Selection and utilization of cultivated fodder trees and shrubs in the Mediterranean Region

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Selection and Utilization of Cultivated Fodder Trees and Shrubs in the Mediterranean Region

Results and researches carried out within the
CAMAR EC/DG.VI Programme, contract 8001-CT90-0030
titled "Selection and utilization of cultivated fodder trees and shrubs in Mediterranean extensive livestock production systems"

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Foreword

This issue of *Options Méditerranéennes* deals with the experimental results of the research project No. 8001-CT90-0030, "Selection and Utilization of Cultivated Fodder Trees and Shrubs in Mediterranean Extensive Livestock Production Systems", carried out between March 1991 and February 1995 and financed by the European Commission under the DG.VI CAMAR Programme.

The main objectives of the project were:

(i) The exploitation of the genetic potential of highly productive, indigenous or exotic – but naturalized in the Mediterranean environment – species, capable of fulfilling through cultivation the demands for abundant and nutritious fodder.

(ii) The application of modern techniques in establishment of their plantations and fitting them to the extensive livestock production systems.

The research work was coordinated by the International Centre for Advanced Mediterranean Agronomic Studies (CIHEAM) through the Mediterranean Agronomic Institute of Zaragoza (IAMZ). Eight research units from four Mediterranean countries participated in the project: (i) from Greece, the Laboratory of Range Science of the Aristotle University of Thessaloniki and two Institutes of the National Agricultural Research Foundation, namely the Forest Research Institute of Thessaloniki and the Fodder Crops and Pastures Institute of Larissa; (ii) from Italy, the Istituto di Agronomia Generale e Coltivazioni Erbacee of the University of Palermo and the Dipartimento di Produzione Vegetale of the University of Tuscia at Viterbo; (iii) from France, two units of the Institut National de la Recherche Agronomique (INRA), namely the Laboratoire d'Ecophysiologie des Plantes sous Stress Environnementaux at Montpellier and the Unité d'Ecodéveloppement at Avignon; and (iv) from Spain, the Servicio de Investigación y Desarrollo Tecnológico of Extremadura at Badajoz.

The project included three actions: (i) germplasm collection, screening and multiplication; (ii) ecological and agronomic evaluation; and (iii) establishment and management of plantations. Altogether, 17 species of fodder trees and shrubs with several cultivars or populations were studied but emphasis was given on only a few of them which are the most promising, such as *Chamaecytisus proliferus, Gleditsia triacanthos, Medicago sativa, Morus alba* and *Robinia pseudoacacia*.

The following most important results were obtained:

(i) In *Chamaecytisus proliferus*, a very productive and palatable fodder shrub, two lines of the sub-species *palmensis* (tagasaste) and one of the sub-species *canariae* were found to be very promising for semi-arid environments with mild winters and acid soils.

(ii) In *Gleditsia triacanthos,* a very interesting fodder tree for its fruits (pods), a great variation in pod production among 400 grafted trees, between 4-5 years old, was found, while pods were readily eaten by sheep during the winter months resulting in substantial net liveweight gains due to their relatively high *in vitro, in vivo* and *in sacco* degradabilities (60-78%).

(iii) In *Medicago arborea,* a very palatable, winter growing shrub, germplasm resistant to winter frost and with low haemolytic saponin content was collected and screened, non-destructive methods for estimation of edible biomass were developed, low-cost establishment methods (e.g. direct seeding) were tested and grazing management options were evaluated.

(iv) In *Morus alba*, a very productive and palatable tree for its foliage, a great growth potential of the shrubby variety 'Kokuso 21' was found, a non-destructive method for estimating its biomass was developed, and grazing management schemes were tested.

(v) In *Robinia pseudoacacia,* a very productive and palatable tree for its foliage, a high variation in growth and morphological parameters was detected, a clone with few thorns was developed, its forage was found to be of high quality and its adaptation to relatively warm and dry conditions was studied.

(vi) In the other species tested such as *Amorpha fruticosa, Atriplex* spp., *Carpinus orientalis, Colutea arborescens, Coronilla emerus, Fraxinus ornus, Ostrya carpinifolia, Pyrus amygdaliformis* and *Quercus* spp., productivity was found variable but quite important because it was available during the critical summer period.

(vii) To avoid competition with weeds, fodder shrub and tree plantations were intercropped with palatable perennial grasses, which also produced additional forage.

(viii) Most species tested produced less than 500g/plant on average sites but their production on an area basis outyielded other resources as they were available in critical periods of the year.

(ix) Dense spacing did not affect shrub or tree growth during the early years of plantation but involved higher cost of establishment as compared to wide-spaced plantations.

(x) As regards the feeding value of fodder trees and shrubs, the majority of the tested species were found to retain relatively high levels of crude protein and satisfactory levels of neutral detergent fibre content, thus suggesting their importance as feed supplements to sheep and goats during summer when herbaceous species are dormant.

We are gratefully indebted to the European Commission, particularly to DG.VI, Division of Agricultural Research, for financing this project, thus making feasible the cooperation of several Mediterranean scientists in the important subject of fodder trees and shrubs. This publication aims at disseminating the numerous results collected through the project as a contribution to sustainable animal production in the marginal areas of the Mediterranean region.

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Summary

Cultivated fodder trees and shrubs can grow in dry and marginal areas of the Mediterranean region and provide invaluable feed to livestock during the long and dry summer period and mid-winter when herbaceous plants are dormant.

The object of this project was to study the genetic potential of highly productive, mainly leguminous species, their adaptation and performance in different ecological environments and production systems, and the application of modern techniques for their establishment and grazing management. Seventeen species were tested but main emphasis was given to *Chamaecytisus proliferus, Gleditsia triacanthos, Medicago arborea, Robinia pseudoacacia* and *Morus alba*. Germplasm was collected, screened and propagated and together with clones from previous experiments was evaluated agronomically in different ecological environments. In total, 24 trials were established at spacings ranging from 0.5 to 12 m. Biomass, nutritive value and resistance to extreme weather conditions were measured and grazing experiments were carried out with sheep and goats.

A great variability in morphological, growth and nutritional characters was found in all species tested. Promising lines of *Chamaecytisus* have been selected for semi-arid conditions with mild winters and acid soils; productive clones of *Gleditsia* were identified with pods of high nutritive and feeding value to sheep; cold resistant and summer growing lines of *Medicago* were identified; and clones of *Robinia* with few thorns and high proportion of leaves of increased crude protein content were developed.

Productivity was found to be affected by the particular species or cultivar involved, the environmental conditions and the age of plants. In addition, spacing, cultivation and grazing management significantly affected their growth and performance. Most species produced about 2 t/ha/year of edible biomass thus outyielding other resources at the critical periods of the year. Also, most species tested were found to retain relatively high levels of crude protein and satisfactory levels of organic matter digestibility thus being suitable as feed supplements to sheep and goats in the summer. It is concluded that fodder trees and shrubs are important strategic forage resources for stabilizing productivity and reducing the cost of livestock production systems in the Mediterranean region.

Key words: Fodder trees, fodder shrubs, germplasm, grazing management, utilization, production systems, Mediterranean region.

Résumé

«Sélection et utilisation d'arbres et arbustes fourragers dans la région méditerranéenne». Des arbres et arbustes fourragers cultivés sont capables de pousser dans les zones sèches marginales de la région méditerranéenne, où ils peuvent fournir des ressources fourragères très appréciées du bétail pendant les périodes estivales et hivernales, quand les plantes herbacées sont en dormance.

Les objectifs de cette étude étaient d'évaluer le potentiel génétique d'espèces prometteuses, pour la plupart des légumineuses, ainsi que d'étudier leur adaptation et leurs performances dans différents environnements et systèmes de production, afin d'élaborer des modes de conduite modernisés pour leur installation et leur gestion par le pâturage. Dix-sept espèces ont été étudiées, l'essentiel de l'effort portant cependant sur les suivantes : Chamaecytisus proliferus, Gleditsia triacanthos, Medicago arborea, Robinia pseudoacacia, *et* Morus alba. *Après collecte de différentes ressources génétiques, y compris des variétés clonales provenant de programmes antérieurs, le matériel génétique disponible a été évalué dans différentes conditions écologiques. Au total, 24 essais ont été mis en place, avec des espacements entre plants variant de 0,5 à 12 m. La production de biomasse, la valeur nutritive, et la résistance aux conditions climatiques extrêmes ont été mesurées, et des expériences de pâturage ont été menées avec des ovins et des caprins.*

Pour toutes les espèces étudiées, nous avons mis en évidence une grande variabilité des caractères morphologiques, mais aussi des potentialités de croissance et des qualités nutritives. Nous avons sélectionné des provenances prometteuses de Chamaecytisus *pour des conditions semi-arides à hiver doux et sur sols acides ; nous avons retenu de nouveaux clones de* Gleditsia *ayant des gousses très nutritives présentant une bonne valeur fourragère pour les ovins ; nous avons identifié des variétés de* Medicago *résistantes au froid et à bonne croissance estivale ; nous avons développé des clones de* Robinia *peu épineux et présentant une proportion élevée de feuilles à teneur améliorée en protéines.*

Nous avons montré comment la productivité fourragère des ligneux étudiés dépendait des espèces et variétés, mais aussi des conditions environnementales et de l'âge des plants. De plus, les espacements entre plants, les travaux d'entretien et la gestion du pâturage influencent significativement leur croissance et les rendements. Beaucoup d'espèces étudiées produisent environ 2 t/ha/an de biomasse consommable, ce qui est plus performant que toutes les autres espèces non ligneuses disponibles aux périodes critiques de l'année. Comme la plupart des espèces étudiées conservaient une teneur en protéines brutes assez élevée et présentaient une digestibilité satisfaisante de la matière organique, elles produisent des compléments fourragers satisfaisants pour les ovins et les caprins en été. Nous en concluons que les arbres et arbustes fourragers sont des ressources fourragères clefs pour stabiliser la productivité et réduire les coûts de production des systèmes d'élevage dans la région méditerranéenne.

