490 kg/ha in Terbol. The mean seed yield was 965 kg/ha, varying from 555 kg/ha in Kamishly to 1560 kg/ha in Homs (Table 22). The results emphasize the very large effect of environmental variation on yield.

The mean dry-matter and seed yields of individual selections over sites varied widely. Narbon vetch, (acc. 67), gave the highest yields. Common vetch (acc. 2541) had relatively high herbage and

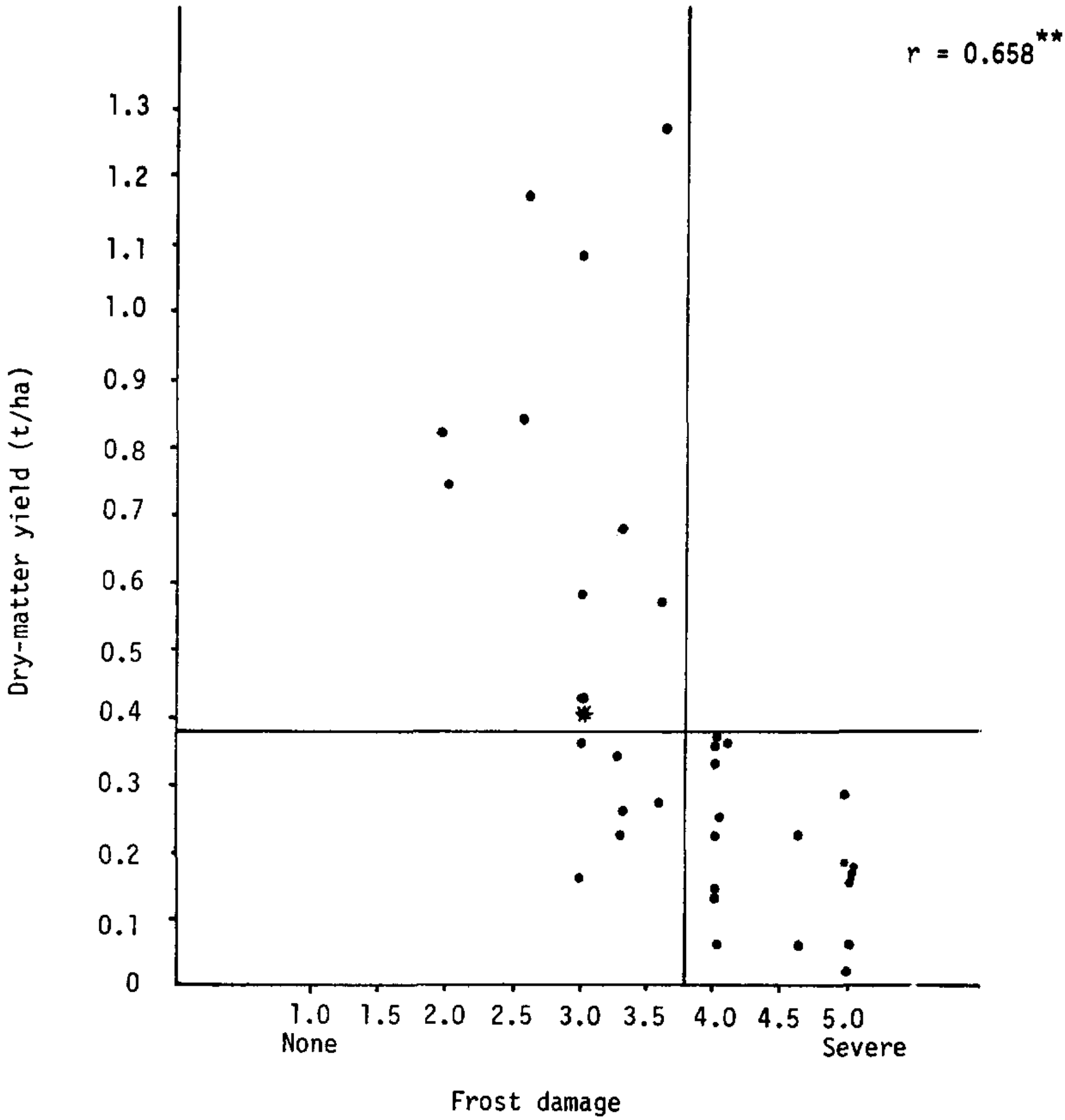


Fig. 33. Relationship between herbage DM yield and frost damage for 36 strains of forage pea at Tel Hadya, in 1984/85 (other details as for Figs 25 and 27).

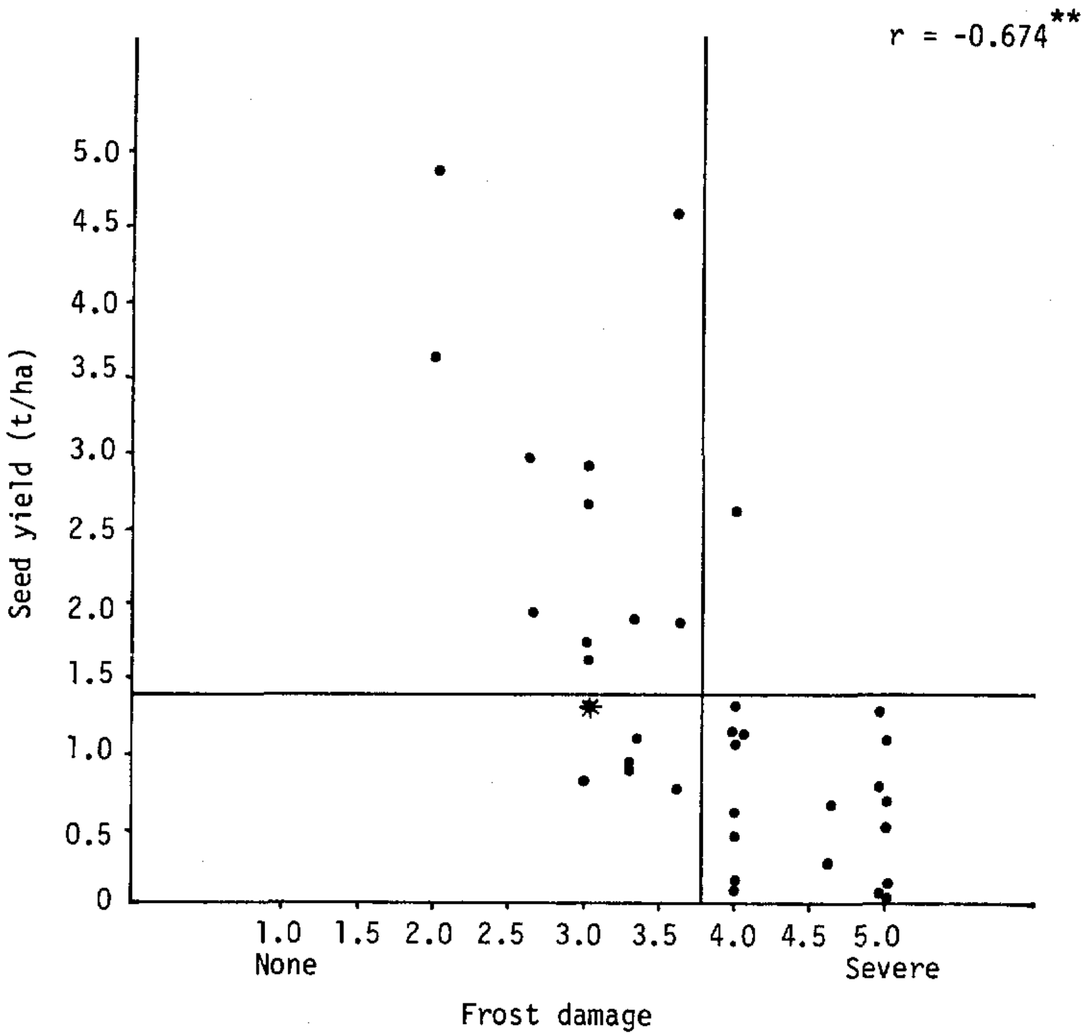


Fig. 34. Relationship between seed yield and frost damage for 36 strains of forage pea at Tel Hadya in 1984/85 (other details as for Figs 25 and 27).

Table 21. Location and meteorological data for five sites in Syria and Lebanon where multilocation testing of vetches and forage peas took place in 1984/85.

Location	Latitude	Longitude	Altitude (m)	Air temperature (Oct. - May, °C) Mean Max.	Mean Min.	Rainfall (mm)
Syria						
Tel Hadya	35°55'N	36° 55'E	362	24.3	10.4	372.6
Kamishly	37°03'N	41° 13'E	467	28.0	9.6	363.7
Homs	34°45'N	36° 43'E	487	27.0	8.0	392.0
Izraa	32°51'N	36° 15'E	575	28.2	5.9	221.9
Lebanon						
Terbol	33°50'N	36° 00'E	950	20.4	2.9	516.4

Table 22. Mean herbage and seed yield (kg/ha) of vetch at five sites in Syria and Lebanon in 1984/85.

	Syria				Lebanon	Mean
	Tel Hadya	Kamishly	Izraa	Homs	Terbol	
Herbage yield	1610	885	2600	3877	4490	2792
Seed yield	693	555	1022	1560	995	965

Table 23. Mean herbage and seed yields (kg/ha) of forage pea at five sites in Syria and Lebanon in 1984/85.

	Syria				Lebanon	Mean
	Tel Hadya	Kamishly	Izraa	Homs	Terbol	
Herbage yield	559	190	3443	3154	1113	1691
Seed yield	183	88	1341	2536	803	990

seed yields at all sites indicating that it also has wide adaptability. Other strains showing wide adaptability were woollypod vetch (acc. 683) and common vetch accessions 715 and 2019.

The mean herbage yield of forage pea for the five sites was 1691 kg/ha, and site means varied from 190 kg/ha at Kamishly to 3443 kg/ha at Izraa (Table 23). Mean seed yield was 990 kg/ha and varied from 88 kg/ha at Kamishly to 2536 kg/ha at Homs. These results demonstrate the wide range of environmental conditions among sites which was manifested above with vetch.

Herbage and seed yields in 1984/85 were generally less than those of 1983/84 (3081 versus 1691 kg/ha and 1557 versus 990 kg/ha respectively). Conventional analyses of variance for each site showed that strains differed significantly in both attributes.

Unreliability of herbage and seed yield has always been a problem in forage pea. Information on genotype x environment interaction is therefore important, and has been obtained from an analysis of variance of the combined data (25 strains, 5 sites and 2 years), involving an examination of the relative magnitudes of different sources of variation. The methods of Finlay and Wilkinson (1963)* and Eberhart and Russel (1966)* were used, in which the

* Finlay, K.W., and Wilkinson, G.N. (1963). Australian Journal of Agricultural Research, 14, 742.
Eberhart, S.A., and Russel, W.A. (1966). Crop Science, 6, 36.
Miller, P.A. Williams, J.C., and Robinson, H.F. (1959). Agronomy Journal 51, 132-134.

environmental mean yield (average of all strains grown in a particular site in a particular year) is subtracted from the mean of all strains in all environments to produce an environmental index for that site. The regression coefficient (b) of individual yields on site mean yields, and mean square deviation from regression ($S^{-2}d$), deviation about the regression line (±Sb), and the coefficient of determination (r^2) were computed. The statistic (b) is the measure of the average increase in yield of a strain per unit of increase in the environmental index, whereas the deviation from the regression line (±Sb) is considered to be a measure of stability.

Stable strains are characterized by regression coefficients near 1.0, low deviations about the regression lines, and high coefficients of determination (r^2). The latter is considered the better index for measuring the validity of the linear regression, because its value ranges from zero to unity, regardless of the scale of measurement of individual strains. The closer it is to 1.0 the better is the fit to a straight line. A high mean yield (average performance) is also a desirable attribute.

Ten strains had above average herbage yields and of these, selections 493, 323 and 335, had regression coefficients near 1.0 and high values for r^2. They are the most stable, high-yielding strains, having wide adaptability. Selections 323 and 335 are superior for all parameters (x, b, S_b and r^2) in both herbage and seed yields (Table 24).

Estimates of S_b showed that there were distinct differences between strains in their deviations from the regressions. Strains

Table 24. Mean dry-matter and seed yields ($\bar{x}$, kg/ha) and estimates of stability parameters b, Sb and r^2 for 10 strains of forage pea.

Strain (selection No.)	Dry-matter yield				Seed yield			
	$\bar{x}$	b	±Sb	r^2	$\bar{x}$	b	±Sb	r^2
454	2461	1.02	0.15	0.85	837	0.40	0.108	0.61
325	2589	1.30	0.18	0.87	1537	1.17	0.07	0.96
323	2593	1.09	0.09	0.93	1308	0.94	0.100	0.91
335	2625	1.10	0.11	0.92	1476	1.18	0.103	0.94
321	2683	1.20	0.15	0.89	1052	0.83	0.07	0.94
175	2822	1.19	0.14	0.90	1176	0.65	0.110	0.79
205[1]	2906	1.31	0.15	0.90	1679	1.15	0.106	0.93
92	3570	1.20	0.19	0.82	643	0.34	0.060	0.80
61	3667	1.26	0.25	0.85	674	0.30	0.067	0.70
493	3679	0.90	0.12	0.91	817	0.41	0.103	0.66
LSD ($P<0.05$)	1104				402			

[1] Local strain.

such as sels. 61, 240, 100, 289, 166, 496 and 466 with high S_b values are unstable. The control (acc. 2541) showed low S_b with high r^2 values and can thus be considered stable for both DM and seed yield. However DM yield was not as high as sel. 493.

Estimates of the pertinent variance components (after Miller Williams and Robinson, 1959) are presented in Table 25. The relative magnitudes of these indicate the relative importance of the corresponding source of variation. The strain x site term was large and highly significant. By contrast, the strain x year term was small and non-significant. The presence of a strain x site interaction indicates that certain strains tended to rank differently in herbage yield at different sites while the small strain x year interaction indicates that year had little effect. The occurrence of a strain x environment x year interaction. The analysis showed similar results for seed yield but here the strain x year interaction was significant.

The 25 strains studied represented the most promising material resulting from our breeding program: they were a highly selected group that had survived previous testing at Tel Hadya.
Such strains might be expected to have wide adaptation, but this was not so, possibly because they originated from selections from accessions collected in the ICARDA region.

Table 25. Variance components (mean squares) from a combined analysis of 25 strains of forage pea grown at 5 sites for 2 years.

Variance source	Dry-matter yield	Seed yield
Strain	238,501 NS	98,888 NS
Strain x year	20,610 NS	47,102 **
Strain x sites	277,978 **	152,154 **
Strain x sites x years	184,458 **	92,524 **

** = P<0.01; NS = not significant.

Table 26. Number of cyst nematodes and root-knot nematodes present in soil samples on five sampling occasions.

Sampling date	Cyst nematode[1]	Root-knot nematode[2]
30.11.1984	29	495
3.3. 1985	33	231
4.4. 1985	34	783
6.5. 1985	35	1275
14.6. 1985	33	-

[1] 200g soil; [2] 500g soil.

Table 27. The number of pods set in *Vicia sativa* crosses in greenhouse (1984/85).

Nature of cross	Number of pods set
716 x 1416	110
2541 x 1416	118
716 x 1361	69
2541 x 1361	121
2541 x 2014	55
716 x 2014	51

Disease screening

Foliar diseases

Twenty-five promising vetches and peas were screened in the field using artificial infections of Ascochyta blight and downy mildew (Peronospora viciae) for vetch and Ascochyta blight, other bacterial diseases (A. pisi, Mycosphaerella pinodes, Phoma medicaginis var pinodella, Pseudomonas pisi) and powdery mildew (Erysiphe pisi) for peas.

Common vetch (sel. 2019), narbon vetch (acc. 67) and woollypod vetch (acc. 683) exhibited resistance to Ascochyta blight, 17 common vetches had moderate resistance and 5 were susceptible to Ascochyta blight. Symptoms of downy or powdery mildew did not appear because of unfavourable conditions for this pathogen.

Two forage peas, (sels 493 and 335) were resistant to both Ascochyta blight and bacterial blight, seven were resistant and nine were moderatly resistant to Ascochyta blight and eight were susceptible. Six peas while susceptible to Ascochyta blight were resistant to bacterial blight, one was moderately resistant, and eight were susceptible.

Observations made on other microplots, which had not been atrificially inoculated, showed that none of the 36 peas exhibited symptoms of Ascochyta blight or bacterial blight. Similarly in vetches, there were no symptoms of Ascochyta blight or downy mildew on the 49 lines tested. This year was probably not typical there being a low chance of natural infection.

Nematode resistance

Nematodes can cause serious infections on the roots of many legumes. In the case of forage legumes, vetches are attacked by root knot nematode (Meloidogyne artiella) and forage peas by cyst nematode (Heterodera rossi). Since both nematodes can attack cereals, use of a legume/cereal rotation is a poor form of cultural control, and may even result in a build-up of the diseases. Not only forage but also food legumes are attacked by the nematodes which can cause serious losses of herbage and seed yield. The above-ground symptoms are similar to nitrogen deficiency (or poor nodulation) in winter, and drought in spring.

The high incidence of root-knot and cyst nematode during the last three years therefore led to a decision to initiate a program of screening for resistance. One hundred strains of forage pea and 81 of vetch (including common vetch, and woollypod vetch) were examined for cyst and root knot nematodes in 1984/85 in a heavily infested field at Tel Hadya. The material included all that which had previously been evaluated in other microplot trials, advanced field trials and at multilocations.

The populations of nematodes were monitored by taking soil samples before planting and during growth of the crops. Each sample was obtained by collecting ten 1 kg lots of soil at random, thoroughly mixing them, and removing 1 kg sub-samples for testing.

One such sample was taken for each of the four replicates within the experiment.