Mots-clés : *Arbres fourragers, arbustes fourragers, ressources génétiques, gestion du pâturage, utilisation, systèmes de production, région méditerranéenne.*

Introduction

Traditional production systems in the Mediterranean region are extensive because they are largely based on grazing lands, namely pastures and rangelands, for animal feeding. The most productive part are grasslands which occupy 40% of the whole area of grazing lands and they are essential in supporting ruminant production (Papanastasis and Mansat, 1996). Forage production in these lands, however, is not uniform in space and time because it is constrained by several factors, especially climate (Talamucci and Chaulet, 1989). As a result of the Mediterranean climate, two feed gaps are formed: one in the winter period when pasture growth is high in quality but insufficient in quantity to cover the animal needs; and another one during the summer period, when herbaceous plants are dormant and have low or no feeding value for the ruminants (Fig. 1).

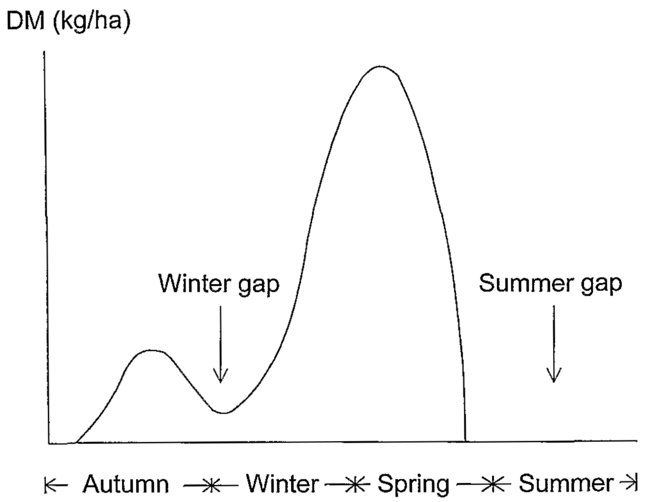


Fig. 1. Seasonal growth of grassland production in semi-arid and warm Mediterranean areas (adapted from Olea *et al.*, 1991).

Trees and shrubs can fill up the feed gaps of the ruminant production systems with fodder (foliage and fruits) rich in protein and minerals because they can grow in dry areas and during the dry periods as well as during the winter season if they are evergreen. This is due to their variable reproductive strategies, deep root growth and efficiency in mobilizing non-structural carbohydrates which make them very resistant to environmental oscillations (Sankary and Ranjhan, 1989). In addition, they can improve the environment by stabilizing the soil against erosion and improving its fertility (Le Houerou, 1993).

Compared with the spontaneously grown species, cultivated fodder trees and shrubs are advantageous because they can be selected for desirable ecological, agronomic and nutritional characteristics and used for meeting specific needs in the ruminant production systems. For these reasons, they have received considerable attention in the last few years and several national and international projects have been carried out in the Mediterranean region with very interesting results. These results however are not enough to solve all the problems related to selection, use and management of cultivated fodder trees and shrubs in the Mediterranean production systems (Correal, 1987; Dupraz, 1987; Le Houerou, 1987; Papanastasis, 1991, 1993a).

To increase the knowledge on the role and potential of cultivated fodder trees and shrubs, a transnational Mediterranean project was carried out within the framework of the European Commission programme "Competitiveness of Agriculture and Management of Agricultural Resources, 1989-1993" entitled "Selection and Utilization of Cultivated Fodder Trees and Shrubs in the Mediterranean Extensive Livestock Production Systems".

The main objectives of this project were the following:

(i) The exploitation of the genetic potential of highly productive indigenous or exotic-but naturalized in the Mediterranean environment-species, capable of fulfilling through cultivation the demands for abundant and nutritious fodder.

(ii) The application of modern techniques in establishment of their plantations and fitting them to the extensive livestock production systems.

Specific objectives of the same project were:

(i) Collection of germplasm of highly productive species of fodder trees and shrubs, screening and multiplication.

(ii) Selection of species or clones of fodder trees and shrubs best producing and well adapted to a wide range of ecological environments and production systems.

(iii) Development of effective methods for establishment of fodder trees and shrubs in the field, biomass estimation and management.

(iv) Integration of fodder trees and shrubs into production systems.

Eight research units from four Mediterranean countries participated in the project under the co-ordination of the Mediterranean Agronomic Institute of Zaragoza. More specifically, there were three participants from Greece, two from Italy, two from France and one from Spain. Table 1 shows the names and location of the participating units, the responsible scientists and the research teams.

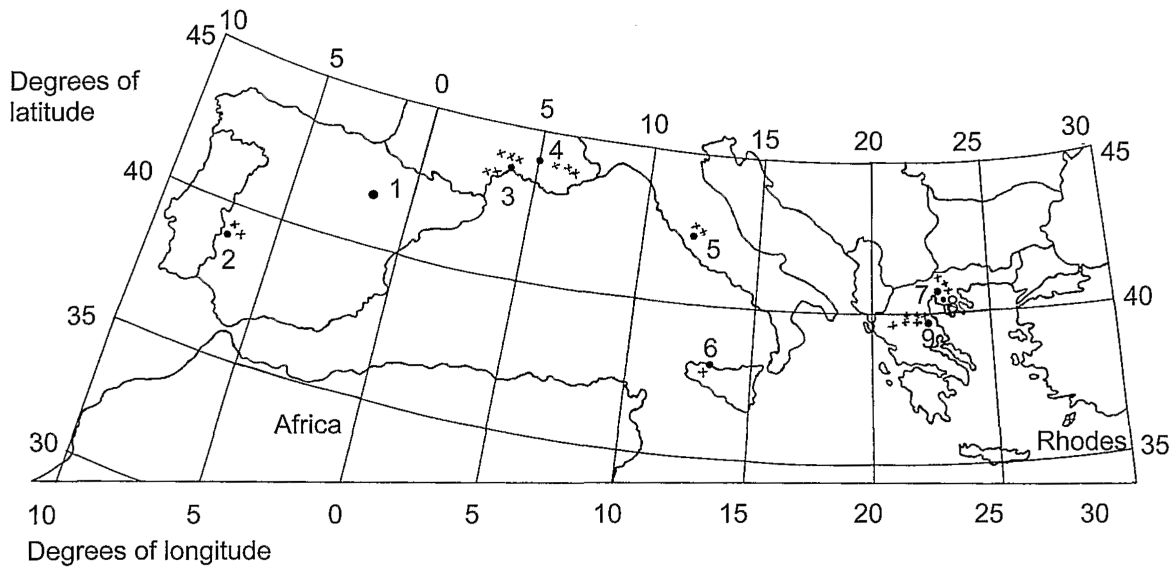
Table 1. Participating units and their scientific staff

Participant	Responsible scientist	Research team
1. Instituto Agronómico Mediterráneo de Zaragoza, Spain	V. Papanastasis (Co-ordinator)	–
2. Laboratory of Range Science, Aristotle University of Thessaloniki, Thessaloniki, Greece	C. Tsiouvaras	V. Papanastasis, A. Nastis, B. Noitsakis, Z. Koukoura, J. Ispikoudis, P. Platis, A. Ainalis, T. Papachristou
3. Forest Research Institute of Thessaloniki, Vassilika, Greece	O. Dini	C. Panetsos
4. Fodder Crops and Pastures Institute, Larissa, Greece	Th. Vaitsis	A. Konstantakis
5. Istituto di Agronomia Generale e Coltivazioni Erbacee, University of Palermo, Italy	L. Stringi	G. Amato, D. Giambalvo, A. Accardo
6. Dipartimento di Produzione Vegetale, University of Tuscia, Viterbo, Italy	C. Cereti	F. Rossini
7. Institut National de la Recherche Agronomique, Laboratoire d'Ecophysiologie des Plantes sous Stress Environnementaux, Montpellier, France	C. Dupraz	J. Lizot, M. Dauzat, S. Ouattara, R. Foroughbakhch, F. Liagre, B. Suard, S. Ploquin, R. Cordesse
8. Institut National de la Recherche Agronomique, Unite d'Ecodéveloppement, Montfavet, Avignon, France	D. Armand	M. Meuret
9. Servicio de Investigación Agraria, Badajoz, Spain	L. Olea	J. Paredes, A. Santos

The project started in 1991 and it was completed in early 1995. This book is a slight version of the final report of the project submitted to European Commission, where the results produced are presented and discussed. For those, limited, results already published in scientific journals or in proceeding of national and international meeting only a brief review is done.