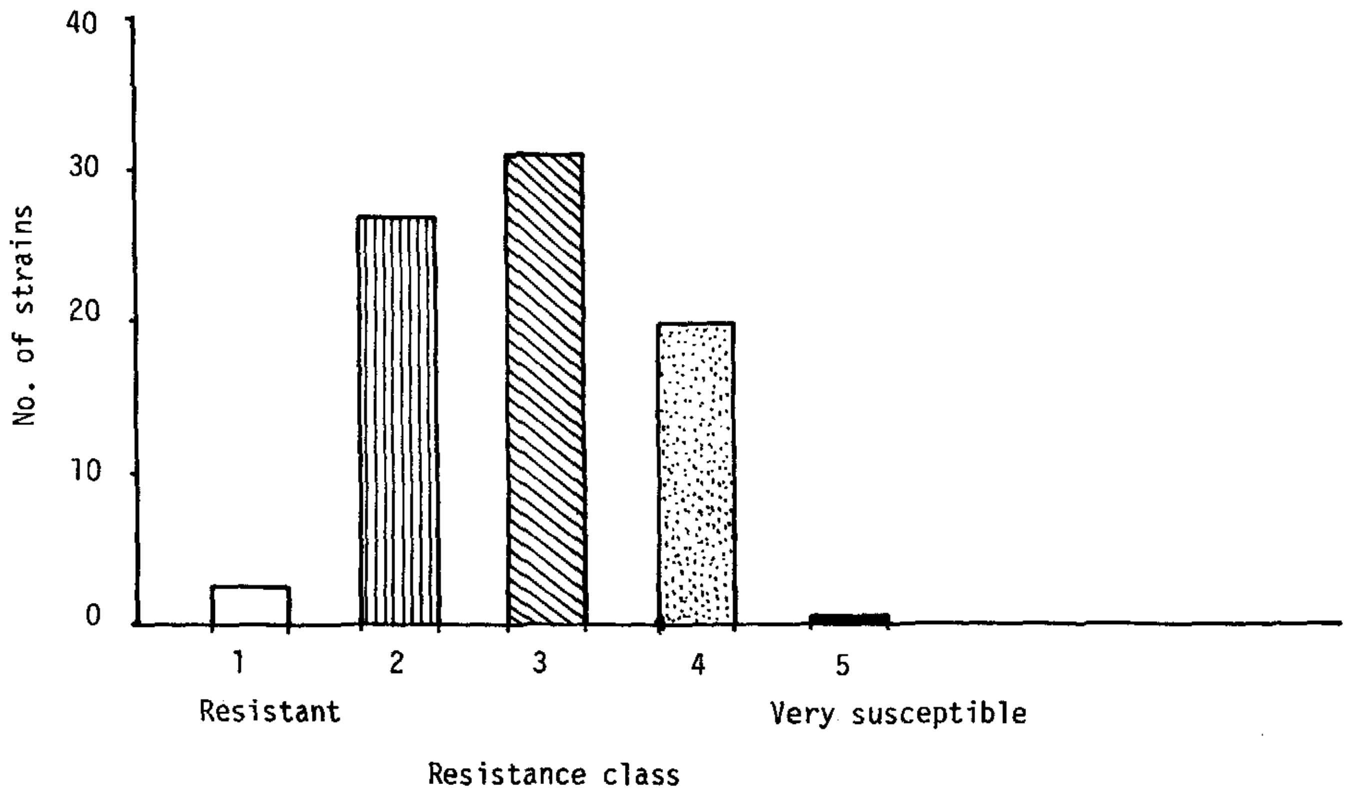
Observations were made after seed germination and continued throughout the growing season. Random samples of plants were taken to isolate the nematodes and to determine the degree of root infestation. Root symptoms were diagnosed as root-knots or root galls, excessive root branching, and injured root-tips.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

Mean numbers of cysts per 200 g soil, and of root-knot nematodes per 500 g soil are presented in Table 26. It shows that the soil was heavily infested by both nematodes, and was thus ideal for the screening experiments.

The preliminary observations confirmed that vetches are severely attacked by root-knot nematodes and peas are severely attacked by cyst nematodes. Only six strains of common vetch were attacked by both cyst and root-knot nematodes.

Three vetches (common vetch sels 2095, 1432, and woollypod vetch acc. 683) resistance (score 1) to root-knot nematode. (Fig. 35); 27 had moderate resistance and the remaining 51 were moderately susceptible or susceptible (scales 3 and 4). Those having scores of 1 and 2 have been selected for further screening. Resistance to

Fig. 35. Variability in resistance to root-knot nematode among 81 strains of vetch, based on the following scores: 1. resistant: no galls or very light galling; 2. moderately resistanct: light galling; 3. moderately susceptible: moderate galling; 4. susceptible: heavy galling; 5. very susceptible: very heavy galling.



root-knot nematode increases the value of woollypod vetch, which was also observed to be resistant to attack by the plant parasite *Orobanche* sp. The local common vetch was moderately susceptible to root-knot nematode.

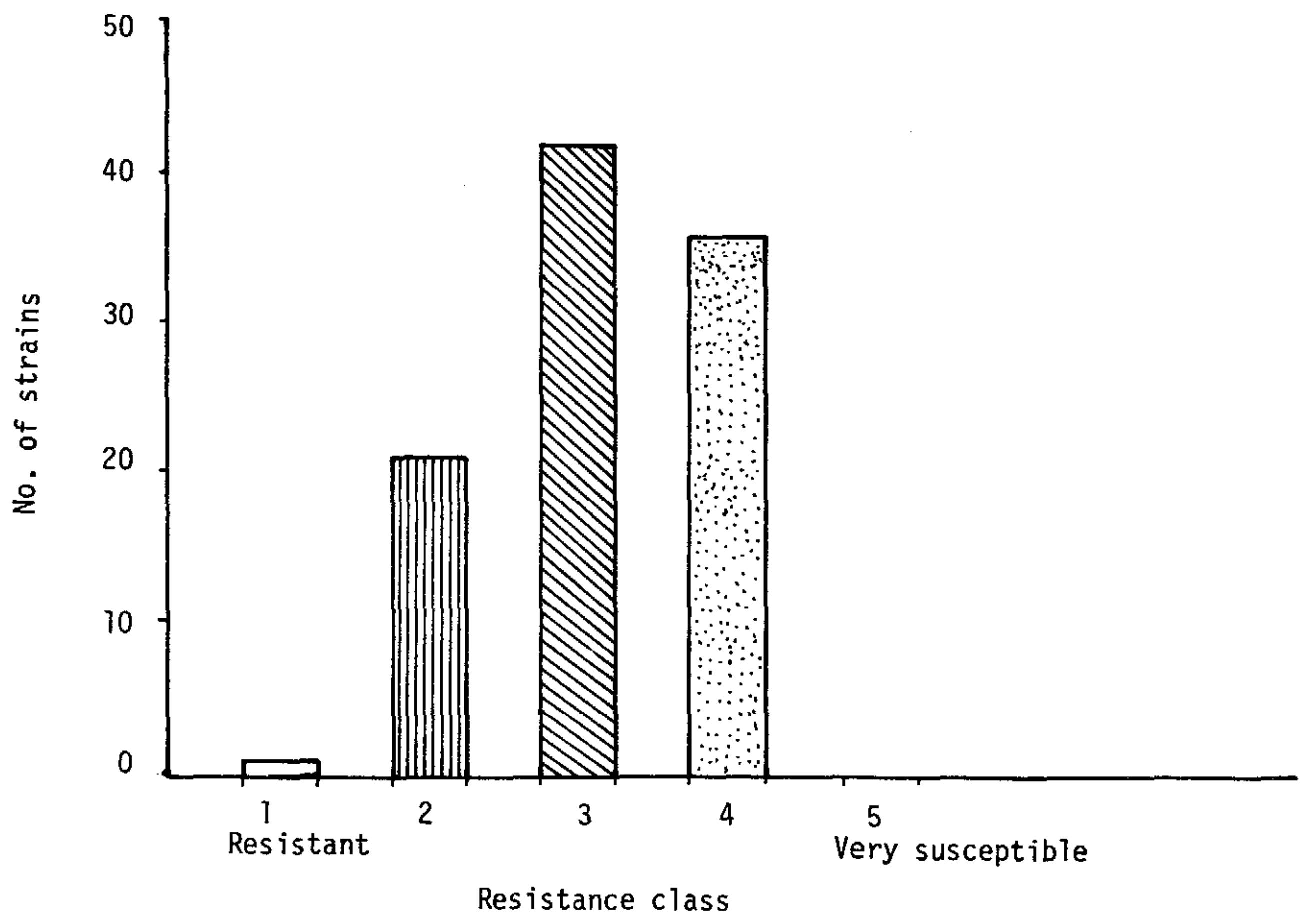
In forage pea, the mean number of cysts per g of roots was 471 varying from 9 (sel. 61) to 3021 (sel. 571). Field screening did not reveal any strains highly resistant to cyst nematode, but some were scored resistant (sel. 61) or moderatly resistant, (Fig. 36). In these initial tests, resistance was characterized by a small number of plants having roots with a few galls, the rest having none. These strains have been retained and will be tested under artificial infestation in a greenhouse.

Breeding non-shattering common vetches

One of the problems in using common vetch is that the pods shatter, and seeds fall to the ground. This makes harvesting time critical and inevitably results in lower seed yields and higher prices. Since the high price of seed is one of the constraints to the use of common vetch, varieties with the ability to retain their seeds would be of great value. Moreover it would greatly improve the feed value of standing vetch crops which are used for grazing in summer: loss of seeds is a serious loss of nutrients, especially protein.

In 1983/84, certain strains of common vetch characterized by a high proportion of non-shattering pods were found. A breeding

Fig. 36. Variability in resistance to cyst nematode among 100 strains of forage pea. (Details as for Fig. 35).



program was initiated in 1984/85 to combine the non-shattering character with other desirable traits, such as high herbage production, high seed yield, early flowering and maturity, and disease resistance.

A number of crosses were made using as parents sels. 1361, 1416 and 2014, all of which are characterized by non-shattering pods, late flowering, and low herbage and seed yield, and sel. 716 and the local common vetch (acc. 2541) both of which are characterized by a high proportion of pod-shattering, early flowering, and high herbage and seed yield. All crosses were in the greenhouse, and the combinations and number of pods set are shown in Table 27.

The F1's will be sown in the field along with their parents, for the production of F2 populations. These will be studied to find out the type of gene action controlling the non-shattering character, and selections of non-shattering strains with good agronomic features will begin.

ROTATION EXPERIMENTS

Wheat grain yield after pastures and forages

An adequate feed supply is essential for the rapidly increasing livestock population of west Asia and north Africa. As has already been discussed, this can be achieved through intensive forage and pasture production on available arable land. However, for this to happen several problems are still to be resolved. Some of them are technical (varieties, seed supply, management etc.) but others are educational since many farmers in the region have not grown pasture or forage crops before. One important concern for farmers would be the effect which these pasture and forage crops will have on the grain yield of cereal grown in the following year. An experiment was therefore established in 1983/84 to study the long-term effect (4-5 years) of pasture and forage crops on grain yield of wheat. The experiment was located in four wheat growing areas of Syria: Kamishly (north east Syria), Tel Hadya, Hama (central Syria) and Izraa in the southern part of the country. There are four treatments (wheat, medic, forage mixture and fallow), each of which is rotated on the same piece of land with a wheat crop. There is a two-phase start to each treatment, both alternative crops for each rotation being present in each year.

The cultivars are: wheat (cv. Mexipak), medic (M. rigidula sel. 1295), and vetch (sel. 2541) are barley (cv. Badia), the last two being used in equal proportions as a forage mixture and the rotations are wheat/fallow, wheat/forage mixture, wheat/medic, and wheat/wheat. The experimental plot size is 8 x 21m and the treatments are laid out in a randomized complete block design with 3 replicates. At the beginning of each season soil samples (depth 0-20cm) representing the various treatments are being collected for monitoring changes in soil nitrogen.

Grain yields in the 1984/85 season are given in Table 28a. At all locations, wheat yield was lowest after wheat compared with other treatments except in Kamishly, where there were no significant

Table 28. (a) Wheat grain yield (t/ha) in relation to the preceeding crop or fallow and (b) the dry-matter yield (t/ha) of pasture and forage crops at four locations in 1984/85.

(a) Location	Rotation W/Fallow	W/Mixture	W/Medic	W/W	LSD (P=0.0.5)
Izraa	1.3	1.0	0.9	0.4	0.6
Hama	4.0	3.0	3.1	2.5	1.2
Tel Hadya	1.4	2.2	2.5	1.3	1.1
Kamishly	2.5	2.3	2.4	2.3	NS
Average	2.3	2.1	2.2	1.6	

(b) Location	Medic	Forage mixture
Izraa	-	4.2
Hama	2.0	5.2
Tel Hadya	2.5	4.6
Kamishly	2.6	4.6
Average	2.4	4.7

W = wheat

differences. The result at Kamishly may be attributed to very poor crop growth at this location in 1983/4 due to frost followed by drought. At both Izraa and Hama, the highest grain yield was recorded after the fallow although the difference was not significant when compared with the yield after either medic or forage mixture. At Tel Hadya the highest grain yields were after the medic and forage treatments. In this location, the yield after medic was highest but not significantly higher than after forage.

Forage yields are given in Table 28b. They ranged from 2 to 2.6 t/ha for medic and 4.2 to 5.2 t/ha for the forage mixture. For forages, these values are comparable with yield levels from the same locations recorded in previous studies, but medic yields, were lower than expected especially at Tel Hadya.

Average grain yields for the four locations (Table 28a) were approximately the same after the three treatments fallow, medic and mixture. This would suggest that the above forage production levels can be obtained on arable land, in replacement of fallow, without any deleterious effect on subsequent grain yield. However, a final conclusion should not be made until there are several more years of data.

Impact of seed ratio in forage mixtures on yield of grain in the following year

The advantages of legume-cereal forage mixtures over their monocultures have been reported in the 1983 and 1984 Annual Reports.

It was concluded then that vetch-cereal or pea-cereal mixtures gave the best yields and qualities. Moreover vetches and peas grow taller when present in mixtures with barley, triticale or oats and thus are easier to harvest. However, since forage mixtures are to be produced in a rotation with grain crops, it is essential also to consider their impact on grain yield.

In previous studies the effect of the legume-cereal proportion on forage productivity was evaluated. In the present experiment the effect of varying seed ratios on grain yield in the following cereal year is examined. The experiment also assessess the need for nitrogen fertilization by the grain crop following these mixtures.

In the 1983/84 season six forage mixtures were established consisting of vetch or pea each of which was grown with three cereals (barley, triticale or oats). Each mixture was sown at 3 alternative seed rates (120, 160, 200 kg/ha) and there were also 5 legume-cereal seed ratios (0:100, 33:66, 50:50, 66:33 and 100:0). Seed rates were laid out as main plots and the seed ratios as subplots, the treatments being replicated 3 times. Areas for main and subplots were 52.5 and 10.5 m^2 respectively. The plots were harvested for hay in April 1984.

Barley was grown for grain in the 1984/85 season on the plots previously used for forage mixtures. The plots were cultivated in November to a depth of 10 cm and sown to barley on December 4, 1984, using cultivar Badia at a rate of 100 kg/ha and fertilized with 40 kg P_2O_5/ha. Nitrogen fertilizer rates of 0, 20 and 40 kg N/ha were applied as main plot treatments in place of the seed rate treatments of the original experiment, since the latter gave no significant differences in forage yield. Nitrogen was applied by hand (broadcast), one half of the total amount at time of sowing, the other half two months later. Barley was harvested on June 9, 1985.

Results of the effect of seed ratio and nitrogen rate on grain yield are given in Table 29. There were only small differences among cereal species in their effect on subsequent grain yield, so the results for them are combined. Barley yield increased with increased nitrogen rate at all seed ratios of both vetch-cereal and pea-cereal. Both 20 and 40 kg N/ha gave a significantly higher ($P<0.05$) average yield than the control, but there were no significant difference between N rates. Grain yield was highest after the pure legumes (100:0), lowest after pure cereal (0:100), and increased with increasing proportion of legume in the previous year. There were no significant differences between grain yields after pure vetch and the 66:33 vetch-cereal mixture or between yield after pure pea and the 50:50 pea-cereal mixture.

The highest grain yield was recorded after pure legumes or mixtures containing a high legume proportion. While the effect of nitrogen input by the legumes cannot be overlocked, similar findings by Rovira (1980)* in Australia on wheat yield after medic and peas and by Cocks (personal communication) on wheat after medic were attributed to the control of cereal root disease by the legumes. - **A.E. Osman**

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* Rovira, A.D. (1980). Proc. Int. Congr. Dryland Farming, Adelaide, South Australia, pp 546-580. South Australian Department of Agriculture, Adelaide, Australia.

Table 29. Yield of barley grain (kg/ha) as affected by nitrogen rate and the seed ratio (%) of the preceding vetch-cereal or pea-cereal forage crop.