Study sites

The participating units covered a large area of the European Mediterranean region; it extends from about 6° west to 28° east longitude and from 36° to 44° north latitude (Fig. 2).



Spain	France	Italy	Greece
1. Zaragoza	3. Montpellier	5. Viterbo	7. Thessaloniki
2. Badajoz	4. Avignon	6. Palermo	8. Vassilika
			9. Larissa

Fig. 2. Distribution of the participating units (+: trial sites).

Each participant established trials in the form of small plantations. Altogether, they were set up 24 such trials, some of which had previously set up and incorporated into the project, covering a total area of more than 12.5 ha. The number of factors studied by each participant in the trials ranged from 1 to 5 and the spacing between plants in the shrub plantations ranged from 0.5 to 12 m (Table 2).

Table 2. Elements of the experimental trials

Participant	Number of trials			Number of factors	Plant spacing (m × m) (within × between rows)	Size of trials (m^2)
	Old	New	Total			
Thessaloniki	1	2	3	4	1.0-12 × 1.5-12	95,600
Vassilika	1	0	1	1	1.5 × 2	3,360
Larissa	4	3	7	2	1.5-2 × 1.5-2	3,236
Palermo	1	0	1	1	1.5 × 2	4,200
Viterbo	1	2	2	2	4 × 2	2,000
Montpellier	5	0	0	5	0.5-5 × 1-5	7,360
Avignon	3	0	0	3	1.5 × 2	1,850
Badajoz	0	2	2	2	5 × 5	7,500
Total	15	9	24		0.5-12	125,106

The physical characteristics of the study sites are shown on Table 3. It is evident that these sites were generally located in the low elevation zone, had a wide range of climatic conditions and relatively gentle slopes with deep soils, slightly acid to neutral (Table 3).

Table 3. Physical characteristics of the study area

Participant	Altitude (m)	Slope (%)	Soil depth (cm)	pH	Mean annual rainfall (mm)	Mean min. temperature of coldest month (°C)	Mean max. temperature of hottest month (°C)
Thessaloniki	100-650	5-7	50-100	6.0	430-650	-0.6-1.0	13-29
Vassilika	10	0	100-120	7.5	420	0.2	31.7
Larissa	30-200	0-6	20-100	7.6-8.0	514	0.8	33.2
Palermo	210	10-15	100-130	7.9-8.1	509	–	31.0
Viterbo	220-300	0-10	50-70	6.2-6.9	650-830	2.5-4.0	27.4-29.0
Montpellier	13-150	0-10	100-160	7.5-7.8	690-850	0-1.8	28.3-38.0
Avignon	24-800	0-10	100-200	7.0-7.5	760-1060	-2.3-1.8	24.2-28.8
Badajoz	220-237	3-5	40-80	5.7-7.0	495-503	3.6-4.5	–

The project involved the study of 17 species of fodder trees and shrubs with several cultivars and populations (Table 4). Emphasis was given, however, on only a few of them which are the most promising such as *Chamaecytisus proliferus, Gleditsia triacanthos, Medicago arborea, Morus alba* and *Robinia pseudoacacia*.

Table 4. Species and cultivars or populations studied by the participants

Species	Cultivar or population	Participant							
		Thessaloniki	Vassilika	Larissa	Palermo	Viterbo	Montpellier	Avignon	Badajoz
Amorpha fruticosa	French						+		
	Italian	+							
Atriplex halimus	Tunisian								+
Atriplex nummularia	S. African								+
Caragana arborescens	French						+		
Carpinus orientalis	Greek	+							
Chamaecytisus proliferus	Canary Islands								+
Colutea arborescens	French						+		
	Greek	+							
Coronilla emerus	French						+		
Fraxinus ornus	Greek	+							
Gleditsia triacanthos	French						+		
	Greek	+							
Medicago arborea	Algerian				+				
	Algerian				+				
	French						+		
	French				+				
	Greek			+	+				
	Greek			+	+				
	Greek			+					
	Italian			+	+				
	Italian				+				
	Italian				+				
	Sicily					+			
	Viterbo					+			

Table 4 (cont.). Species and cultivars or populations studied by the participants

Species	Cultivar or population	Participant							
		Thessaloniki	Vassilika	Larissa	Palermo	Viterbo	Montpellier	Avignon	Badajoz
Morus alba	Greek	+							
	Kokuso 21						+	+	
	Spanish								+
Ostrya carpinifolia	Greek	+							
Pirus amygdaliformis	Greek	+							
Quercus pubescens	Greek	+							
Quercus sessiliflora	Greek	+							
Robinia pseudoacacia	French						+		
	Greek	+							
	Greek (spineless)	+	+						

Photographs

Plate I

1. Selected *Chamaecytisus proliferus* ssp. *palmensis* for Extremadura, Spain.
2. A resistant to summer drought ecotype of *Medicago arborea* in Central Greece.
3. A selected *Robinia pseudoacacia* clone with few and large leaflets in northern Greece.
4. Grafting *Gleditsia triacanthos* in Montpellier, France.

Plate II

1. Establishing a young plantation of *Medicago arborea* with selected genetic material in Viterbo, Italy.
2. An established *Medicago arborea* plantation in Larissa area, Greece.
3. An established *Medicago arborea* plantation in Pietranera, Sicily with great variability in flowering time.
4. A cut plant of *Medicago arborea* to measure biomass production in Pietranera, Sicily.

Plate III

1. A grafted *Gleditsia triacanthos* fodder tree with many pods in Montpellier, France.
2. Sheep relishing on *Gleditsia triacanthos* pods during late autumn in Montpellier, France.
3. A sheep with faeces collector to measure intake by the lignin budget technique.
4. A plantation of *Robinia pseudoacacia* with plastic tubes in northern Greece.

Plate IV

1. Part of the research group on fodder trees and shrubs in a plantation in southern France.
2. A fodder shrub plantation with various deciduous species in northern Greece.
3. A *Morus alba* cv. Kokuso 21 plantation in Provence, France.
4. Sheep eating planted *Robinia pseudoacacia* in northern Greece.

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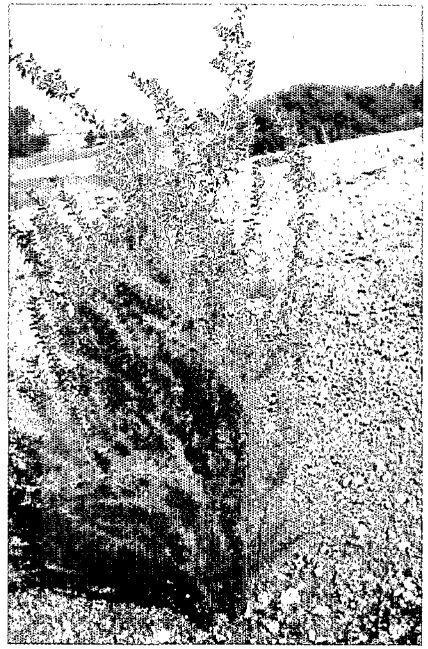

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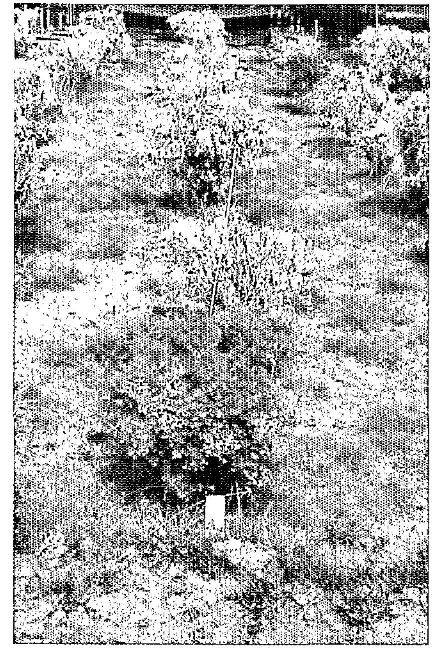