Nitrogen rate (kg/ha)	seed ratio 0:100	33:66	50:50	66:33	100:0	Mean
			Vetch-cereal			
0	1581	1920	2098	2069	2195	1972
20	2488	2584	2521	2538	2979	2622
40	2726	3021	2947	3496	3398	3117
Mean	2265	2508	2522	2701	2857	
			Pea-cereal			
0	1658	1849	1966	2074	2511	2011
20	2469	2750	2995	2488	2849	2710
40	2941	2876	3354	2983	3285	3087
Mean	2356	2491	2771	2515	2881	

	Vetch-cereal	Pea-cereal
LSD (P=0.05) for nitrogen rates	620	422
LSD (P=0.05) for seed ratio	287	338
LSD (P=0.05) for seed ratio within nitrogen rates	NS	NS

Marginal land improvement

The importance of marginal land is extensively discussed in the 1984 Annual Report. At present this land is characterized by low productivity, and animals using it are heavily supplemented from various sources. Improving the productivity of this land is therefore expected to reduce the need for supplementation and increase its carrying capacity. Moreover, in western Syria, marginal land constitutes about 30% of the total surface and up to 60% of the land of some villages, therefore its improvement is important for the village economy as well as for the country as whole. However, due to the nature of this marginal land, improvement is faced with many difficulties. By its nature it is not arable: if it were, it would be sown to barley or some other crop. It is often steep, usually stony and the soils are often shallow. It is intensively grazed and in many cases severe soil erosion occurs. Nevertheless we believe three possibilities exist for improving marginal land productivity. The first, and possibly the only method applicable to marginal land with low rainfall (<300 mm) is to change grazing management so that grazing pressure is eased during the critical period of seed set. The second method is to change botanical composition by sowing improved pasture species. The third possibility is to apply suitable fertilizer(s). Both the second and third approaches would require favourable climatic conditions and proper grazing management.

Effect of fertilizer application on marginal lands

In this study the third approach (fertilizer application) is being tested at Tel Hadya where a long-term experiment has been designed to look into three aspects of marginal land development:

- the effect of phosphorus application on the botanical composition of grazed pastures with particular reference to its effect on legume content and hence its responsiveness to phosphorus
- the economic results of phosphorus application in terms of animal productivity
- the effect of stocking rate and its interaction with phosphorus application on the stability of the marginal land ecosystem

The experiment consists of 3 rates of superphosphate (0, 25 and 60 kg P_2O_5/ha equivalent to 0, 10, 24 kg P/ha) and two rates of stocking: low (1.2 ha/sheep) and high (0.6 ha/sheep). The treatments are arranged in a randomized complete block design with 3 replicates. The total area for the experiment is approximately 83 ha. In the present season the animals were excluded from the experiment while waiting for the completion of plot fencing, therefore the research was restricted to the effect of superphosphate application on the natural vegetation.

Fertilizer (triple superphosphate) was broadcast by hand in early November 1984 following soil sampling at a depth of 0-10cm for phosphorus analysis. The herbage was sampled on six occasions, at monthly intervals from December to May. At each sampling date, ten samples were collected from each plot along a transect between two opposite corners. Each sample consisted of four cylindrical units (10.5cm diameter) taken at a depth of 10cm, removing the plants together with a large portion of their root systems. These were separated in the laboratory into legumes, grasses and other species, and the number of plants of each was recorded. The roots were separated and discarded and the shoot portion of each category was dried ($70^{o}C$) and weighed. Samples were stored for chemical analysis.

Seed yield was measured in June. Twenty and forty quadrat samples (50 x 50cm) were taken from the high and low stocking rate plots respectively, taking all vegetation and the top one cm of soil. Seeds were separated from the soil and vegetation of each sample, bulked, counted and weighed.

Analytical results indicate that the soil is low in phosphorus (Fig. 37): over 87% of the samples analysed had values less than 10 ppm. The effect of fertilizer application on dry-matter yields of legumes, grasses and weeds is shown in Figures 38, 39 and 40 respectively. In each case the yield in kg/ha was plotted against the number of days after phosphorus application, and regression lines were fitted. The total herbage yield (grasses and legumes) is plotted against days after fertilizer application in Fig. 41. While the phosphorus application appeared to have resulted in a total yield increase for the most significant individual increase was recorded in the legume component. The slope of the regression lines for the 25 and 60 kg/ha rates were significantly greater than that of the control (Fig. 38).

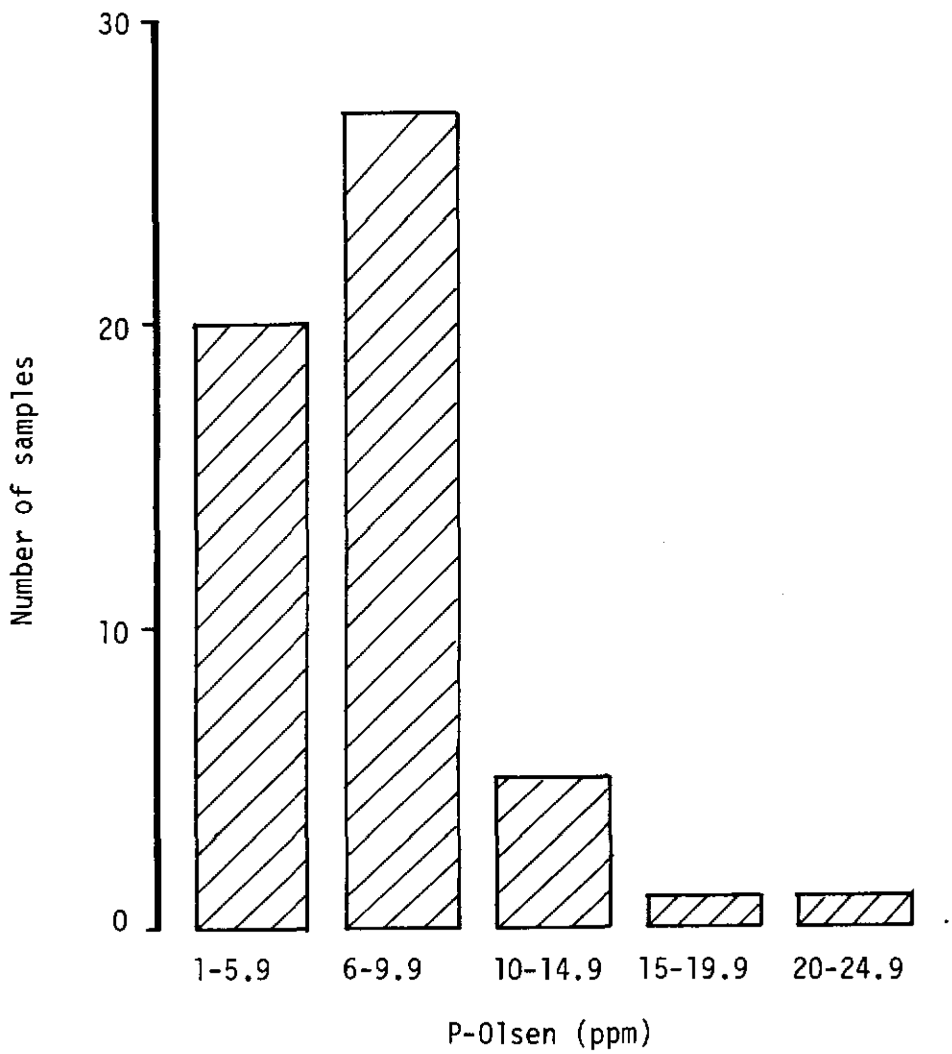

Fig. 37. Distribution of phosphorus levels (ppm) in 54 soil samples from marginal land prior to the application of superphosphate fertilizer.

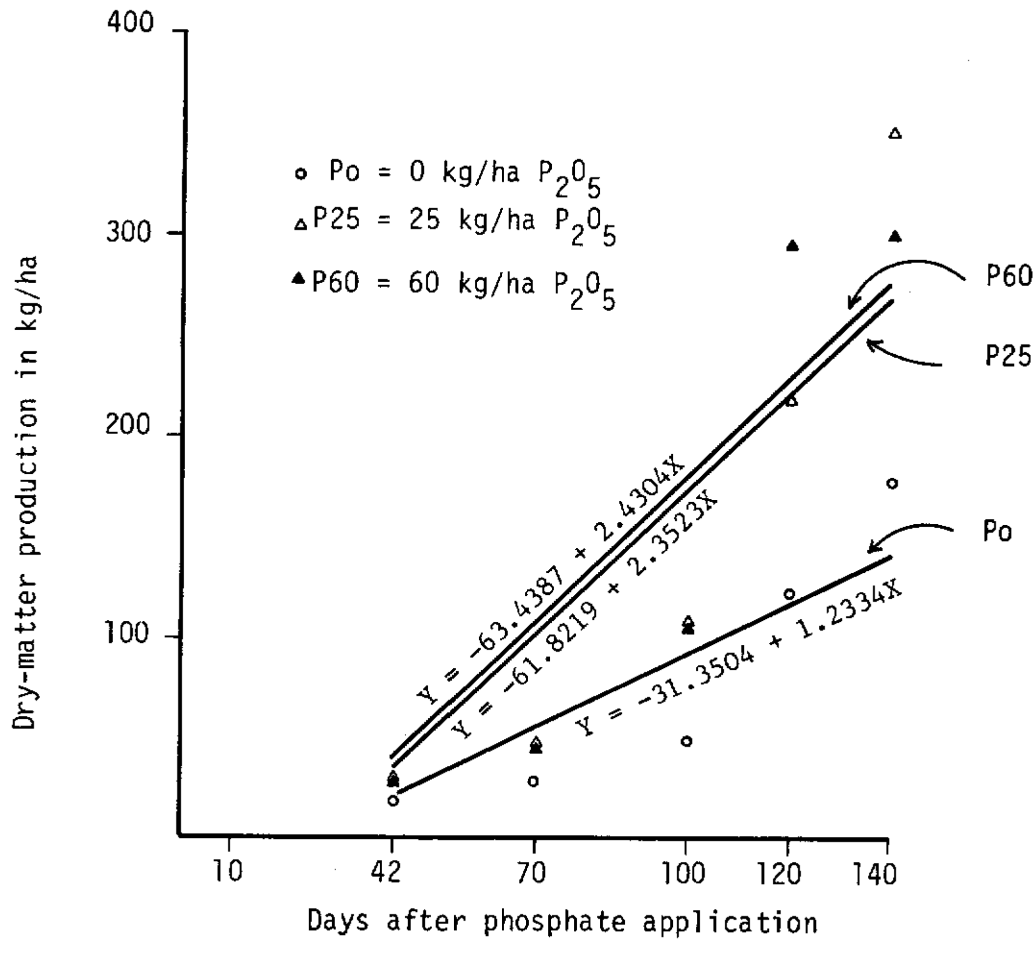

Fig. 38. Dry-matter production of legumes in kg/ha as influenced by phosphate fertilizer in 1984/85 season.

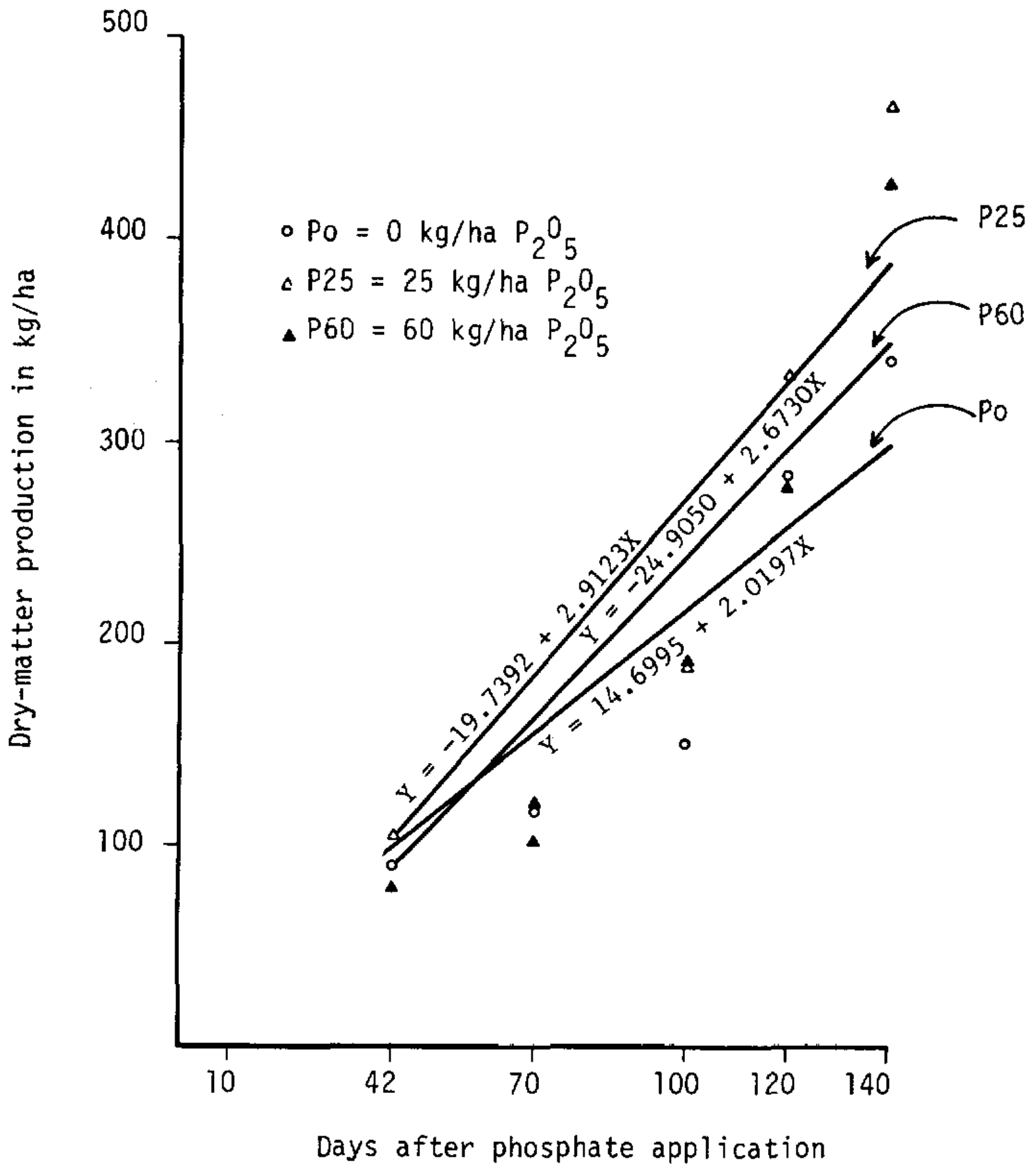

Fig. 39. Dry-matter production of grasses in kg/ha as influenced by phosphate fertilizer in 1984/85 season.

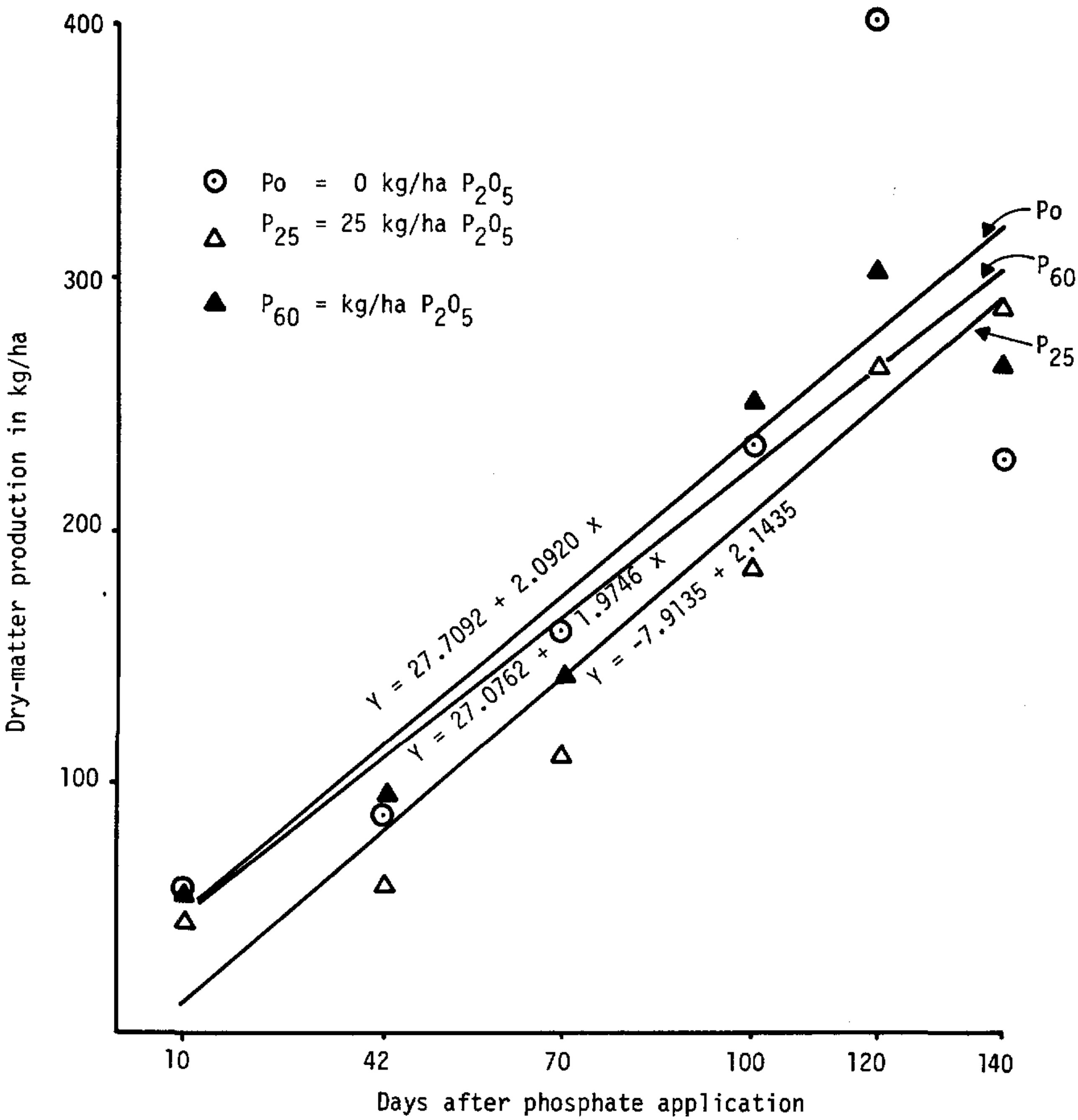

Fig. 40. Dry-matter production of weeds in kg/ha as influenced by phosphate fertilizer in 1984/85 season.

A significant improvement in total herbage yield (legume + grass) as the result of fertilizer was recorded at the March sampling (100 days after application) and this continued through the rest of the growing season (Fig. 41). A survey carried out in April 1985 indicated that over 40 legume species were present in the plots (Table 30). The most dominant species were T. campestre, T. tomentosum and T. stellatum.

The most important effect of the fertilizer, however, is probably the one shown in Table 31, where legume seed yield on marginal land was increased by 27 and 61% over the control as the result of applying 25 and 60 kg P_2O_5/ha respectively. This is expected to reflect favourably on legume growth, forage quality and more importantly on the sheep carrying capacity of the pasture in the coming season. - **A.E. Osman and L. Russi**

Ecology and productivity of marginal land near Terbol, Lebanon

In Lebanon only 23% of the total area is considered cultivatable, while marginal lands constitute over 50% of the whole area of the country. The latter is classified into four main categories - the hills and foot hills of the temperate zone, the temperate mountain ranges facing the Mediterranean Sea, the slopes of the Beka'a Valley, and the northern Beka'a Valley - all of which are used primarily for sheep and goat grazing.

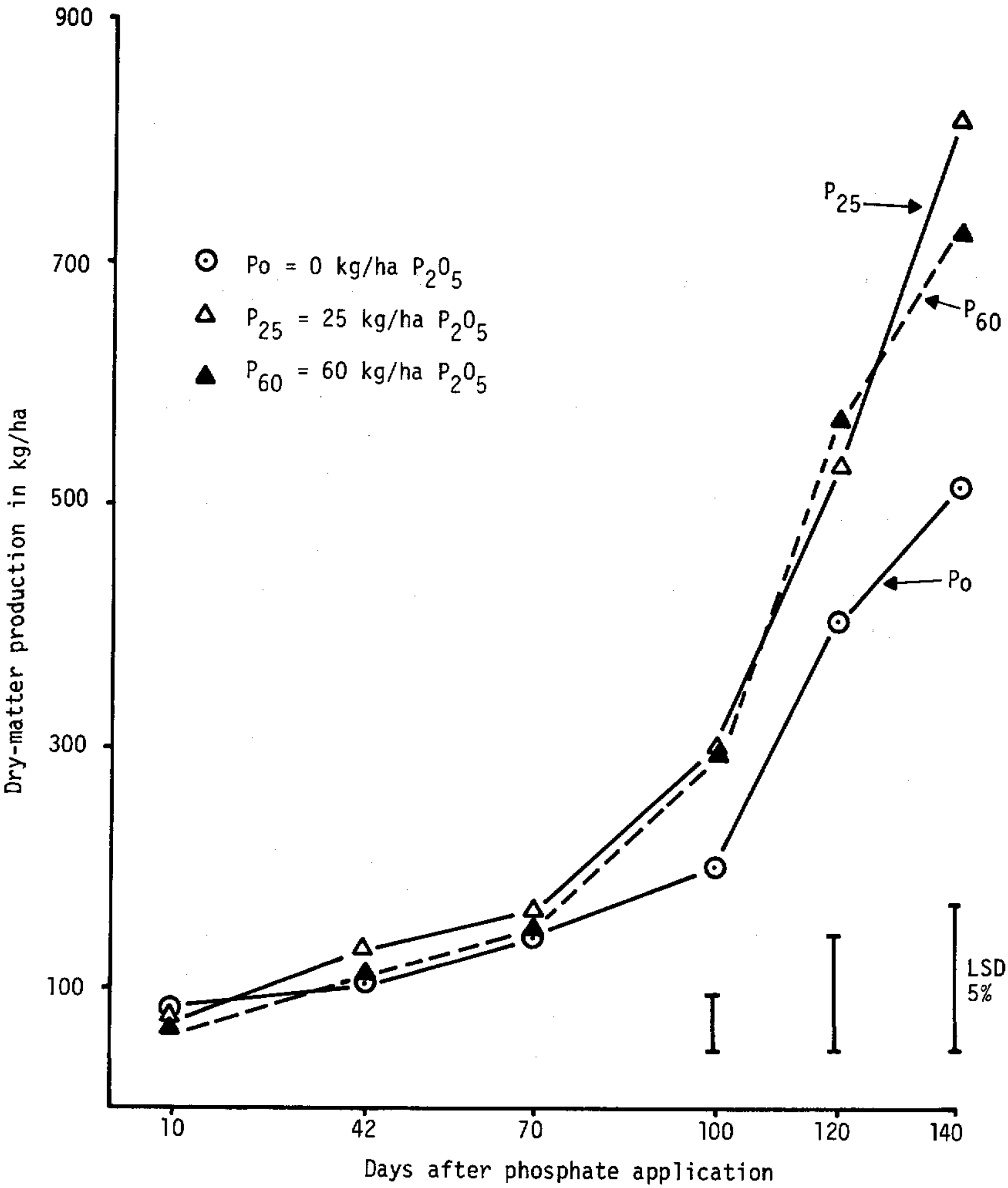

Fig. 41. Total dry-matter production of legume and grass species during 1984/85 season under different phosphate fertilizer levels.

Table 30. Legume species present in a survey of marginal land at Tel Hadya April 1985.

Astragalus hamosus	Trifolium stellatum
A. triradiatus	T. argutum
A. suberosus	T. pauciflorum
A. asterias	T. cherleri
Coronilla scorpioides	T. tomentosum
C. sp.	T. scabrum
Hippocrepis unisiliquosa	T. spumosum
Hymenocarpus circinnatus	T. campestre
Lathyrus aphaca	T. haussknechtii
L. incospicuus	T. pilulare
L. annuus	T. angustifolium
L. cicera	Trigonella foenum-graecum
Medicago rigidula	T. stellata
M. coronata	T. astroites
M. rotata	T. mesopotamica
M. orbicularis	T. monspeliaca
M. minima	T. monantha
Onobrychis crista-galli	T. filipes
O. kotschyana	Vicia sativa
Ononis sp.	V. peregrina
Pisum sativum	V. villosa
Scorpiurus muricatus	

This report deals with one of the categories: the slopes of the Beka'a Valley. The land is generally steep with hills rising above 500 m. The soil is shallow and covered with rocks which in some areas occupy over 50% of the land surface. In early winter, spring and early summer, the area is heavily used for grazing by sheep and goats. In late summer, animals from nearby villages pass over the land on the way to the Beka'a Valley to feed on crop residues. The land is controlled by individual villages or groups, but grazing is not controlled, therefore accessible areas are overgrazed. A survey conducted in the spring of 1985 revealed that goat grass (Aegilops triuncialis) and bulbous barley (Hordeum bulbosum) are the most dominant species. The former is often considered to be an indication of overgrazing under Mediterranean conditions. Although several legume species are present such as Trifolium stellatum, T. pilulare, T. tomentosum, T. subterraneum, Medicago rigidula, M. orbicularis and Hymenocarpus circinnatus - their contribution to the overall productivity of the pasture is low.

The aim of work carried out in 1984/85 was to collect data on the biological and environmental resource base of the grazing land of these mountain slopes and to relate soil fertility, plant genetic resources and plant numbers to the primary productivity and level of available herbage. Primary productivity was measured along five transects: two on north-facing slopes of two separate hills, one on a south-facing slope, one on a west-facing slope and the last in the valley between two hills. Each transect was about 200m long. Plant population, available herbage and total primary productivity were measured at 50 sites together with soil depth and soil chemical composition. Available herbage was measured at monthly intervals while total herbage was measured once at the end of the season after being protected in metal cages, 50 of which were placed along the transects in November 1984. Vegetation sampling was done using cylindrical quadrats as described for the marginal land work at Tel Hadya. The sampling was made at monthly intervals for six months (Nov - April). Two hundred samples were taken at each sampling date giving a total of 1200 samples. An additional 200 samples were taken in April from inside the cages (4 samples each) to estimate total productivity. Measurements on all samples were made as described for the work at Tel Hadya. Soil samples (0 - 10 cm) were collected in November from each site on the transect for chemical and physical analyses.

Seed yield was measured in early May: on open pasture and inside cages using 0.5m x 0.25m quadrats. The straw and the top 2cm of soil were collected, and the seeds were separated into species, counted and weighed.

Although full analysis of data is not yet complete, the results show that pasture productivity was low in winter (November - January) varying from 250 to 600 kg/ha and consisting mainly of grasses (Fig. 42), which contributed 65, 74 and 98% to the available herbage in November, December and January respectively. From the beginning of spring, legumes become a more important component of the pasture reaching 37% of the total in April. At this stage other broad-leaved plants were contributing 18% to total herbage.

Plant numbers varied through the season reaching a peak of more than $9000/m^2$ in December and falling to a little more than $1000/m^2$ in

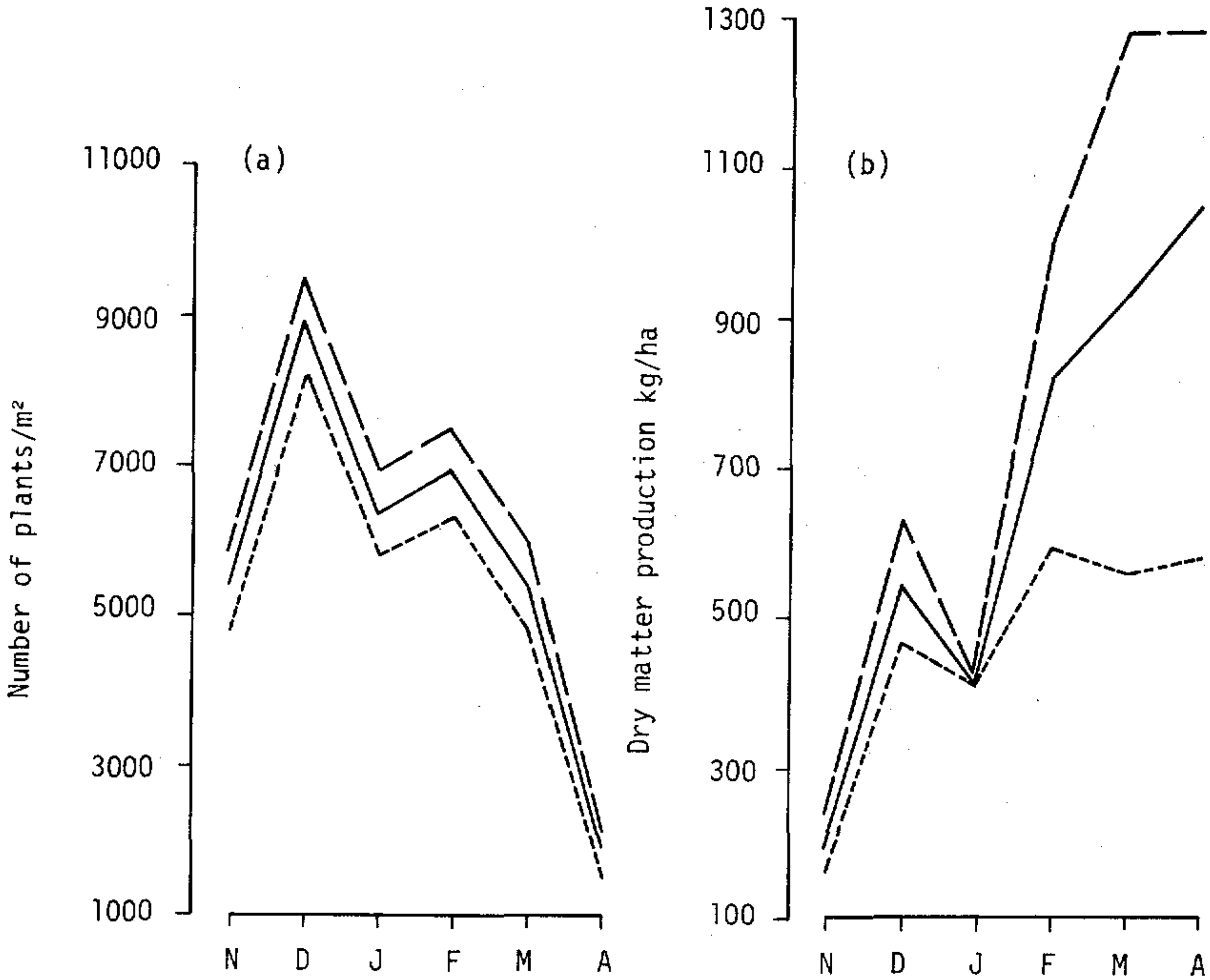

Fig.42. Number of plants per m² (a) and dry matter production in kg/ha (b) of grass (------), legume + grass (————), other species + legume + grass (— —) recorded at monthly intervals (Nov - Apr) on marginal land at Terbol, Lebanon in the 1984/85 season under grazing conditions.

April (Fig. 42). Although these numbers seem high they compare with up to 200,000/m^2 on similar land in California (Biswell and Graham 1956*). Moreover the number of legumes (500/m^2) is very low compared with the number necessary for maximum production at Tel Hadya (see page 40 of this Report).

The yield of pasture in protected plots was 1.8 t/ha in April. In view of the high rainfall (516 mm in 1984/85 season) and high soil phosphorus (35 ppm) this yield seems low. Reasons for this are being sought in current studies: possibilities include inadequate legume populations, and low overall plant numbers.

Several legume species were recognized at the site, the most dominant being clovers (Table 32). This suggests that sowing improved pastures comprising annual clovers may be the best way of increasing the productivity of this high rainfall marginal land. Commercial cultivars are available (especially of subterrenean clover) and are commonly used for improving the productivity of Mediterranean pastures with neutral to slightly alkaline soils, (soil pH of this site ranges from 7.1 to 7.9) in other parts of the world. It may not even be necessary to sow clovers since the total seed yield of legumes was 19 kg/ha in the open range and 27 kg/ha within the cages, suggesting that protection, even for only one year, will increase seed yield by 40% or more. It is clear that there are many options for improving this land. - **A.E. Osman**

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* Biswell, H.H., and Graham, G.A. (1956). J. Range Management, 9, 116.

Table 31. Effect of superphosphate fertilizer rates on yield* (kg/ha) and seed number* of legume species on marginal land in 1985.

Fertilizer rate (kg/ha)	Seed yield	Seed number/m²
0	28.6	2072
25	36.6	3114
60	46.1	3995
LSD (P=0.05)	11.7	825

*Each value is an average of 180 quadrat samples.

Table 32. Seed yield (kg/ha) and seed numbers (seed/m²) of legume species in protected plots and on open range at Terbol in 1985.

Species	Protected		Open range	
	Yield	number	Yield	number
Hippocrepis unsiliquosa	0.2	4	0.1	2
Hymenocarpus circinnatus	0.1	2	0.5	9
Medicago rigidula	2.0	33	0.6	14
M. orbicularis	-	-	-	2
Trifolium stellatum	16.9	664	10.5	468
T. pilulare	5.5	210	4.3	175
T. tomentosum	1.0	104	0.1	23
T. campestre	-	-	-	6
T. subterraneum	0.1	3	1.0	29
T. scabrus	0.6	66	0.9	105
Trigonella sp.	0.9	110	0.8	106
Total	27.3	1196	18.8	939

LIVESTOCK MANAGEMENT AND NUTRITION

Livestock research is mainly concerned with the way in which forage crops, pastures, marginal land, and cereal by-products are used for meat and milk production. We work on sheep since they are the most important domestic animals in the ICARDA region. Included in our research is an animal health component - the study of internal parasites - but like the rest of our work, it reflects problems concerned with the feeding of sheep.

It is important to point out that the Program's livestock work includes extensive on-farm research. Particularly important is the forage utilization research being carried out at Breda in collaboration with the Farming Systems Program. Although reported by that Program, PFLP is heavily involved in the project and provides a significant proportion of the manpower and resources. Collaboration with other ICARDA Programs is of great importance, and this project in particular is a good example of inter-Program co-operation.

In 1985 several long-standing projects were concluded and the opportunity is taken to present the final year's results. Such projects include the effect of body condition on ewe fertility, cotton seed cake supplementation of ewes grazing stubbles, and seasonal patterns of parasite burdens in sheep. They also include the so-called Unit Farms project, which was completed this year, and which has been replaced by a new experiment to study sheep productivity in wheat/medic systems. A summary of Unit Farm data and some preliminary analyses using linear programming are presented. The three experimental flocks, subjected to contrasting levels of nutrition, will continue to be used for one more feeding trial before the complete data for six years are analysed.

The work on straw continued. Studies in 1985 concentrated on four main areas: the confirmation of in vivo differences in quality of barley straw using a wider range of cultivars; the effect of different supplements on the nutritive value of barley straw from contrasting cultivars; investigations on plant morphology in traditional barley cultivars (landraces) grown at Breda; and preliminary observations on variation in wheat straw morphology. The valuable contribution of the Tropical Development and Research Institute, London, is again acknowledged.

Unit Farms: a basis for profitability analysis

The Unit Farm project at Tel Hadya was completed after six cropping cycles. This project aimed to compare the biological productivity and profitability of various combinations of cropped land, marginal land, and sheep. The main elements of the project were: two 3-year rotations on deep soil; two 2-year rotations on shallow soil; three experimental flocks; and three adjacent areas of unimproved marginal land.

A traditional 3-year rotation - wheat/lentils/summer crop (water melon), typical of the Tel Hadya area - was compared with one in which a forage crop replaced lentils and 'improved' management practices were adopted (Table 33). A traditional 2-year rotation - barley/fallow - also typical of the poorer cultivated land around Tel Hadya was compared with a barley/forage legume rotation, again using improved management practices. The latter included reduced tillage, higher fertilizer levels, better crop varieties, and machine-planting.

Table 33. Rotations, area of cropped and marginal land, and stocking rate of two Unit Farms having traditional or improved management.