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PLATE I

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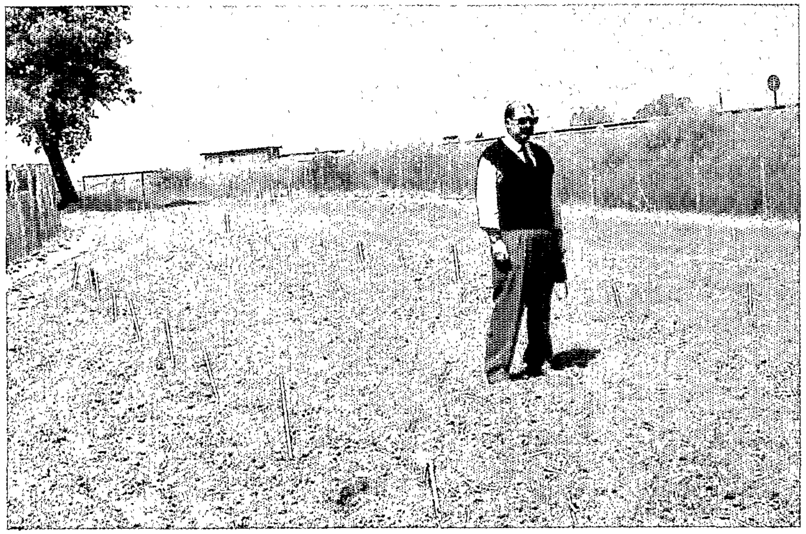

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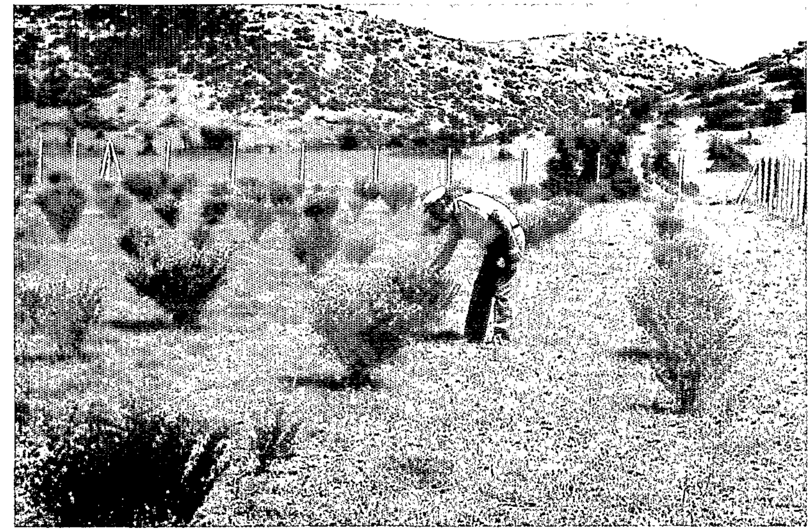

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PLATE II

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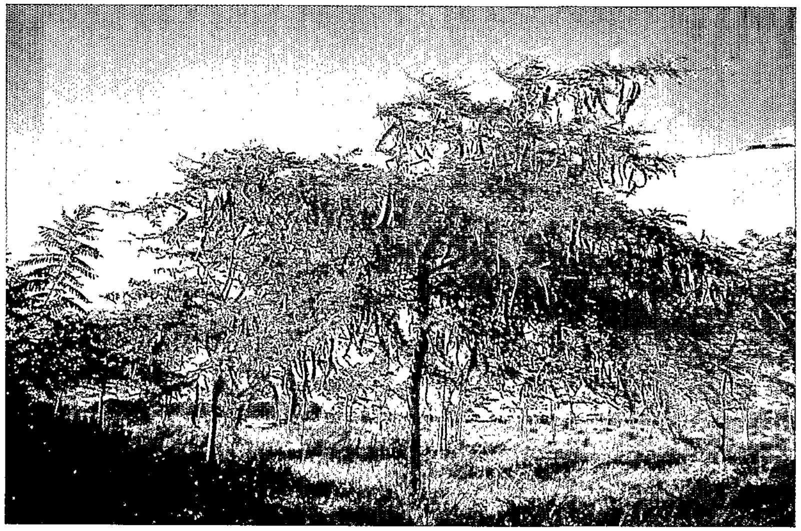

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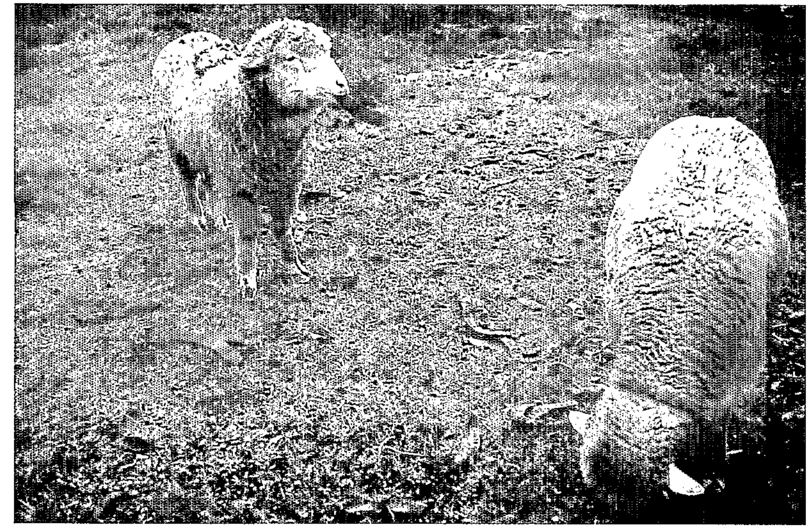

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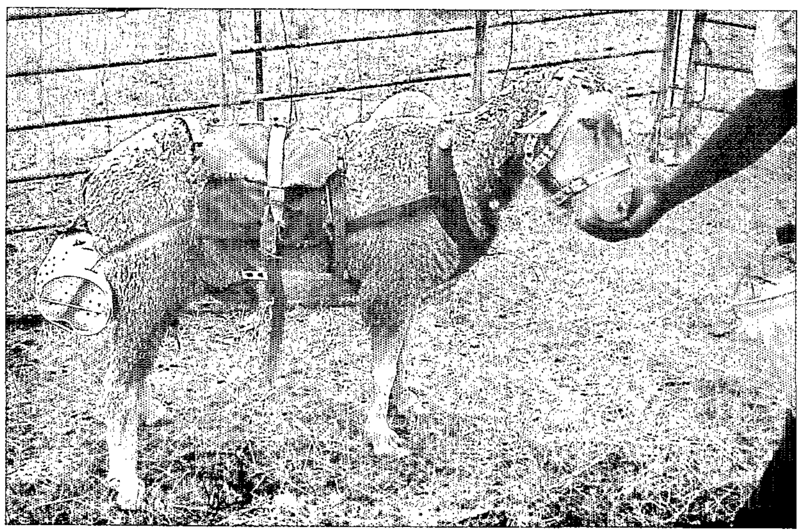

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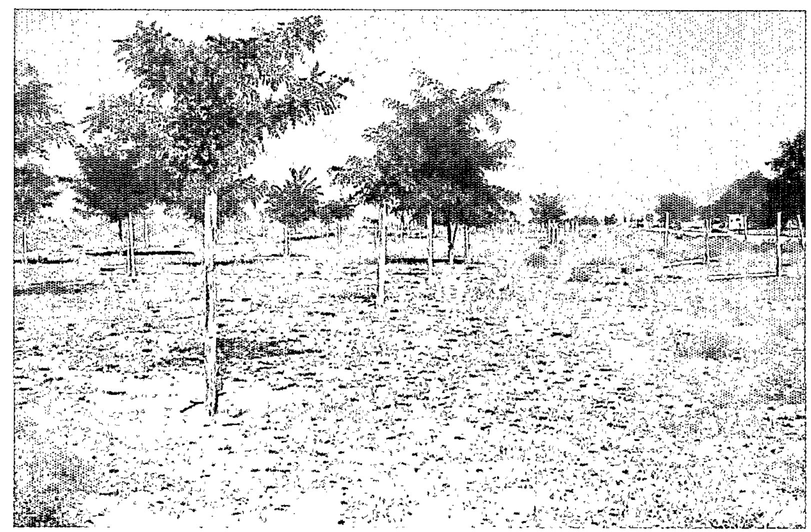

PLATE III

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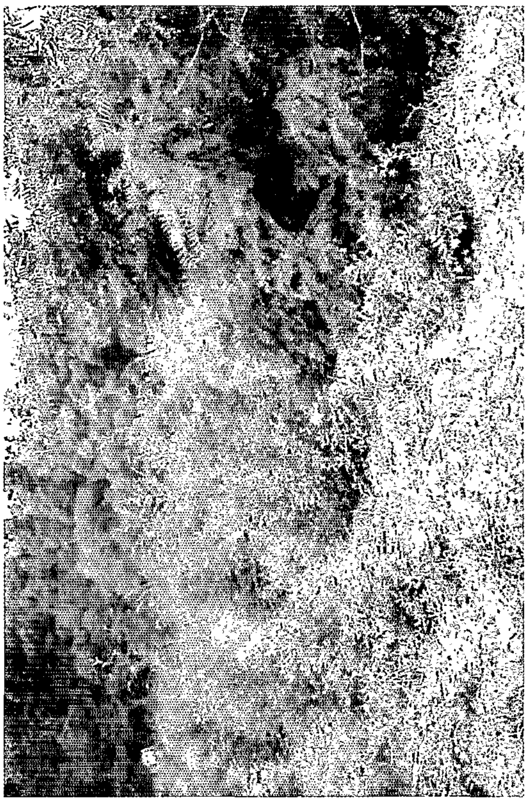