	Unit Farm	
	Traditional	Improved
Rotation[1]:		
- shallow soil	B/F	B/V
- deep soil	W/L/S	W/H/S
Cropped land area (ha):		
- shallow soil	4.0	3.0
- deep soil	10.3	7.8
Marginal land area (ha)	9.9	9.9
Stocking rate (sheep/ha):		
- cropped land	2.87	4.44
- marginal land	4.14	4.85

[1]B= barley, F=fallow, V=vetch, W=wheat, L=lentils, S=summer crop (water melon), H=vetch-wheat hay.

The experimental flocks of genotypically similar sheep were subjected to a low (L), medium (M) or high (H) level of nutrition during pregnancy and lactation. In summer all flocks grazed cereal stubbles or marginal land and the H flock received some supplementary feed. The M flock was attached to the land cropped using traditional practices amd the H flock to the land cropped using improved management practices. The L flock was supported only by marginal land. The L, M and H flocks contained 30, 30 and 35 ewes and 10, 10 and 12 female yearlings respectively, and one ram except during the mating season when a second ram was added. These differences in flock size resulted in a higher stocking rate on the Unit Farm managed according to improved practices (Table 33).

The differences in productivity between the traditional rotations and those using a forage crop and improved management were considerable. Although wheat yields in the 3-year rotation were increased by only 10 to 20% (Table 34), barley yields with the 2-year rotation were increased by 39%. The fact that the improvement in yield of wheat was lower than that of barley, even though they were grown on deep and shallow soils respectively, suggests that the management practices applied to the wheat may not have been ideal. This is confirmed by the low hay yields which were a little higher than those of lentil straw. Yields of straw reflected grain yields although improved wheat varieties tended to produce 22 to 25% more straw than Hourani, the local variety. The yield of water melon was similar in the two rotations and lentil yields were typical of the area.

Table 34. Crop yields at two levels of management (quadrat data from 1980 to 1985).

Crop yields (kg/ha)	Management level		SED
	Traditional	Improved	
Wheat grain	1877	2328[1] 2034[2]	178.8
Barley grain	1600	2639	225.7
Water melon	3945	4162	672.9
Wheat straw	3690	3772[1] 4567[2]	547.4
Barley straw	2524	3507	1519.1
Lentil grain	1072	-	-
Lentil straw	2376	-	-
Vetch/wheat hay	-	2814	-
Vetch pasture	-	2292	-

[1]Durum wheat.

[2]Bread wheat.

In addition to generating a considerable volume of biological data, the project provided information for a linear program which will be of great value for comparing the whole-farm profitability of several systems and will assist in the development of better ways of using marginal land. A model was developed which divides the year into four discreet periods according to the reproductive calender of the local Awassi sheep as follows: June to September - mating; October to December - pregnancy; January and February - early lactation; and March to May - late lactation. For any combination of cropped and marginal land, the model determines maximum profit and optimum combinations of crop sales, feed purchases, grazing management and ewe numbers. A summary of some initial results are presented here, while a complete analysis for six years, taking seasonal variations into account, will be reported next year.

Initial runs were made for the following conditions: no sales of straw, hay or stubble were permitted; sales or feeding of wheat and lentil grain were optional; each ewe had an annual replacement value of 100 Syrian pounds; and capital for the purchase of ewes was unlimited. Upper limits on dry matter intake, and lower limits on metabolizable energy and crude protein were specified for each flock and each period. The eighteen solutions shown in Table 35 compare the two 3-year rotations either alone, or with 10 ha of unimproved or 10 ha of improved marginal land. These combinations were tested using the L, M and H flocks separately. Results from the 2-course rotations are not reported here.

The addition of unimproved marginal land to a farm using the traditional rotation almost doubles the number of ewes required for

Table 35. Optimal ewe numbers and maximum profits from two crop rotations, various mixes of cropped and marginal land and three levels of flock nutrition.

Cropped/marginal land (ha)	10/0			10/10			10/10 +[1]		
Level of flock nutrition	Low	Medium	High	Low	Medium	High	Low	Medium	High
<u>Traditional rotation</u> (wheat-lentil-melon)									
No. of ewes	19.9	19.1	10.9	36.0	27.4	23.5	52.9	52.6	40.6
Max profit (000'SL)	9.8	9.6	9.2	12.4	12.8	12.4	13.3	14.4	14.3
<u>Improved rotation</u> (wheat-vetch-melon)									
No. of ewes	40.8	38.2	25.6	54.4	51.9	34.4	70.4	65.4	43.6
Max profit (000'SL)	15.3	16.2	16.1	16.9	18.3	18.2	17.9	19.6	19.6

[1] With 25 kg/ha P_2O_5 applied to marginal land.

maximum profit, yet profits increase by only 25%. Improving the marginal land by applying 25 kg/ha of phosphate increases optimum flock size by a further 47 to 92% and profits by a smaller but significant amount. The addition of marginal land to vetch rotations increases ewe numbers by 72% and profits by 21%. A major difference between the two rotations was the projected doubling of flock size caused by replacing lentils with vetch if no marginal land were available. Where marginal land was improved, the projected increase in optimal flock size was only 33% compared with the unimproved land, and in this case profits improved by a similar amount. Shifts from grazing vetch to harvesting it as hay accompanied the change from the low to the high nutritional regime.

Changing from the low to high level of nutrition involves a reduction in flock size for every combination of cropped and marginal land. But profits increased in most cases by switching from low to medium levels of nutrition. Profits at high nutritional levels never exceeded those at medium nutritional levels because the extra feed requirement of the better fed flock was greater than the relatively small improvements in meat and milk production.

This analysis of the Unit Farm results by linear programming shows how the introduction of a forage crop into a rotation should result in a substantial increase in profit. The results help to define the best crop/livestock combination which depends on the availability of cropped and marginal land. More detailed analyses using the same method will help to define the sheep performance necessary to make improved feeding regimes profitable. The method will also assist scientists to choose combinations of rotations, crops, and marginal land which maximize profits to farmers using stable farming systems. - **E.F. Thomson, T.L. Nordblom (Farming Systems Program) and F. Bahhady**

Ewe body condition and fertility

The number of lambs born each year influences the profitability of sheep production and is profoundly affected by body condition, itself a function of the nutritional regime. Poor body condition occurs during summer when stubbles of low nutritive value are the only available feed resource. Defining the relationship between body condition and fertility is therefore an important goal since surveys have shown that lambing rate is below the genetic potential of the local Awassi breed in up to 90 percent of flocks. A three year study was therefore conducted to investigate this relationship. Liveweight was used as an indicator of body condition since a technique suitable for direct measurement of the latter has not been developed for this fat-tailed breed.

The three experimental flocks subjected to high (H), medium (M) or low (L) levels of nutrition, were used in the study. The average liveweight of the flocks was 41, 43 and 50 kg when mating took place in August and September each year. Vasectomised rams accompanied the ewes from early May until late July so that the effect of liveweight on the number of oestruses could be assessed without conception taking place. Thereafter intact rams accompanied the ewes until late October. The ram: ewe ratio was 1:15 and all rams carried a marker crayon to indicate that mating had occurred. The L flock grazed sparse native pasture (marginal land), while the M and H flocks also had access to cereal stubbles. In addition to grazing, the H flock received small amounts of supplementary feed.

The H flock was significantly heavier than the M and L flocks at mating, although the differences in daily liveweight gains of the flocks were not significant during the 56 day premating phase (Table 36). The frequency of oestrus increased with level of nutrition from the L to the H flock, the highest values for anoestrus occurring in the L flock, and the highest values for single or multiple oestruses occurring in the H flock.

There was a tendency for more M and H ewes to conceive at the first and second matings compared with the L ewes (Table 36). As a result, 26 percent of L ewes were mated three or more times compared with 7 and 11 percent in the M and H ewes. It also appeared that the frequency of conception during the first and second 17 days increased with ewe liveweight.

The relationship between lambing rate and ewe liveweight at mating is given in Fig. 43. A curvilinear relationship is expected for the breed since below 35 kg ewes become anoestrus and above 50 kg lambing rate reaches a maximum. However, a linear regression gave the best fit for the present results as liveweights were from 38 to 50 kg.

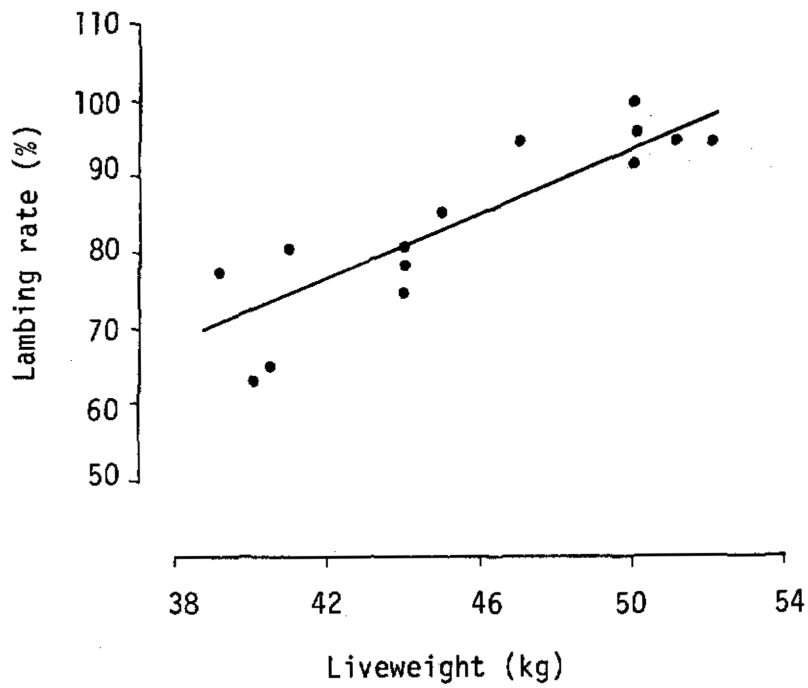
This study confirmed that liveweight of ewes at mating has a marked effect on reproductive function and fertility. The reproductive season of well nourished ewes starts earlier, oestruses

Table 36. The effect of level of nutrition on ewe liveweight, frequency of oestrus and conception rate.

	Level of nutrition			SED	Probability level
	Low (L)	Mediem (M)	High (H)		
Number of ewes	30	30	35	-	-
Pre-mating phase (56 days):					
- Daily liveweight gain, g	37	22	46	19.5	0.495
- Frequency of oestrus[1]:					
- zero	53	31	9	10.4	0.016
- one	30	40	38	7.7	0.438
- two	15	26	41	7.9	0.047
- three	2	3	13	7.8	0.421
Mating phase (68 days):					
- Liveweight at mating, kg	41	43	50	1.7	0.004
- Conception rate[1]:					
- first mating	56	70	69	14.3	0.538
- second mating	18	23	20	13.4	0.733
- subsequent matings	26	7	11	12.8	0.213

[1]Percentage of ewes in category.

Fig. 43. The influence of ewe liveweight at mating on lambing rate: the fitted regression was significant at $P<0.001$ ($r^2=0.75$).



are more frequent and conception rates are higher, compared with ewes in poor condition. Contrary to modern management thinking, traditional systems which allow continuous presence of rams and the associated long lambing season, also ensure satisfactory lambing rates, and a supply of milk products to the family or for sale, over at least six months of the year. These aspects must be considered when designing management strategies which allow the maximum fertility of the breed to be reached. - **E.F. Thomson and F. Bahhady**

Helminth burdens of sheep

Measuring the severity of helminth infections in sheep and the egg laying pattern of parasites are necessary before deciding on appropriate control measures. This was the major goal of a recently completed 18-month survey which used sheep selected from the L, M, and H flocks. The nutritional regimes imposed on the sheep made it possible to assess their tolerance to a parasite burden. The sheep had not previously been treated with anthelminthics.

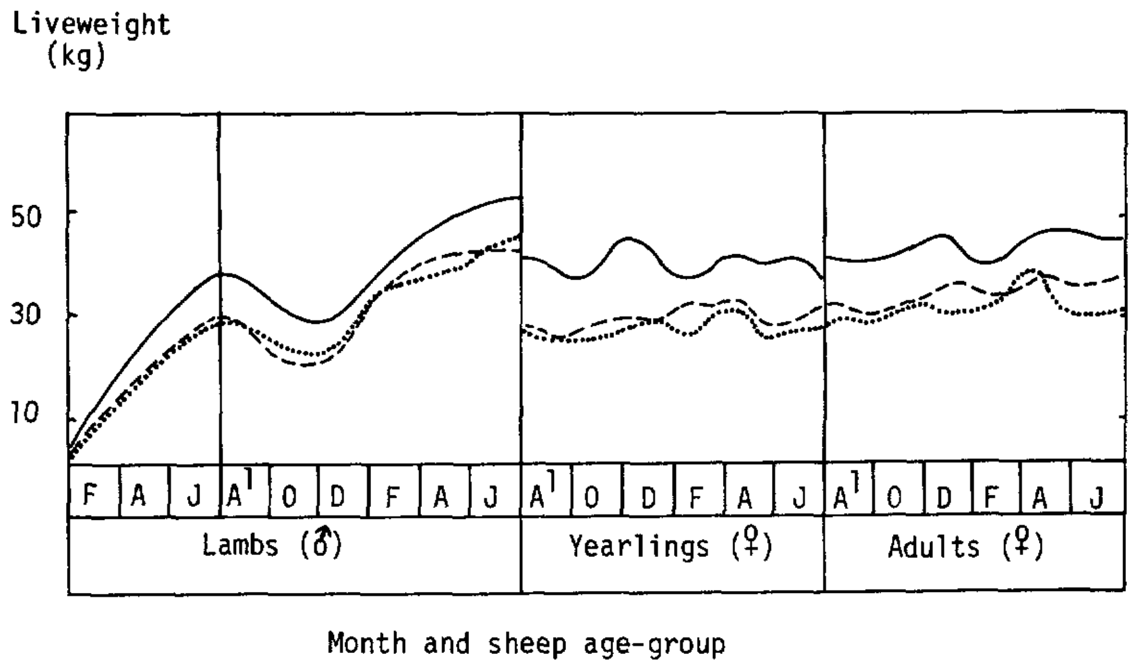
Six ewes, six female yearlings (one year old at the beginning of the survey) and six male lambs were selected at random from each of the three experimental flocks. This resulted in animals with contrasting body condition when monitoring of faecal egg and larval burdens began in February 1984. Monitoring of the lambs started one month after birth.

Eggs of easily identifiable nematodes (genera Nematodirus and Marshallagia) and cestodes (genera Moniezia) were extracted from faecal samples by flotation in saturated salt solution and counted using McMaster slides. Lungworms belonging to the nematode genera Dictyocaulus and Muellarius were counted as first-stage larvae after extraction from faeces. Results for Nematodirus and Marshallagia are expressed as eggs per g faeces, for Moniezia as present or absent, and for lungworms on a numerical scale from 0 to 3 where a value of 0.5 or less indicates a low level of infection and above 1.5 a severe infection.

The seasonal changes in sheep liveweight, air temperature, relative humidity and the level of infection with four of the above parasites are shown in Figs. 44 and 45, in chronological order to illustrate the transition from lambs to adult ewes, but the data for yearlings and adults were obtained concurrently with those for lambs. Patterns of nematode eggs and larvae in faeces are related to the climatic characteristics of the region and to host immunity. During the hot, dry summer when host immunity following spring infection is high, faecal egg counts are low since the parasites enter the arrested or hypobiotic phase. In the autumn, as immunity levels and temperatures fall and humidity rises, the parasites become active and faecal burdens increase until reaching a peak in spring. This peak is accentuated by the post-parturient rise in parasite activity associated with lambing in winter.

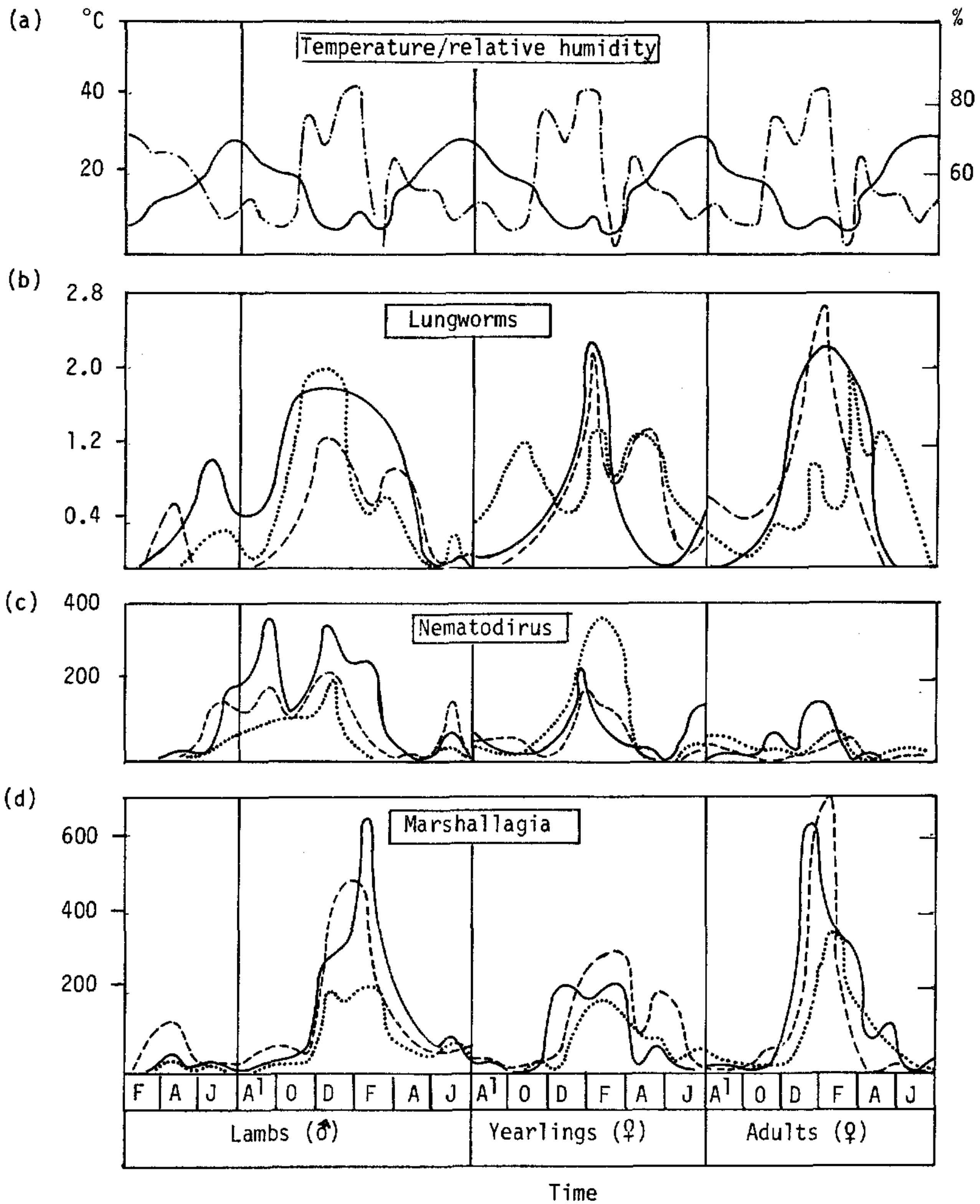
Differences in infection depending on age of sheep, level of nutrition, and nematode species were apparent during the season. Mean peak levels of infection from three observations in spring each

Fig. 44. Seasonal liveweight changes of male lambs, female yearlings and adult ewes subjected to three nutritional regimes. (Dotted, broken and solid lines represent low, medium and high levels of nutrition). Bimonthly means are given.



[1]August 1984.

Fig. 45. Seasonal changes in (a) air temperature (°C, solid line) and relative humidity (%, broken line), and faecal egg burden of (b) lungworms (infection score), (c) Nematodirus (egg per g faeces) and (d) Marshallagia (eggs per g faeces) of lambs (left), yearlings (center) and ewes (right) subjected to a low (dotted line), medium (broken line) and high (solid line) level of nutrition.



[1]August 1984.

separated by a month, were used to compare these factors. High number of lungworm larvae indicated severe level of infection in all groups of well nourished adult sheep, but only in the lambs of the poorly nourished flocks (Table 37). In the flock subjected to a medium level of nutrition, lungworm infections were high in yearling and adult ewes but low in lambs.

All egg counts were well below the threshold for a severe infection in both Marshallagia (2000 eggs per g) and Nematodirus (600 eggs per g). There was a tendency for lambs in the well nourished flocks to show heavier infection levels than in the L and M flocks, but this did not occur with yearlings and adults. Moniezia levels, which are not shown, were low and little affected by age of sheep or level of nutrition.

These results have to be interpreted with care since faecal egg counts can be a poor indicator of a parasite burden. There are also large differences in the pathogenicity of different helminth species which have to be taken into account. Lungworms are probably the only parasites which are likely to cause a loss of productivity in Awassi sheep at Tel Hadya. There is evidence that burdens in well nourished sheep may be higher than in poorly nourished sheep which may indicate the ability of the former sheep to tolerate a higher parasite burden without an effect on productivity. The continued reinfection of replacements and adults following the well known development of host immunity suggests that immunity is of short duration, a result contrary to reports in the literature.

Table 37. Peak faecal larvae and egg burdens of four nematode genera in sheep flocks subjected to three levels of nutrition.

Nematode genera	Age category	Level of nutrition: Low (L)	Medium (M)	High (H)	SED	Probability level
Dictyocaulus/ Muellarius[1]	Adults(♀)	0.7	2.2	1.9	0.55	<0.001
	Yearlings (♀)	1.2	1.9	1.8	0.72	0.163
	Lambs (♂)	1.7	1.0	1.6	0.45	0.018
Marshallagia (EPG)[2]	Adults	157	343	164	137.1	0.037
	Yearlings	158	179	145	123.6	0.890
	Lambs	186	428	425	99.9	<0.001
Nematodirus (EPG)[2]	Adults	35	25	97	58.7	0.080
	Yearlings	162	63	76	96.8	0.169
	Lambs	122	178	261	79.5	0.015

[1]Severity of infection: <0.5 = mild; 0.5 - 1.5 = moderate; >1.5 = severe.

[2]Eggs per gram faeces.

Future research will attempt to define the threshold at which lungworms affect productivity. Studies on Marshallagia and Nematodirus will cease since the recorded levels of infection are unlikely to reduce productivity.

Generous assistance from the Japanese International Cooperation Agency made this research possible. - **G. Orita and E.F. Thomson**

Ewe and lamb feeding

Barley grain and straw account for over half of the energy supplied by supplementaty feeds which are given in liberal amounts to sheep flocks in winter. Barley grain also forms an important component of the concentrate feeds offered to lambs in commercial fattening operations at several locations in Syria. Such feeds represent a large proportion of the direct costs of a sheep breeding or fattening operation and any way of increasing efficiency of feed use will markedly benefit profitability. Indeed, farmers are feeding such large amounts of supplements in winter that it appears unnecessary for flocks to be taken to grazing. This is particularly the case where marginal grazing is poor. Feed saved during winter and used in summer might have a positive effect on flock fertility. It might also be better to give some of the excess directly to lambs.

Experiments were conducted to study these questions. One experiment compared the performance of ewes and lambs receiving supplements in a grazing and a confined system. Two other experiments studied supplementation of suckling lambs (creep feeding) and the growth performance of intensively fed lambs. A final experiment investigated the effect of a protein supplement on the liveweight changes of ewes grazing cereal stubbles.

Supplementary feeding of grazing and confined ewes

The three experimental flocks were offered low (L), medium (M) and high (H) levels of supplementary feed during lactation, estimated to cover 100, 115 and 130 percent of the metabolizable energy (ME) needs respectively. Each flock was split to give confining versus grazing treatments. The former were penned while the latter spent about six hours on poor marginal land each day and were penned for the rest of the time.

The intakes of dry matter, (DM) ME, and crude protein differed significantly between flocks but not between management systems (Table 38). However, differences in ME intake between flocks became smaller when expressed on the basis of metabolic body weight ($kg^{0.75}$). Differences in liveweights, and liveweight changes of ewes were small. However, there was a tendency for penned ewes to lose more liveweight than when grazing, and losses were higher in the L than in the H flock.

Penning during pregnancy led to significantly heavier lambs at birth. However, at weaning, lambs in the grazing flocks were slightly heavier because they had a higher growth rate.

Table 38. Daily intakes by ewes of dry matter, metabolizable energy and crude protein, and liveweights and liveweight changes of ewes and lambs until 56 days after lambing.

Level of nutrition	Low		Medium		High		
Mangenent system	Grazed	Penned	Grazed	Penned	Grazed	Penned	S[1]
Ewes							
Number of ewes	6	4	8	9	20	7	-
Daily intakes:							
- dry matter, g	928	952	1249	1230	1601	1753	150.5
- metabolizable energy, MJ	10.8	11.1	13.8	13.6	17.1	19.2	1.68
- met. energy, kJ/MBW[2]	755	784	833	857	970	973	75.8
- crude protein, g	120	123	141	139	180	198	17.3
Liveweights, kg:							
- start lactation	38.2	40.2	46.2	45.5	50.7	57.9	4.41
- after 56 days	34.2	33.3	41.9	40.1	47.1	53.5	4.06
- daily gain, g	-73	-123	-76	-96	-64	-80	52.6
Lambs							
Number of lambs	6	4	8	9	20	7	
Liveweights, kg:							
- birth weight	4.1	4.5	4.8	4.6	4.8	5.5	0.51
- after 56 days	14.8	13.1	17.7	16.4	16.6	16.2	1.89
- daily gain	190	151	230	207	211	186	30.7

[1] $\sqrt{\text{residual mean square}}$.

[2] Metabolic body weight.

Grazing ewes removed 200 to 300 kg DM/ha from the native pasture which offered 400 to 700 kg DM/ha at the start of winter. Herbage grazed was barely sufficient to give a slight liveweight increase. However, when herbage on offer falls below 300 kg DM/ha it may become advantageous to confine flocks. Such levels of herbage were recorded for Bueda marginal land in the 1983/84 winter. - **E.F. Thomson and F. Bahhady**

Lamb fattening

The intensive fattening of lambs has several important advantages. It allows the considerable growth potential of the Awassi breed to be exploited; it could allow native pasture on marginal land to regenerate by reducing grazing pressure in spring; and more of the ewe's milk is available for sale or home use.

To study growth during intensive fattening, eight male lambs from both the medium (M) and well (H) nourished flocks of the ewe feeding trial were weaned at about 10 weeks and offered a concentrate diet for 77 days. Management during suckling had little effect on growth rate up to weaning (Table 39), but the small initial difference which developed between the liveweights of the two groups had increased to 4.8 kg at the end of the fattening phase. The higher daily gain of the H lambs was associated with a higher concentrate intake but feed conversion ratios were unchanged.

This study confirms that male Awassi lambs are efficient feed converters up to 40 kg liveweight. However, earlier weaning may

Table 39. Growth rates of male Awassi lambs during suckling at two levels of ewe nutrition, and a subsequent fattening phase, and feed conversion ratio during fattening.

	Level of nutrition during suckling		SED
	Medium(M) (n=8)	High(H) (n=8)	
Suckling phase (70 days):			
- daily gain, g	223	230	17.9
Fattening phase (77 days):			
- age at start, days	68	70	1.07
- start liveweight, kg	19.7	21.1	1.16
- end liveweight, kg	39.2	44.0	2.81
- daily gain, g	254	297	27.9
- feed intake, g:			
- concentrate[1]	1011	1211	-
- vetch hay	100	100	-
- feed conversion ratio[2]	4.0	4.2	-

[1]830 kg whole barley grain, 150 kg soya-bean meal, 20 kg vitamin-mineral mix.

[2]kg feed/kg liveweight gain.

improve efficiency still further and release more milk for sale or home use. Feed conversion ratios of lambs in local feed lots could be halved through improved management and nutrition; this is equivalent to doubling the meat production from a unit of barley grain. - **E.F. Thomson and F. Bahhady**

Creep feeding of lambs

Previous experiments at Tel Hadya showed that Awassi ewes produce sufficient milk to enable their lambs to reach a liveweight of 10 kg in 21 days. Thereafter lamb growth may be limited unless additional feed is offered. Creep feeding is a way of helping lambs to reach their growth potential: a small study of this system was therefore conducted.

Two groups of lactating Awassi ewes receiving either 100% (M) or 130% (H) of their metabolizable energy (ME) requirements from concentrates were used. After 21 days of suckling, half the lambs in each flock were progressively given access to concentrates where they were not in competition with their mothers (creep feeding). The remaining lambs served as controls. The experiment continued until the lambs were 70 days old.

During the first 21 days ME intake of the M and H flocks were similar (Table 40), and growth rates of lambs were also similar. Thereafter lambs receiving creep feed gained 60 to 80% more weight daily than the controls. Cold weather during the second phase may have reduced lamb performance to atypical levels. However this

Table 40. Ewe liveweight changes and metabolizable energy intake, and growth responses of lambs to creep feed.

	Level of supplementary feed				
	Medium(M)		High(H)		S[1]
	Control	Creep	Control	Creep	
Number of ewes	8	8	10	9	-
Ewe performance					
Phase 1 (21 days):					
- Initial liveweight, kg	43.6	43.8	43.6	42.4	2.63
- Daily gain, g	-179	-167	-85	-143	105.1
- Met. energy intake, MJ	13.5	12.3	14.6	12.6	2.28
Phase 2 (49 days):					
- Initial liveweight, kg	39.9	40.3	41.8	39.4	2.78
- daily gain, g	-59	-23	9	-2	47.5
- Met. energy intake, MJ	13.1	12.8	16.8	13.9	1.22
Lamb performance					
Phase 1 (21 days):					
- birth liveweight, kg	4.7	4.3	4.5	4.2	0.48
- daily gain, g	225	260	216	253	53.4
Phase 2 (49 days):					
- initial liveweight, kg	10.2	9.0	9.8	8.7	1.37
- daily gain, g	103	187	114	183	48.7
- creep feed intake:					
- dry-matter, g	-	158	-	146	14.0
- Met. energy, MJ	-	2.0	-	1.8	0.18

[1] $\sqrt{\text{residual mean square}}$

experiment strongly suggests that lambs benefit from creep feeding, and further studies are needed. - **E.F. Thomson and M. Rafiq (Arid Zones Research Institute, Quetta, Pakistan)**

Stubble grazing and protein supplementation

Sheep flocks in north Africa and west Asia are heavily dependent on cereal stubbles during summer. Numerous studies have shown that feeding a small amount of protein promotes the intake of low quality straw, but the liveweight changes of sheep grazing stubbles of contrasting cereal varieties, with or without protein supplementation, has not been measured.

The three experimental flocks, (L, M and H) were used in this study which started in June 1985. The experiment had a preliminary period of 35 days when the L flock grazed wheat stubbles from several varieties and the M and H flocks grazed barley stubble (cv. Arabi Abiad). During the main period of 63 days, all flocks grazed wheat stubbles. For the preliminary period, ewes within flocks were divided into a control group, and a group receiving 100 g cotton seed cake daily per animal. During the main period the control and supplemented groups of the L and M flocks grazed either mixed wheat stubbles or Hourani wheat stubble respectively. The H flock was further subdivided in order to graze stubbles of the new wheat cultivars, Sham 1 and Sham 2. Attempts at the start of the trial to balance straw availabilities across treatments were only partly successfull and comparisons between varieties are confounded by straw availability.

The differences in liveweights within flocks at the start of the experiment were due to differences occurring during the preliminary period (Table 41). Except in the L flock, intakes of straw per kg metabolic body weight ($W^{0.75}$) were similar for all the controls. In the supplemented treatments they were similar except for Sham 1. The low straw availability in the L flock may have reduced intake.

Supplementation with protein increased liveweight gains in all treatments (Fig. 46), although the effect was significant only in the L and M flocks. If, as a result of supplementation, lambing rate increases by 2% (2 lambs/100 ewes) for every kg of extra liveweight, and the stubble is grazed in this way for 126 days, the protein supplementation should improve lambing by a total of up to 14 percent, depending on cereal variety and straw availability. This increase would markedly increase flock profitability.

We know that sheep lose weight if stocked at a high rate on cereal stubble. This loss can be arrested by adding a small quantity of a protein supplement, such as cotton seed cake, which is readily available in Syria. However, the local variety Hourani and the improved varieties Sham 1 and Sham 2, appeared to give different animal responses under protein supplementation. Further studies will be necessary to determine whether there are interactions between protein supplementation, cereal variety, and stubble availability.

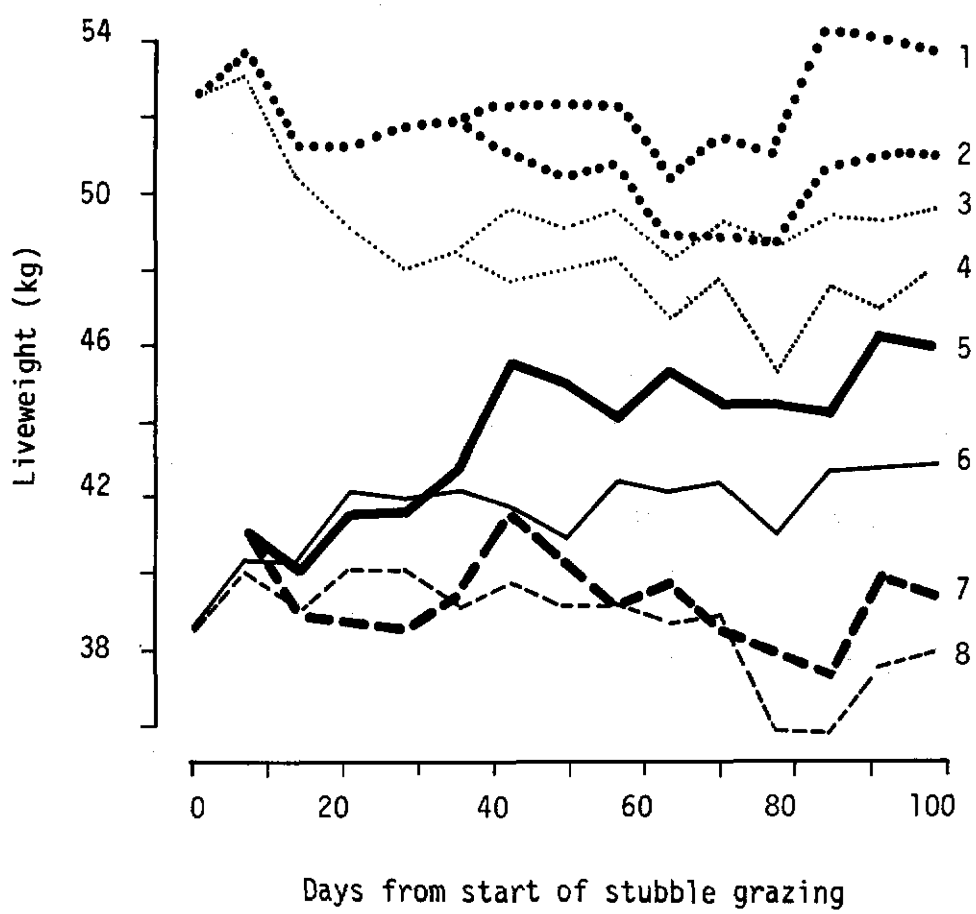


Fig. 46. Liveweight of sheep grazing cereal stubbles with and without supplementation with cotton seed cake.