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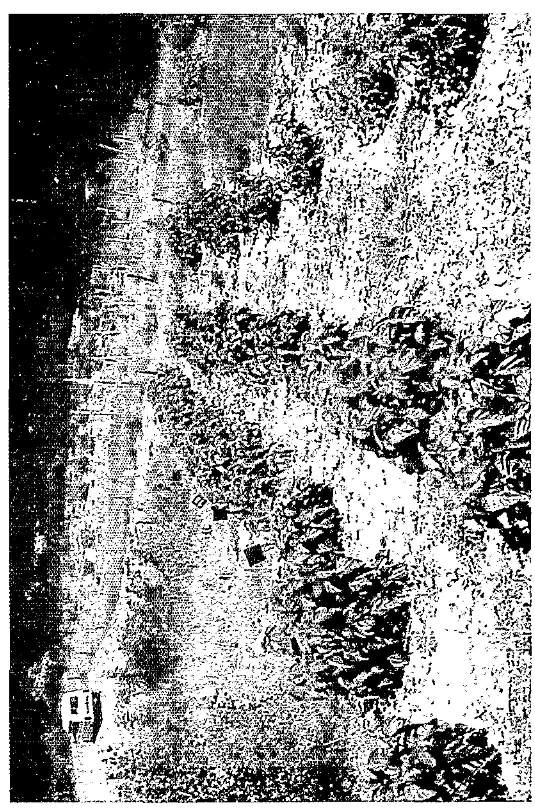

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PLATE IV

Methodology

For efficient implementation, the whole project was divided into three actions: germplasm collection, screening and multiplication; ecological and economic evaluation; establishment and management of plantations. In each of these actions different methodologies were applied which are described hereafter.

Germplasm collection, screening and multiplication

Chamaecytisus proliferus

Seeds of the taxonomic complex of this shrub were collected from the Canary Islands where it is endemic and used as fodder plant. Altogether 26 lines of four different subspecies grown in a variety of environments were included in the collection, namely *Chamaecytisus proliferus* ssp. *palmensis* (tagasaste), *Chamaecytisus proliferus* ssp. *proliferus* (escobón), *Ch. proliferus* ssp. *proliferus* × *Ch. proliferus* ssp. *palmensis* and *Chamaecytisus proliferus* ssp. *canariae*. The seeds were transferred to the farm "La Orden" near Badajoz, SW Spain, and sown in soil and polyethylene bags which were later transplanted in the field. The evaluation lasted for 3 years and included the following parameters: adaptation to the acid soils and semi-arid climate of the SW Spain, cold resistance, leaf area, flowering time, regrowth capacity after harvest, persistence and palatability.

Gleditsia triacanthos

A clonal orchard of grafted *Gleditsia* trees was established at Melgueil, 7 km east of Montpellier, in 1987. It contained 16 clones originating from naturalized populations of *Gleditsia* in southern France including one American variety selected for the sugar content of its pods. The abbreviated names of the varieties are: ZDV, BRL, CAB, CAS, CYN, GAR, JEA, MIL (the American), REB, REV, SBR, SGO, SUM, TOT, VFM and VPD. The experiment design was a latin square with 9 trees per clone. Grafting was carried out in 1988 and 1989. The orchard was intercropped with the grass *Festuca arundinacea* to control the weeds and produce additional forage. When the current project started in 1991, the oldest grafted trees were 3 years old and a close monitoring of the orchard was initiated by recording pod production every year. Similar monitoring of pod production was also done on the parental trees and compared with the grafted trees.

Medicago arborea

Germplasm collection of *Medicago* from indigenous populations in Greece was carried out during the course of the project. It included seeds and cuttings from wild or semi-natural populations grown in Attica, Delphi, Peloponnese and the Aegean islands, especially Kos and Karpathos. All the material was transferred to Larissa, central Greece, and established in conservation nurseries in the farm of the Fodder Crops and Pastures Institute. In these nurseries, selection was done for cold and drought resistance, leafiness and persistence. Conservation nurseries with collected material from Karpathos were also established in Rhodes.

Survived populations or individuals were multiplied and used in trials together with older selections (e.g. 'Naxos') as well as an Italian accession for further testing. For this reason, three trials with 9 selected populations were established at three locations in Greece, in the autumn 1991. One location was in the farm of Fodder Crops and Pasture Institute at Larissa (good soil), another in Messochori, 40 km north of Larissa (marginal soil), and a third one in Rhodes in the farm of the Agricultural Research Station (good soil) where the climate is milder and better than in central Greece (Larissa area). In addition, a local variety of the grass *Dactylis glomerata* was seeded in all the trials as a companion crop. The experimental layout was a randomized block design and measurements included mortality and growth data.

Furthermore, new trials were established in 1993 and 1994 with seeds or cuttings in the experimental farm of the Institute at Larissa and measurements such as mortality and growth performance were taken. Finally, the trial in Rhodes was subjected to sheep grazing is late spring-early summer and observations were made on animal preference.

Robinia pseudoacacia

Germplasm was collected in the form of seeds, stem and root cuttings from individual trees with interesting characters (few or no thorns, few leaflets per compound leaf) grown in several parts of Macedonia, Greece.

In addition, a progeny trial was established in the farm of the Forest Research Institute at Vassilika, 20 km east of Thessaloniki, Greece. The trial included saplings from 14 open pollinated tree-families originally selected in Macedonia for their few thorns and variable leaf size. Experimental layout was a completely randomized block design. Measurements were carried out in the middle to late autumn every year and involved growth data (height and diameter) phenological observations, leafiness (number and size of leaflets per compound leaf) and thorniness (number and size of thorns).

Moreover, vegetative propagation trials were carried out with hardwood (winter) and softwood (green or leaf) cuttings in 1992. In the first trial, 3 root promoting chemicals, 2 ages of cuttings (one and two years old) and 2 dimensions (thin, thick) were compared with controls in the greenhouse; in the second trial, two different rooting media were used (perlite and a mixture of peat and sand) in cuttings originating from different interesting individuals.

Finally, a clonal test was carried out in 1994. It included: 14 clones produced from (i) outstanding individuals of the progeny trial (12) belonging to 7 out of the 14 original open-pollinated tree-families of the progeny trial and selected for their superior growth performance including their very dense and rich foliage, (ii) a spherical thornless clone (1), and (iii) an interesting spontaneous tree (1); and 9 half-sib families, 7 from the parental families of the progeny trial, 1 from all the families (mixture) of the progeny trial and 1 from a common *Robinia*. As a whole, 420 one year-old plants were established in a completely randomized design. Measurements at the end of October included growth parameters (height and diameter), maximum thorn length, phenological development, biomass and specific leaf weight (SLW).

Ecological and agronomic evaluation

Gleditsia triacanthos

Two trials with the selected clones of the Melgueil orchard were established at two different sites in Notre-Dame de Londres, 25 km north of Montpellier, in 1992. One site (Masclac) had a deep sandy soil and the other (Le Rouet) site had a very clayish soil. Both trials were replicates of the clonal test at Melgueil but they had fewer cultivars (13 out of 16), larger spacing and were protected from grazing by tubex shelters. Measurements included mortality and growth (height) in 1993 and 1994.

Similar trials but with fewer clones (10) were established in Macedonia, Greece with grafted trees sent by Dr Christian Dupraz, scientific responsible of the Montpellier team. The 100 trees were planted in two sites, one at Loutra Thermis, in the farm of the Forest Research Institute of Thessaloniki (clayish soil) and another at Scholari, 40 km east of Thessaloniki (sandy soil). Measurements were the same as in France but started in 1992.

Medicago arborea

A trial with 10 populations (4 from Greece, 3 from southern Italy, 2 from Algeria and 1 from France) was established at Pietranera, a University of Palermo farm in Sicily, at a spacing 2 × 1.5 m, in 1990. During the course of the project several measurements were taken including mortality, phenological characters, leafiness, growth dimensions (height and diameter), shrub volume, pod and seed yields and biomass above 70 cm from the ground in the winter period. In addition, a progeny test was initiated with clones produced from rooted cuttings of the 15 most important phenotypes of the plantation.

On the other hand, two trials with two populations (one from seeds coming from Sicily and another from cuttings obtained by locally adapted and frost resistant plants) were established at two sites in the region of north Lathium, central Italy. One site was at the farm of the University of Tuscia in Viterbo and the other at Tessennano, a coaster area to the west of Viterbo. In the former trial, the grass *F. arundinacea* was seeded to control the weeds and also ensure additional forage to animals. Measurements included cold resistance and forage production. Also the photographic method was applied for evaluation of biomass while both trials were subjected to grazing by cattle and sheep to evaluate the resistance of *M. arborea* to animal pressure.