1. Flock H grazing Sham 2 wheat with supplement.
2. Flock H grazing Sham 1 wheat with supplement.
3. Flock H grazing Sham 2 wheat only.
4. Flock H grazing Sham 1 wheat only.
5. Flock M grazing Hourani wheat with supplement.
6. Flock M grazing Hourani wheat only.
7. Flock L grazing various varieties with supplement.
8. Flock L grazing various varieties only.

Table 41. Daily intakes of straw, grain and cotton seed cake and liveweight changes of Awassi sheep, with or without cotton seed cake supplementation, grazing stubbles of three wheat varieties for 63 days.

Liveweight (variety)	Low (Hourani)		Medium (Hourani)		High (Sham 1)		High (Sham 2)		S[1]
± cotton seed cake	-CSC	+CSC	-CSC	+CSC	-CSC	+CSC	-CSC	+CSC	
Number of sheep	22	22	27	27	12	12	12	12	-
Area of stubbles, ha	2.02	2.02	1.73	1.73	0.66	0.66	0.66	0.66	-
Stocking rate, m^2/day	14.6	14.6	10.1	10.1	8.8	8.8	8.8	8.8	-
Daily intakes per head:									
- available straw, g	1029	1162	1554	1668	1210	1210	1577	1577	-
- residual straw, g	439	400	738	840	354	422	598	715	-
- straw intake, g	590	762	816	827	856	789	979	862	-
- grain, g	67	61	14	10	14	14	12	12	-
- cotton seed cake, g	0	100	0	100	0	100	0	100	-
Straw intake,g/$W^{0.75}$	38	46	52	48	47	21	53	44	-
Liveweights:									
- end, kg	37.9	43.4	39.4	46.0	48.0	52.8	49.6	54.1	4.00
- start, kg	39.1	42.1	39.4	42.6	48.3	52.4	48.7	52.5	4.32
- daily liveweight gain, g	-18.1	19.3	0.8	53.2	-5.3	6.0	14.1	25.8	29.39

[1] $\sqrt{\text{residual mean square}}$.

Nutritive value of forage

The exciting challenge of increasing the quantity of livestock feed has led ICARDA to place considerable effort in the breeding and agronomy of common vetch (Vicia sativa), forage pea (Pisum sativum), and, to a lesser extent, chickling (Lathyrus sativus). However, the nutritive value of these species for ruminants has been poorly studied, particularly in the case of forage pea which seem to be the least palatable. A study was therefore conducted in which fresh herbage, hay, and straw of common vetch, chickling, forage pea and barley were fed ad libitum to Awassi sheep in order to measure intake and digestibility. It was also possible to measure the harvesting losses during hay-making, and the yields of energy and protein harvested at the hay, as compared with the mature stage. Barley was added as a treatment because of its importance as a feedstuff in the region.

The four species were sown in two replicates. Material at the mid-flowering stage was cut every second day and fed fresh. Hay was made by machine, and the mature crop (straw) was hand collected and then threshed to remove the grain. All materials were chopped before feeding to Awassi wethers. Fresh herbage of each forage was offered to only three sheep, while hay and straw were offered to four sheep. The voluntary feed intake and digestibility of the materials were measured in 28 day-digestibility trials.

There was a high harvesting loss from the forage legumes, similar to those reported in previous studies and mainly representing leaf loss (Table 42). This loss was virtually nil in barley. The particularly high loss from pea is difficult to explain and may have been due to difficulties in mowing the crop, which had lodged. Grazing of the aftermath by sheep reduced these losses to between 10 and 20%.

Results of intake, digestibility and sheep performance are given in Table 43. Whereas the effect of increasing plant maturity was normal in barley, common vetch, and chickling, forage pea showed a remarkably low intake of fresh herbage and of hay. The lower digestibility of the acid detergent fibre (ADF) in forage pea is insufficient to explain the lower intake. Indeed, at the hay stage, digestibility of forage pea, vetch and barley ADF were similar but forage pea intake was only 32 and 38 percent of vetch and barley intake, respectively. By the mature stage forage pea intake was above that of barley but still about half that of vetch and chickling.

These results show that barley, common vetch, and chickling fed as fresh herbage or as hay can provide sheep with twice to three times their metabolizable energy (ME) requirement for maintenance. The liveweight gains are a clear reflection of these high intakes which would sustain an Awassi ewe at the peak of lactation. However, the ME intakes of sheep offered fresh pea and pea hay were below their maintenance requirement as can be seen from the liveweight losses in Table 43.

Intakes of vetch and chickling straw were still adequate for maintenance even though sheep offered vetch lost liveweight. This

Table 42. Hay yields and harvesting losses of barley, vetch, pea and lathyrus (kg DM per ha, 100% flowering-early pod stage).

	Barley	Vetch	Pea	Lathyrus
Potential yield[1]	4432	4977	6181	3583
Harvested yield[1]	4432	4009	2876	3133
Apparent loss %	0	19	53	13

[1]See text for explanation.

Table 43. Ad-libitum intake and liveweight changes of Awassi sheep offered fresh herbage, hay or straw of barley, vetch, pea and chickling.

	Fresh herbage					Hay					Straw				
	Barley	Vetch	Pea	Chickling	$S_{\bar{d}}$[1]	Barley	Vetch	Pea	Chickling	$S_{\bar{d}}$	Barley	Vetch	Pea	Chickling	$S_{\bar{d}}$
Daily intakes (g):															
- dry matter	1954	2411	506	2080	329.2	2005	2422	765	2094	264.0	813	1786	842	1608	187.8
- met. energy (MJ)	19.3	25.6	4.7	22.2	3.58	18.0	22.3	7.1	19.8	2.44	4.7	13.0	6.0	11.3	1.53
Intakes ($g/W^{0.75}$):															
- dry matter	96	115	28	100	15.0	97	112	42	98	11.0	39	79	50	72	6.9
- met. energy (kJ)	944	1221	258	1072	164.5	887	1034	391	923	101.6	227	574	360	507	57.7
Digestibilities (%):															
- dry matter	68.7	76.8	63.6	76.1	2.94	59.7	64.1	62.7	63.9	0.91	39.8	50.5	48.8	47.4	1.81
- organic matter	72.1	79.1	65.8	77.6	2.82	64.8	69.0	67.2	68.3	0.79	44.8	53.4	51.6	51.5	1.77
- AD fibre[2]	58.9	64.0	41.7	61.2	5.04	46.9	45.0	44.7	38.0	1.32	37.4	46.1	46.5	38.9	1.75
Liveweight changes (g)	309	395	-210	383	112.9	321	259	-71	205	65.9	-259	-27	89	13	55.7

[1]Standars error of difference.   [2]Acid detergent fibre

can be attributed to a rumen fill effect when passing from a high to a low level of intake. This source of error applies to all treatments but is most obvious when intakes change substantially between one feed and another.

The trial confirms the very low palatability of forage pea which was observed in several earlier studies. No satisfactory explanation for this can be found in the scientific literature since the nutritive value of pea as a forage crop has not been determined. It is not clear whether all pea strains are unpalatable but there are indications of strain differences. The low palatability, and the high cold, insect and disease susceptibility of forage pea offset the high yield and nitrogen fixing potential of the species. The trial has highlighted the need to assess nutritional characteristics of major forage and pasture plants early in the evaluation process. - **E.F. Thomson**

Nutritive Value of Straw

Extensive research in 1984 showed that factors such as nitrogen fertilization, time of sowing, seed rate and grazing at the tillering stage did not influence the nutritive value of barley straw. However, preliminary feeding trials indicated that there were substantial differences in straw quality between barley genotypes. These differences were associated with variation in the proportions of leaf blade, leaf sheath and stem in the straw. Taller genotypes or those which matured early had less leaf and more stem than shorter, late maturing varieties. Environment was also important because, in dry Syrian conditions, barley plants were shorter and contained more leaf than those grown in a temperate environment. Variation also occurred in the chemical composition and *in vitro* digestibility of the leaf blade and stem. Stems of taller varieties were more lignified and less digestible.

Proportion of leaf and straw quality

Barley. The Cereal Crops Improvement Program is giving increasing attention to the selection of barley strains suitable for areas receiving less than 300 mm rainfall. As part of this research PFLP is involved in sampling mature barley plants at Breda to investigate the influence of plant height and time to maturity on proportions of leaf blade and stem. Leaf proportion (blade + sheath) was very strongly influenced by stem length (Fig. 47), varying between 0.7 and 0.8 when stem length ranged from 15 to 20 cm compared with 0.5 to 0.6 when stem length was 40-50 cm. Proportion of leaf blade was less than 0.3 in taller plants but was 0.5 to 0.6 in shorter plants (Fig. 47). Interestingly, the regression coefficient for changes in leaf blade proportion with stem length was higher (-0.0098 versus -0.0037) for material grown at Breda in 1985 compared with material grown at Tel Hadya in 1984. These results suggest that plant morphology is important in determining the nutritive value of different barley straws.

Similar results were obtained on straw from the traditional cultivars (landraces), Arabi Abiad (white) and Arabi Aswad (black) as can be seen from a comparison of Figs. 47 and 48. Although Arabi

Fig. 47. Proportion of leaf (blade + sheath), leaf blade only, and stem in barley straw of F_3 segregating populations at Breda.

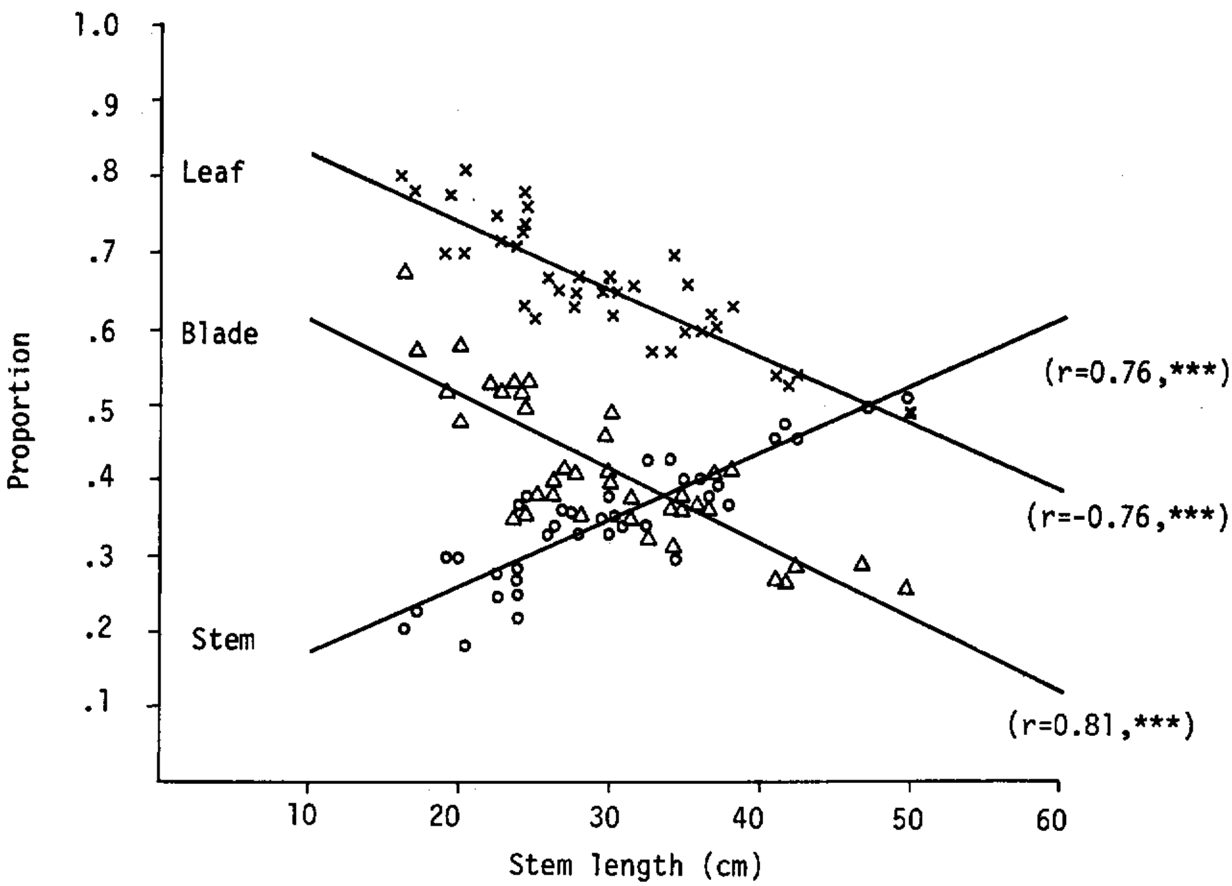
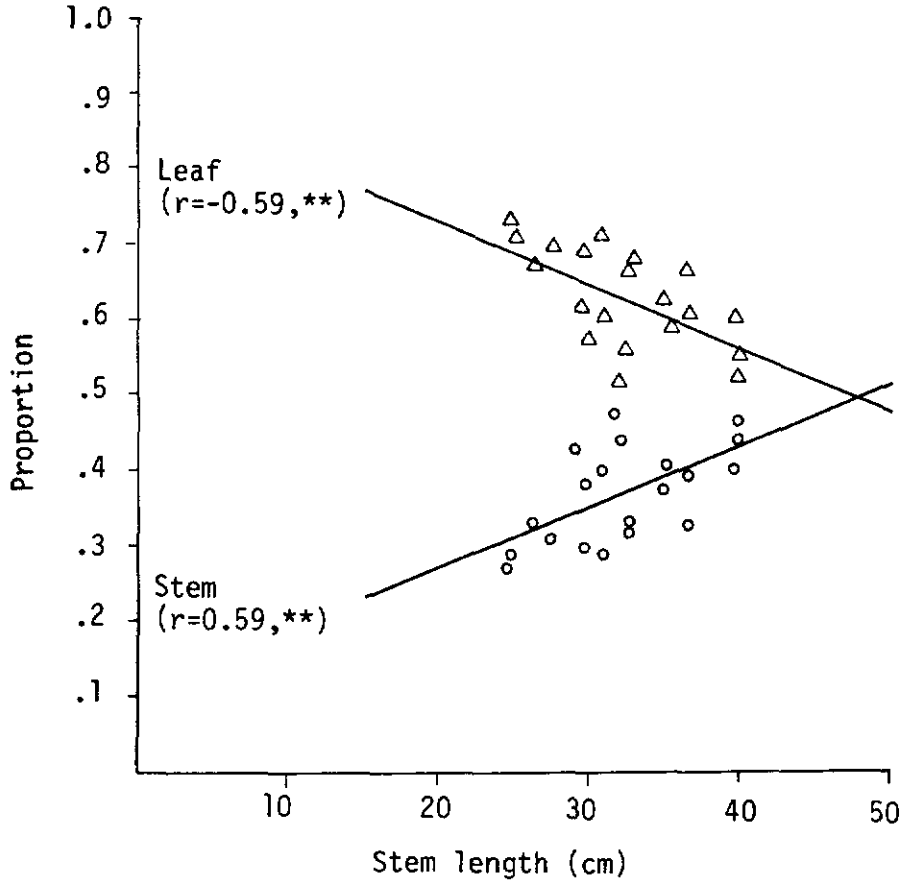


Fig. 48. Proportion of leaf and stem in barley straw of landraces at Breda.



Abiad was slightly shorter than Arabi Aswad (Table 44) they were otherwise very similar. - **B.S. Capper (TDRI) and S. Ceccarelli (Cereal Crops Improvement Program)**

Wheat. Previously unreported information from durum and bread wheat trials harvested in 1983 have showned that there is wide variation in straw quality (Table 45). Straw from durum wheat may also be superior to that of bread wheat. This question was studied by examining the proportion of leaf blade, leaf sheath and stem in samples from three wheat trials conducted in 1984-85 (Table 46). Despite being taller, durum wheat had similar leaf proportions compared with the bread wheats.

As has been consistently found in barley, the proportion of leaf in wheat is significantly influenced by stem length (Table 47 and Fig. 49). But, although stem diameter may influence leaf proportion, it is less important than length. An increase in the number of days to heading caused an increase in leaf proportion similar to that in barley. It appears that many of the principles of ICARDA's research with barley straw are also applicable to wheat straw. - **B.S. Capper (TDRI), M. Nachit (Cereal Improvement Program) and O. Ferrare (Cereal Improvement Program)**

Comments on the influence of breeding

There is a global concern among livestock scientists that the breeding of cereals for increased yield and lodging-resistance may adversely affect the nutritive value of straw. It is considered that

Table 44. Comparison of mean morphology of Arabi Abiad and Arabi Aswad at Breda.

	Arabi Abiad	Arabi Aswad
Stem length (cm)	31.7	32.9
Days to maturity	173.2	172.9
Proportion		
Total leaf	.64	.62
Leaf blade	.41	.37
Leaf sheath	.23	.25
Stem	.36	.38

Table 45. Variation in the nutritive value of wheat straw (1983).

	Durum wheat			Bread wheat		
	Mean	SEM	Range	Mean	SEM	Range
Crude protein	2.7	.06	2.4-3.2	2.2	.17	1.9-2.7
D value[1]	36.1	.29	34.4-37.6	30.9	.51	27.1-35.5
Neutral detergent fibre (%)	78.0	.31	75.1-80.6	78.6	1.17	76.5-80.1
Ash (%)	9.8	.85	8.4-11.6	9.5	.69	8.3-10.8

[1]Digestible organic matter (g/100g dry matter)

Table 46. Stem morphology and the proportion of leaf blade and sheath in wheat straw.