Morus alba

Three trials with *Morus alba* cv. Kokuso 21 were established in southern France in 1986-1988, two on marginal sites (1 and 3) located in the Alpes de Haute-Provence at 400 and 800 m altitude respectively and one (site 2) in a better site at the plain of Vaucluse, in Montfavet near Avignon, at 24 m altitude as a control of the other two sites. In site 1, plants were produced from cuttings, established in 1986 and 1987 at a spacing 1.5 × 2 m and subjected to 4 defoliation intensities (0, 50, 80 and 100%). In site 2, plants were originated both from cuttings and *in vitro* multiplication and established in 1987 and 1988 at the same spacing as in site 1 without being subjected to defoliation. In site 3, finally, plants were originated from *in vitro* multiplication and established in 1988 in a farm with a spacing 1.5 × 2.5 m and subjected to browsing by a flock of 250 sheep since 1991. All the sites had a basic soil with pH 7.8-8.3. In each plantation, fertilization with ammonium nitrate in the first years and ammonium phosphate in the last years was applied as well as weed control with herbicides (glyphosate). In all shrubs three cutting schemes were applied: cups and pollards at 20-30 cm height and clear cutting at 30-34 cm height above ground level. The measurements taken were:

(i) Climatic factors from the meteorological stations of the study areas to estimate the periods "free of frost" during which the available soil water permitted the photosynthetic activity of plants.

(ii) Base diameter (DB) at 3-4 cm above ground.

(iii) Shrub height (H).

(iv) Shrub diameter, small (d) and big (D) at two perpendicular directions.

(v) Number (RA) and the cumulated length of annual ramets (LRA).

(vi) Effective shrub volume (VOL) by using the formula (Armand, 1994): $VOL = \pi \times D \times d \times H/4000\ dm^3$.

(vii) Estimated dry matter production of leaves (*matière sèche estimée*, MSE) by using linear equations.

Finally, 6 farmers utilizing ancient *Morus* trees for supplemental feeding of their animals at the end of the summer were interviewed with questionnaires containing information for 4 calendars (animal production, forage, supplementation and working activities) while new plantations were established (sites 4 and 5) with 'Kokuso 21' in farms already utilizing ancient *Morus* trees for a more efficient use of this important resource.

Other species

A trial was established in a subhumid Mediterranean environment with cold winters of central Macedonia (Chrysopigi, Serres), Greece with ten species of deciduous fodder trees and shrubs: *Amorpha fruticosa*, *Carpinus orientalis, Colutea arborescens, Corylus avellana, Fraxinus ornus, Ostrya carpinifolia, Pirus amygdaliformis, Quercus pubescens, Quercus sessiliflora* and *R. pseudoacacia* with two accessions, common and thornless. A completely randomized block design was set up in 1986. Each species covered a plot of 42 m^2 with four replications. The original plants were one year-old and planted at a spacing 1.0 × 1.5 m. The above ground biomass and plant height were measured at the end of August since 1987 and throughout the course of the project. In each year, 5 plants of each species were cut at 10 cm aboveground. In half of the samples taken, the leaves and twigs were hand separated from the branches so that the edible biomass is determined. In addition, their nutritional quality was measured by collecting forage samples (leaves and twigs) from each species in 1991 and 1992 at six stages of maturity (May, June, July, August, September-October and October-November). Measurements included N, crude protein (CP) and *in vitro* organic matter digestibility (IVOMD). Finally, the relative acceptance index (RAI) was determined with a small flock of goats by directly measuring the number of bites on each species as compared to the total number of bites in July and August.

Shrub productivity was also measured at two trials at Melgueil and Saint-Gély in Montpellier, southern France for the following species: *A. fruticosa, C. arborescens, R. pseudoacacia, M. alba* cv. Kokuso 21, *Coronilla emerus* and *M. arborea*. The trials were established in 1988 while the *M. alba* plantations also included N fertilization. Measurements involved were dry matter (DM) production of leaves at the beginning of August which was correlated with seasonal rainfall within each year to find out the impact of climate on shrub productivity.

Finally, two trials were established at two sites ("La Orden" and Valdesequera) in Extremadura, SW Spain in 1991 with the following species of shrubs: *Atriplex halimus, Atriplex nummularia, Atriplex repanda* and *Atriplex cinerea, M. arborea, Ch. proliferus* and *M. alba.* Measurements included persistence, production and nutritive value.

Establishment and management of plantations

Establishment of fodder shrubs

Establishment techniques for *Medicago* were investigated at the Tessennano site in north Lathium, central Italy, in 1992. Treatments included: direct pocket drilling, transplanting of 4 months-old seedlings and transplanting of 5 months-old rooted cuttings. All the treatments were applied both in autumn and spring.

Establishment experiments were also carried out in Extremadura, SW Spain, in 1992 with several species of fodder shrubs. The methods employed were: direct seeding in the field, transplanting of containerized seedlings 20-30 cm tall and stem cuttings. Transplants were planted at three different periods (autumn, winter and spring). The same (Spanish) team carried out experiments on seed pre-treatment. For leguminous species, the following pre-treatment was applied: boiling water for 20 and 45 seconds and 1, 2 and 3 minutes soaking in peroxidated water; scarification by hand and sulphuric acid. For *Atriplex* species, they were applied: removal of seed pericarp and seeds washed with running water.

Cultivation and management schemes

The problem of weeds and their competition with fodder shrubs was studied in southern France, and especially if spring weeding is necessary in a mature stand of shrubs or alternative ways should be sought such as sowing of winter growing species as intercrops. Late winter grazing was conducted to obtain clear plots at bud opening time in the spring. Moreover, the role of fertilization on *Morus* growth was studied, the shrub age at the first cut or grazing, the size and the feeding value of fruits and dry dropped leaves; and the use of flexible tall stems of shrubs by sheep.

The shrub age at first cut as well as the frequency of cutting back of various species of deciduous fodder trees and shrubs was also investigated in Greece.

Spacing and grazing of fodder shrubs

A trial involving the study of the effects of three spacings (1.5 × 1.5, 2.5 × 2.5 and 3.5 × 3.5 m) and sheep grazing on growth and productivity of the species *A. fruticosa, G. triacanthos, M. alba* and *R. pseudoacacia* was established in a communally grazed grassland with poor soils (sandy) in Scholari, 40 km east of Thessaloniki, Greece. Plants were one year old at the time of planting in 1991 and originated from seeds. The experimental layout was split-plot design with three replications. Individual plants which died during the 4-year period were replaced every spring with similar age saplings. Grazing by sheep was applied in late June to early July of 1992, 1993 and 1994, while in the last two years grazing was also applied in late August to early September. The whole trial was protected from communal grazing by fences. Measurements included cover, species composition and biomass of the herbaceous layer as well as growth dynamics, height, production and nutritive values of the planted shrub species. Growth dynamics of shrubs involved leaf growth and leaf water potential.

Feeding value of pods of *Gleditsia triacanthos*

A bumper harvest of *Gleditsia* pods at the end of 1992 was used to study their feed quality by the Montpellier team in 1993. They were studied: the chemical composition and *in vitro* digestibility of four varieties together with samples of dehydrated alfalfa used as supplement; the *in vivo* digestibility by using 6 castrated rams, 3 of which were fistulated, and measuring pod intake by sheep, animal weight changes, the coefficient of digestibility (CD) for the dry matter, organic matter (OM) and crude protein, and the budgets of the ingested seeds.

Moreover, the same team continued the study of the feeding value of pods in 1994 by using a different technique, the *in sacco* degradability, which gives the opportunity to measure degradability of pods in the very exact incubation conditions of the rumen. More specifically, two experiments were carried out, one with a standard diet and another with a pod diet fed to the sheep by placing nylon bags with feed in the rumen of fistulated animals. The standard feed used in the first trial was high quality alfalfa pellets, straw, barley and minerals and tested in three fistulated ewes. The pods of the second diet came from 4 *Gleditsia* varieties as in the previous' year digestibility trials and tested in three fistulated rams. The results of this method were compared with the ones received by the other two techniques applied the previous year.

Fodder shrubs as a summer feed supplement

Three experiments on the value of fodder shrubs as a summer feed supplement were conducted: two in southern France with sheep by the Montpellier team and one in northern Greece with goats by the Thessaloniki team.

The first experiment in Montpellier was carried out in 1991 and involved three flocks of sheep: a control flock fed only on rangeland, a flock supplemented with barley (300 g/day) and a flock supplemented with shrubs (400 g DM/day). The experiment lasted for seven weeks in the summer.

In the second experiment carried out in 1994, four treatments were used: *M. alba* cv. Kokuso 21 a mixture of leguminous shrubs (*Robinia, Amorpha, Colutea* and *Coronilla*), alfalfa (dehydrated pellets) and no supplement. Each treatment was allocated to a group of 8 meat sheep (32 sheep altogether). During the experiment, which lasted for 9 weeks (June 26 to August 26), sheep were grazing freely in the rangelands from 4-8 a.m. in the morning and 7-11 p.m. in late afternoon. The supplementation which corresponded only to 10% of the daily requirements of each animal was provided at 8 a.m. Animals were weighed periodically, their diet composition was observed both in the rangelands and in their rumens in two fistulated sheep per group, their faeces were collected and analysed, their grazing activity was recorded and the *in sacco* degradability of a standard feed was determined.

In Greece, eight treatments were used: *Amorpha, Carpinus, Colutea, Fraxinus, Ostrya, Robinia,* alfalfa pellets and no supplement. Each treatment was allocated to a group of four meat goats (32 goats altogether). The experiment was conducted in 1994, during two 15-day periods, July 17-31 and August 27 to September 10.

Wide spacing of protected fodder trees

A trial involving wide planting of fodder trees, namely *R. pseudoacacia* and *G. triacanthos,* at three spacings (4 × 4, 8 × 8 and 12 × 12 m) and with two protective measures (plastic tubes and wire nets) was established in a communally grazed grassland with poor sandy soil in Scholari, 40 km east of Thessaloniki, Greece. Planting was carried out with one year-old seedlings in the spring of 1991. Individuals destroyed by summer drought or by animals were replaced every spring with similar age saplings. In the summer, plants were irrigated every 20 days to reduce losses due to drought. In 1993, the trial was modified by replacing *G. triacanthos* with *M. alba* due to poor growth of the former species and the wire nets by barbwire fences. Measurements included ground cover and production of the herbaceous layer as well as mortality and height of the planted trees. In addition, observations were made on the interaction between protected trees and shepherds who continued to use the experimental area as grazing land, as well as the resistance of protected trees to various pressures and interventions by both animals and people.

Results

The results of the project were numerous and quite variable. For easier comprehension, they are presented in the same way as in the chapter of methodology.

Germplasm selection and evaluation

Chamaecytisus proliferus

From the evaluation of the germplasm originating in Canary Islands it was found that most of the lines collected are adapted to semi-arid conditions (500-600 mm rainfall); they can tolerate low winter temperatures (2-3°C); they prefer soil of medium texture and acid soils (pH 5.5-6.5); and they have a good regrowth capacity and persistence (Olea *et al.*, 1993a,b,c). The most promising lines selected for SW Spain were: (i) two lines of tagasaste (*Ch. proliferus* ssp. *palmensis*) (numbers 1 and 24); and (ii) one line of *Ch. proliferus* ssp. *canariae.*

Both these ecotypes have been transplanted in the "dehesa" region to be studied under real management conditions. In the meantime, tagasaste has been requested to be tested in other environments by participants of this project as well as by other Mediterranean scientists.

Gleditsia triacanthos

Pod production of the grafted trees

The clonal orchard with the grafted *Gleditsia* trees at Melgueil, Montpellier (southern France) displayed a distinct pod production pattern within each of the varieties tested.

The number of productive trees (trees having produced pods during at least one year) was increased from 1991 to 1994 (Fig. 3). In 1994, 107 trees produced pods out of a total of 136 grafted individuals. Mean pod yield per productive tree, however, was decreased in the last two years as compared to 1992 (Fig. 3) possibly due to the strong competition for water and nitrogen by the intercropped *F. arundinacea,* accentuated by the dry weather prevailed in the spring and the lack of any management (e.g. weed control) in both years 1993 and 1994.

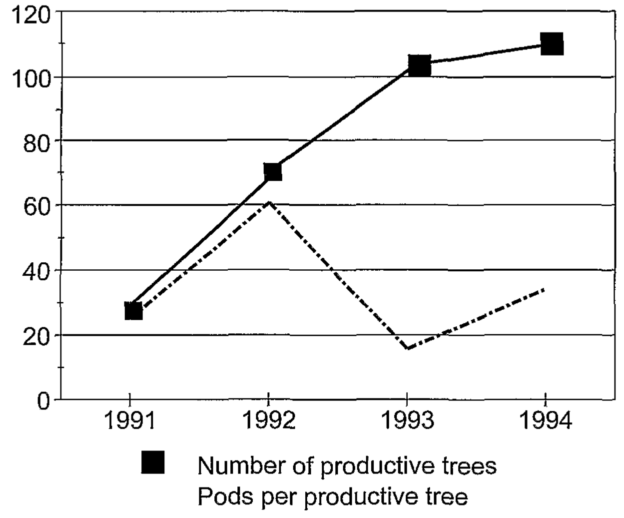


Fig. 3. Number of productive trees and mean yield per productive tree in the Melgueil *Gleditsia triacanthos* orchard in southern France.

Pod production was different among varieties and between years. The production of the orchard as a whole clearly followed an alternate bearing pattern (Table 5), with even years (1992 and 1994) as high production years and odd years (1991 and 1993) as low production years. This pattern was shared by most trees in the orchard, but some trees behaved differently. Some varieties exhibited two opposite alternate production patterns, with as many trees with a high production level in even and odd years: ADV, CYN, GAR, SBR and VPO. But the bulk of the varieties followed the main pattern, with only a few trees making an exception to the rule for CAS, JEA, REB, REV, SGO, TOT and VFM varieties.

Table 5. Pod yields for the different varieties in the Melgueil orchard (1991 to 1994) of southern France

Variety	Number of trees		Pods per productive tree			
	Grafted	Productive	1991	1992	1993	1994
ADV	7	5	–	49	20	12
BRL	9	5	37	54	16	48
CAB	5	5	6	125	4	60
CAS	9	5	–	24	9	24
CYN	6	6	60	70	23	7
GAR	9	6	1	4	19	0
JEA	9	8	41	81	18	61
MIL	9	8	20	105	5	74
REB	9	5	34	96	8	30
REV	6	5	194	116	40	70
SBR	9	9	1	66	40	60
SGO	8	5	7	15	5	14
SUM	9	7	16	52	10	52
TOT	9	7	7	73	12	31
VFM	9	8	–	38	20	19
VPO	9	8	1	37	12	8

Expressed in kg per ha in a 400 trees per ha orchard, the pod yields were relatively low and varied widely among varieties and between years (Table 6). They ranged from 0 in one variety to 376 kg/ha in the best producing variety in 1994 or 117 kg/ha on the average for the 17 varieties. Production is expected to increase in the next few years as the trees get older. No matter how big this production was, however, it should be considered on top of the herbage production provided by the intercropped sward of *F. arundinacea*. In 1992, sward production was measured to a level of 2 t DM/ha. Since the orchard was seeded with this grass, however, tree growth was reduced. This means that *Gleditsia* trees are sensitive to grass competition without affecting considerably sward productivity. Anyhow, the problem of associating fodder trees and pasture should be investigated in a future project so that the best management schemes are developed.

Based on the age since production started and the reliability, the varieties of Table 6 may be classified into the following five groups:

(i) Early producers keeping their promises (CAB, JEA, MIL, REV). These varieties yielded significant amounts of pods as soon as at age 3 to 4 and kept producing pods for the next two years. Most of the grafted trees went into production.

(ii) Disappointing early producer (REB). This variety had high yields at age 4, but did not confirm during the next two years. Moreover, four grafted trees of this variety did not bear any pods.

(iii) Fair producers (SBR, TOT, BRL, CYN, SUM). They had a significant early production (but with few trees producing), but fair results in the next two years.

(iv) Poor producers (VPO, VFM, ADV). They yielded less than 50 pods per tree per year.

(v) Very few trees in production yet, and low levels of production (SGO, CAS, GAR). GAR trees seem to have changed sex, and bear now mainly male flowers.

Table 6. Dry matter yields of pods in the Melgueil orchard of southern France

Variety	Pod yields (kg DM/ha)				
	1991	1992	1993	1994	Total
ADV	0	38	39	24	100
BRL	60	146	43	130	380
CAB	7	382	13	183	585
CAS	0	23	15	39	77
CYN	58	136	135	39	369
C81	0	60	18	33	111
GAR	0	3	40	0	43
JEA	130	302	77	258	768
MIL	51	400	18	376	846
REB	15	86	10	68	179
REV	109	261	113	197	680
SBR	0	136	151	224	511
SGO	5	21	10	49	86
SUM	13	153	30	153	348
TOT	18	230	44	115	408
VFM	0	40	41	53	135
VPO	1	109	68	48	226
Mean	28	149	51	117	344

Moreover, clear differences were found among varieties in terms of pod retention on the tree. In general, pod dropping from the trees started in late September and continued until the end of January, while certain individual trees kept some of their pods even longer.

Finally, pods displayed a wide range of morphological characters in terms of length (22-35 cm), width (3-4 cm), number of seeds per pot (12-24) and seeds to pods ratio (17-43% of DM) (Table 7).

From these observations, the varieties may also be classified into three categories:

(i) Varieties with thin and light pods, very little pulp and high seed to pod ratios (34% and 43% for SBR and SUM).

(ii) Varieties with a seed to pod ratio varying between 25 and 30% (BRL, JEA, REB, REV, TOT and VFM).

(iii) Varieties with very thick pods, a high content of sweet pulp, and low seed to pod ratios (CYN, MIL, SGO, VPO).

Pod production of the parental trees

Table 8 shows the annual pod production of the parental *Gleditsia* trees since 1984 when monitoring started. It is quite clear that these trees follow the alternate pattern, as it was also observed in the grafted trees. Most of the parental trees were found to have a good harvest of pods every two years while the average production of the best producing variety was found to be about 89 kg of pods and 24 kg of seeds corresponding to about 6000 pods per tree. However, most of the other varieties produced much less quantities thus indicating the great importance of the selection programme applied on *Gleditsia*.