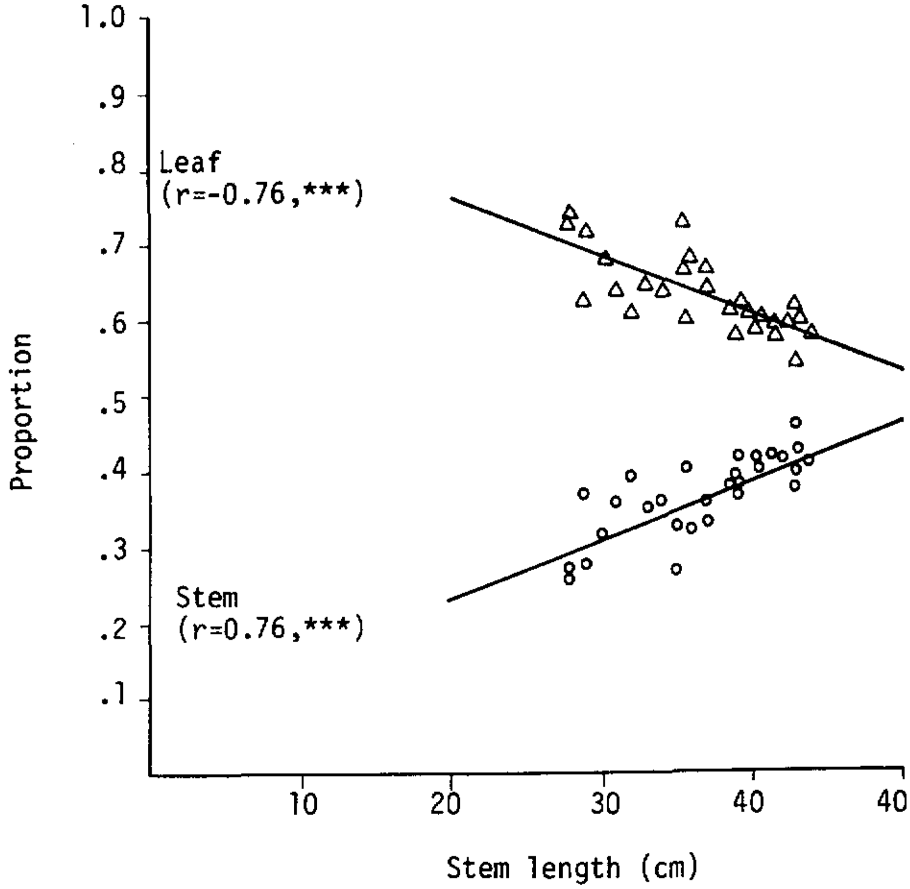
	Durum wheat						Bread wheat (CIMMYT)		
	Regional trial			Rainfed trial					
	Mean	SEM	Range	Mean	SEM	Range	Mean	SEM	Range
Stem length (cm)	52.0	1.27	41.2-63.2	52.2	1.12	38.8-61.4	36.8	.94	28.0-44.1
Stem diameter (mm)	2.9	.07	2.3-3.7	3.0	.07	2.5-4.0	2.6	.06	2.5-3.9
Proportion									
Total leaf	.62	.01	.01-.70	.60	.01	.51-.70	.63	.01	.54-.74
Leaf blade	.43	.01	.27-.52	.40	.01	.30-.54	.37	.01	.30-.49
Leaf sheath	.19	.005	.15-.26	.20	.01	.15-.30	.26	.003	.22-.29
Stem	.38	.01	.30-.50	.40	.01	.32-.49	.37	.01	.26-.46

Table 47. Correlation coefficients between genotype characteristics and leaf blade, leaf sheath and stem proportions in elite bread wheat lines

	Stem length (cm)	Stem diameter (mm)	Days to heading
Total leaf	-.76***[1]	-.25	.20
Leaf blade	-.78***	-.30	.22
Leaf sheath	.19	.19	-.08
Stem	.76***	.25	-.20

[1] ***; P <0.01

Fig. 49. Proportion of leaf and stem in the straw of 28 wheat cultivars grown at Tel Hadya.



shorter, thicker and stiffer stems would give straw of less value. However, Research at ICARDA has shown that breeding for shorter material may actually improve straw value: stem diameter is of little consequence and there appears to be a lower consumption from early-maturing genotypes. This can be partly explained by lower proportions of leaf blade and by structural or chemical factors which may influence rumen degradability. For example, variation in levels of certain phenolic compounds of low-molecular weight, such as p-coumaric and ferulic acids, have been implicated in affecting straw digestion by rumen micro-organisms. The extent to which these substances vary in straws from different varieties will be investigated. - **B.S. Capper (TDRI)**

Voluntary intake and digestibility in barley straws

Straw was obtained for seven barley varieties which had been mechanically harvested at Tel Hadya at a cutting height of 15-20 cm Arabi Abiad straw, harvested in a similar way, was purchased from a nearby farm. The straws were chopped to 2.5 cm lengths and each was fed for 28 days to 4 Awassi wethers housed in digestibility crates. Straw was offered at 20% above appetite levels without supplementation.

Voluntary feed intake (VFI) of straw varied significantly between barley varieties so that considerable differences in daily ME supply were apparent (Table 48). Intake of ME from Arabi Abiad straw was highest but C63 followed closely. Overall liveweight changes were not significantly different but animals on Arabi Abiad and C63 shorter, thicker and stiffer stems would give straw of less value. However, Research at ICARDA has shown that breeding for shorter material may actually improve straw value: stem diameter is of little consequence and there appears to be a lower consumption from early-maturing genotypes. This can be partly explained by lower proportions of leaf blade and by structural or chemical factors which may influence rumen degradability. For example, variation in levels of certain phenolic compounds of low-molecular weight, such as p-coumaric and ferulic acids, have been implicated in affecting straw digestion by rumen micro-organisms. The extent to which these substances vary in straws from different varieties will be investigated. - **B.S. Capper (TDRI)**

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Table 48. Feeding value of unsupplemented straw from 8 cultivars of barley

	Arar	ER/Apam	Rihane 'S'	Arabi Abiad[1]	Beecher	Badia	C 63	Antares	Sig.	SEM
Genotype characteristics										
Stem length (cm)	48.0	39.2	49.3	-	69.6	69.0	61.2	43.4	-	-
Days to maturity	142	143	144	-	146	147	151	156	-	-
Leaf proportion	0.62	0.63	0.65	-	0.53	0.54	0.69	0.64	-	-
Digestibility (%)										
Dry matter	44.5	42.9	45.3	46.5	42.6	40.4	43.0	40.6	*	0.47
Organic matter	47.7	45.8	47.7	49.8	45.2	43.0	45.7	43.5	ns	0.51
Intake ($g/W^{0.75}/day$)										
Dry matter	34.8	39.0	40.3	51.1	38.9	43.8	50.9	45.2	**	0.93
Organic matter	31.0	34.9	36.6	47.5	35.6	39.2	45.9	40.8	**	0.82
Digestible organic matter	14.7	15.9	17.4	23.7	16.1	17.0	21.0	17.8	*	0.50
Metabolizable energy (MJ/day)										
Supply	5.1	5.6	6.0	8.7	5.7	5.9	7.7	6.6	*	0.42
Maintenance requirement	7.5	7.6	7.4	7.9	7.7	7.6	7.9	8.0	ns	1.16
Liveweight change (g/day)	-142.9	-133.9	-107.2	+17.9	-107.1	-80.4	-8.9	-80.4	ns	16.3

[1]Purchased, combine-harvested material.

straw maintained liveweight without supplementation.

Correlation coefficients between the feeding values of straws and varietal characteristics showed that intakes were higher in later-maturing varieties (Table 49). A quadratic function described more precisely the relationship between the VFI of organic matter and days to maturity (Fig. 50). Improvement in intake was partly a result of a higher proportion of leaf since leaf material breaks down more rapidly in the rumen of the sheep enabling the sheep to eat more. In vitro digestibility measured with cellulase indicated that leaf material from late maturing varieties was more digestible. - **B.S. Capper (TDRI) and E.F. Thomson**

Effect of barley grain and cotton seed cake on barley straw voluntary intake and digestion

Straw from four barley varieties was offered to four Awassi wethers alone or supplemented with either barley grain, to supply energy, or cotton seed cake, to supply protein. Feeding periods lasted 28 days and supplements were fed each morning followed by straw offered at 20% above appetite levels. The digestibility of the two supplements was measured in separate trials and the straw digestibility calculated by difference.

Barley grain supplementation reduced the digestibility of Beecher, Badia and C63 straws but not ER/Apam (Table 50). Substantially improved intakes of C63 and ER/Apam, which had leaf proportions of 0.63 and 0.69 respectively, were seen. But intakes of

Fig. 50. Relationship between voluntary intake of barley straw (O.M.) and number of days from sowing to maturity.

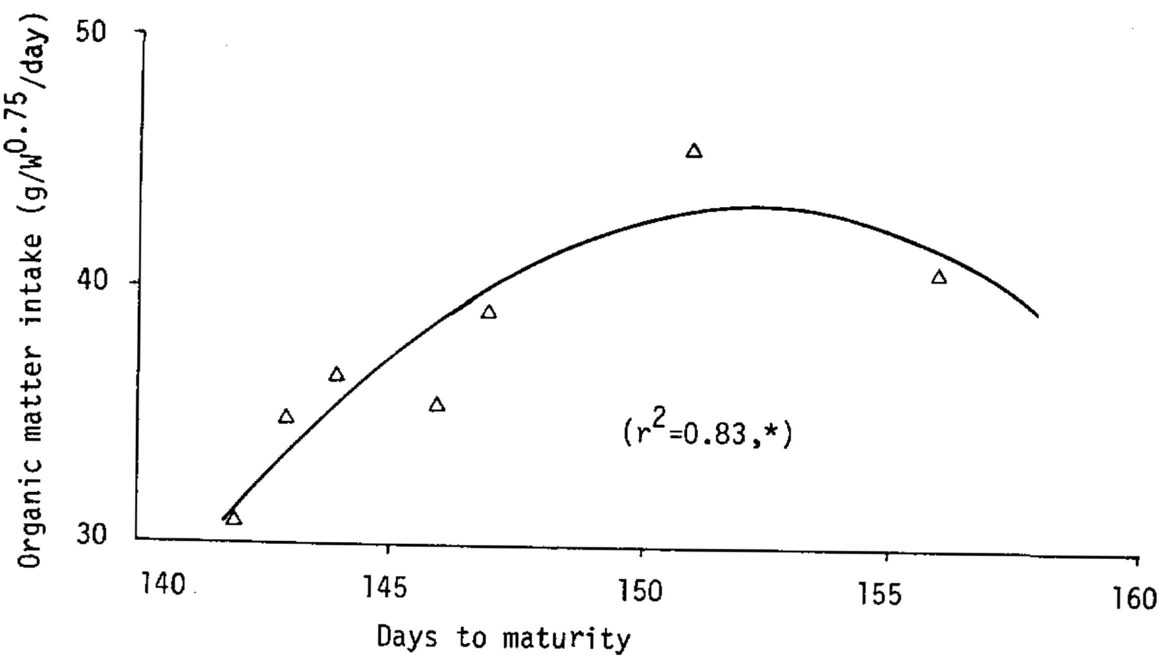

Table 49. Correlation coefficients (r) between feeding value of barley straws and cultivar characteristics,

	Grain yield (kg/ha)	Straw yield (kg/ha)	Days to maturity	Stem length (cm)	Leaf proportion
Digestibility (%)					
Dry matter	-.48	-.64	-.65	-.28	.40
Organic matter	-.50	-.68	-.65	-.35	.42
Intake ($g/W^{0.75}/day$)					
Dry matter	-.08	.82*[1]	.77*	.27	.40
Organic matter	-.11	.82*	.78*	.27	.38
Digestible organic matter	-.27	.71	.65	.23	.55

[1]*; $P<0.05$.

Table 50. Influence of barley grain (BG) and cottonseed cake (CSC) supplementation on the feeding value of straw from contrasting barley cultivars.

Type of supplement	ER/Apam			Beecher			Badia			C 63			Significance		SEM
	Nil	BG	CSC	Nil	BG	CSC	Nil	BG	CSC	Nil	BG	CSC	Cultivars	Supplementation	
Amount of supplement (g dry matter/day)	-	165.6	123.9	-	171.6	132.8	-	163.9	130.3	-	176.2	132.6	-	-	-
Straw digestibility (%)															
Dry matter	42.9	42.9	46.2	42.6	40.8	42.9	40.4	35.3	43.7	43.0	40.6	42.6	**	***	0.39
Organic matter	45.8	45.7	49.1	45.2	43.6	45.9	43.0	37.7	46.8	45.7	43.5	45.1	**	***	0.41
Straw intake ($g/W^{0.75}/day$)[†]															
Dry matter	39.0	46.6	62.1	38.9	40.9	47.6	43.8	45.4	61.0	50.9	57.5	61.9	***	***	0.99
Organic matter	34.9	41.7	55.6	35.6	37.4	43.5	39.2	40.6	54.5	45.9	51.8	55.7	***	***	0.89
Digestible organic matter	15.9	18.9	27.3	16.1	16.3	20.0	17.0	15.7	25.5	21.0	22.5	25.1	**	***	0.48
Estimated metabolizable energy supply (MJ/day)															
Straw	5.6	6.9	9.8	5.7	5.9	7.2	5.9	5.5	9.4	7.7	8.4	9.5	**	***	0.22
Supplement	-	2.3	1.3	-	2.4	1.4	-	2.3	1.4	-	2.5	1.4	-	-	-
Total	5.6	9.2	11.1	5.7	8.3	8.6	5.9	7.8	10.8	7.7	10.9	10.9	-	-	-
Estimated ME requirement for maintenance (MJ/day)	7.6	7.7	7.7	7.7	7.7	8.0	7.6	7.4	8.0	7.9	8.1	8.2	ns	ns	0.15
Liveweight change (g/day)	-133.9	+17.9	+196.4	-107.1	+17.9	+98.2	-80.4	+80.4	+169.7	-8.9	+133.9	+232.2	*	***	12.0

[†]Metabolic body weight where W = liveweight in kg.

Beecher slightly increased and Badia slightly decreased, these cultivars having leaf proportions of 0.53 and 0.54 respectively. By contrast, cotton seed cake improved digestibility of three out of four straws. Intake was improved markedly for ER/Apam, Badia and C63 straws but was less marked for Beecher.

There were significant effects of supplementation on liveweight and differences between varieties were also significant. These results confirm that later maturing cultivars generally have better quality straw. However supplementation with cotton seed cake improved the feeding value of straw from the early maturing cultivars ER/Apam. This, together with the results of supplementing straw from Badia, demonstrates the existence of cultivars x supplement interactions. Generally it appears better to supplement straws with cotton seed cake than with barley grain. - **B.S. Capper (TDRI) and E.F. Thomson**

Training

Training is considered an essential part of the Program's activities. It is a way in which our results can be put into practice, and disseminated to other countries. The Program aims to improve technical skills for research in the subjects of pastures, forages and livestock.

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The following training was offered in 1984/85.

1. A long-term residential course of 3 months duration (March-June).

2. Individual training for Junior Scientists.

Residential course

The residential course took place at Tel Hadya where eight trainees from 7 countries (Egypt, Ethiopia, Somalia, Syria, North Yemen, Pakistan and China) participated. The syllabus focused on field and laboratory techniques for annual forage production and breeding, annual pastures, marginal land improvement, germplasm evaluation and utilization, microbiology, and livestock husbandry. Seventy-five percent of the time was devoted to practical work and 25% percent to lectures.

Each participant was assigned a small experiment and supervised by a senior scientist, taking into account the previous experience and background of the trainee, and his country's needs. This gave the trainee experience in planning, conducting, analysing and reporting experimental work. Details are given in Table 51.

Table 51. Experiments assigned to 1985 residential course participants.

Name of Trainee	Country	Title of experiment	Supervisor
Adel Ismaeil El Daly	Egypt	Determination of residual seeds of certain annual *Medicago* spp. in medic-cereal rotation.	Dr P.S.Cocks
Tedese Tsadik	Ethiopia	Isolation of rhizobia and plant inoculation.	Dr Luis Materon
Mohamed Muffareh	N. Yemen	Response of marginal land to superphosphate application.	Dr A. Osman
Khadija Mahdi	Somalia	Effect of seed size and seed rate on agronomic characters of forage vetch.	Dr Ali Abd El-Moneim
Basam Mawlawi	Syria	Selection criteria for forage vetch.	Dr Ali Abd El-Moneim
Ihtisham Ali Sayed	Pakistan	Effect of seed size and seed rate on herbage and seed yield of forage pea.	Dr Ali Abd El-Moneim
Ghen Guxiand	China	Forage pea germplasm evaluation.	Dr Ali Abd El-Moneim
Zhou Lixia	China	Evaluation annual forages for frost-tolerance.	Dr Ali Abd El-Moneim

Individual training

Seven Junior Scientists were trained individually, the duration of their training varying from two weeks to nine months. They worked closely with senior scientists on subjects relevant to research in their national programs.

Two research assistants from the Syrian Agricultural Research Centre (ARC) were trained in the screening of annual forage legumes for disease resistance. One from the Steppe and Range Directorate received one month's training on survey techniques for the natural vegetation of marginal land.

Another scientist from the Steppe and Range Directorate, and one from the Pakistan Agricultural Research Council were trained for a period of 9 months (November 1984-July 1985). Their training focussed on experimental sheep flocks, livestock on-farm trials, keeping of records and their analysis, and reporting of feeding experiments.

One young scientist from Tanzania was trained on marginal land evaluation and improvement for a period of 8 months (January - July, 1985). His training focused on the effect of superphosphate on pasture productivity, with special emphasis on indigenous legumes.

From Nepal, a trainee received instruction on annual forage production (February - April, 1985). His training focused on agronomic characteristics of forage legumes, and the determination of yield and its components.

Former trainees were included in the mailing list for relevant publications and were provided with seeds for use in their own countries. Results are fed back to ICARDA. The Program's Training Officer and senior scientists try to visit the former trainees in their home countries when on official business. In these ways trainees maintain contact with the Program, and the success of their training can be evaluated.

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