Table 7. Morphological aspects of the pods of the varieties included in the Melgueil orchard of southern France

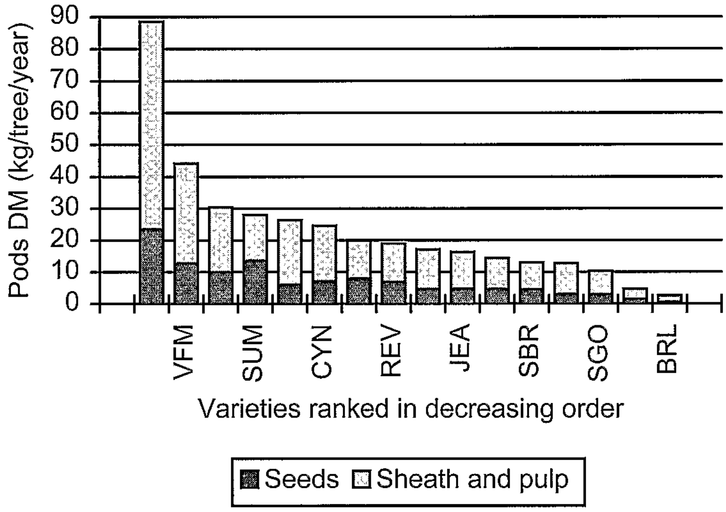
Variety	Length (cm)	Width (cm)	Seeds	Seeds to pods ratio (% of DM)
MIL	28.1±2.8	3.8±0.2	19.4±2.7	22.3
REV	24.9±1.8	3.3±0.2	17.2±3.4	25.6
JEA	35.3±4.1	2.8±0.2	20.1±3.3	30.5
TOT	31.3±2.6	2.4±0.1	19.3±7.1	27.6
CAB	23.8±2.3	3.1±0.2	13.8±5.3	25.1
CYN	27.2±2.7	2.9±0.2	13.0±5.1	25.2
SUM	25.8±1.7	3.0±0.2	17.4±3.0	42.7
SBR	30.4±3.1	3.1±0.2	18.1±3.8	33.6
BRL	32.9±2.5	3.2±0.6	19.2±2.2	26.6
VPO	43.0±7.9	3.9±0.5	18.7±2.3	24.6
REB	29.5±3.3	3.4±0.3	16.1±4.3	26.6
SGO	30.8±2.9	4.3±0.3	12.4±3.7	17.3
CAS	29.1±2.0	2.6±0.2	22.4±6.1	24.5
VFM	25.6±3.0	2.9±0.3	14.3±4.1	27.8
ADV	22.2±2.7	3.4±0.3	12.1±3.2	23.7
GAR	26.5	2.7	22.0	25.8

Table 8. Annual pod production of *Gleditsia triacanthos* trees selected as parental trees for clonal multiplication in southern France

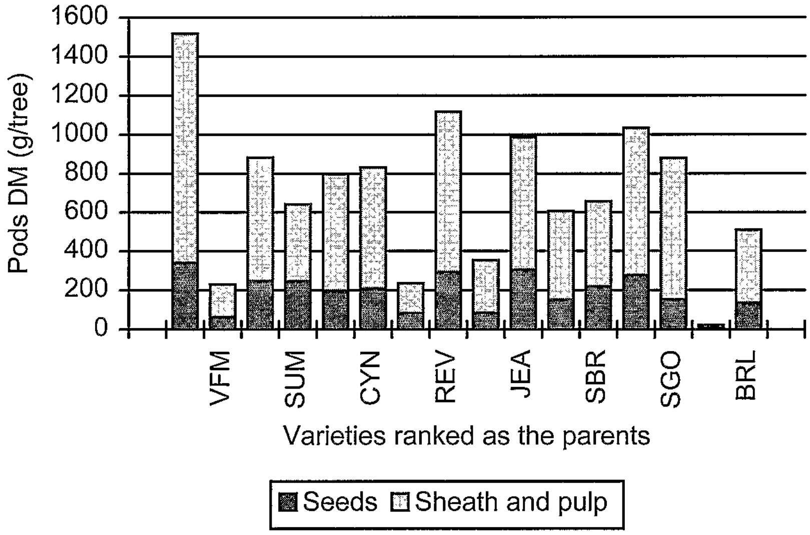
Variety	Number of pods per tree										
	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
ADV	NM†	5400	20	2050	200	2000	NM	2250	2000	200	200
BRL	200	0	200	200	200	100	NM	3	430	10	125
CAB	NM	3	20	5000	500	200	NM	10	TD††	–	–
CAS	700	2700	2100	1850	1400	3000	NM	1600	1600	60	2500
CYN	900	1360	1000	3400	1000	3500	NM	4200	150	4500	4
GAR	NM	3000	100	NM	500	30	NM	10	800	600	200
JEA	NM	0	600	NM	50	5000	NM	0†††	10	TD	–
MIL	NM	1600	2500	1100	9000	150	NM	0	25000	0	15000
REB	NM	0	350	700	500	2500	NM	2000	100	1200	0
REV	NM	0	5000	4500	5500	TD	–	–	–	–	–
SBR	NM	2400	200	NM	50	500	NM	4300	1500	6000	400
SGO	300	520	200	NM	300	1500	NM	500	880	110	100
SUM	NM	0	4000	0	3400	0	NM	4	8600	0	10000
TOT	NM	0	700	1150	1400	2000	NM	150	6000	0	3500
VFM	NM	5000	6000	2100	6000	800	NM	0	13000	10	20000
VPO	1000	1120	500	NM	100	2000	NM	1500	2200	200	500

†NM: no measure
††TD: tree destroyed
†††Tree cut back

Productivity of the grafted trees was not found to be correlated with the parental trees apparently because all the grafted trees were still young and grown at the same site which is inferior in terms of physical conditions (soil, water, microclimate) to the sites where the majority of parental trees are grown. However, in most of the cases there was a synchronization of the alternate bearing pattern between parental and grafted trees (Fig. 4).



Parental trees



Grafted trees

Fig. 4. Pod yields of parental and grafted *Gleditsia triacanthos* trees in southern France.

Medicago arborea

The indigenous *M. arborea* germplasm programme of the Fodder Crops and Pastures Institute in Larissa, Greece, resulted in the collection of 38 different populations listed on Table 9. In addition, a large number of clones and breeder's lines have been also produced. All this material has been included in 15 experimental plantations, most of them established during the course of the project (Table 10). The most important results were the following:

(i) The best time to collect seed samples was early summer and cuttings for vegetative propagation middle of autumn.

(ii) Considerable variability was found between and within collected populations in flowering time, cold and drought resistance, plant height, crown diameter, total annual dry matter production, leaves and fruit crops and hibernate recovery. A very interesting cultivar named 'Naxos' has been already released (Vaitsis, 1993).

Table 9. Collected indigenous accessions of *Medicago arborea* in central Greece

Code no.	Status	Origin	Year of collection
M-11237	Seminatural	A. Anargyri, Attiki	1971
M-14352	Seminatural	Naxos	1980
M-15131	Seminatural	Rafina, Attiki	1984
M-15132	Seminatural	Kini, Syros	1984
M-15133	Seminatural	Finikas, Syros	1984
M-15721	Mass selected variety	Naxos-84	1985
M-16442	Seminatural	Akropoli, Attiki	1987
M-16731	Mass selected variety	Naxos-90	1990
M-16911	Seminatural	Apolakkia, Rhodos	1991
M-16912	Seminatural	Kalamonas, Rhodos	1991
M-16913	Seminatural	Kalamonas, Rhodos	1991
M-16914	Seminatural	Mytilini, Lesvos	1991
M-17053	Seminatural	Airport, Kos	1992
M-17054	Seminatural	Kossari, Kos	1992
M-17055	Seminatural	Pylae, Karpathos	1992
M-17056	Wild	Menetae, Karpathos	1992
M-17057	Seminatural	Aperi, Karpathos	1992
M-17152	Wild	Kastalia, Delfi	1993
M-17153	Seminatural	Museum, Delfi	1993
M-17154	Seminatural	Park, Delfi	1993
M-17155	Seminatural	Galaxidi, Fokida	1993
M-17156	Seminatural	Elliniko, Argolida	1993
M-17157	Seminatural	Ligourio, Argolida	1993
M-17158	Seminatural	Porto Cheli	1993
M-17159	Seminatural	Ermioni, Argolida	1993
M-17160	Seminatural	Karpathos	1993
M-17161	Seminatural	Poliochni, Limnos	1993
M-17178	Seminatural	Methymna, Lesvos	1993
M-17179	Seminatural	Hypsilometopo, Lesvos	1993
M-17180	Seminatural	Kerami, Lesvos	1993
M-17214	Seminatural	Dyros, Lakonia	1994
M-17215	Seminatural	Dyros, Lakonia	1994
M-17216	Seminatural	Areopoli, Lakonia	1994
M-17217	Seminatural	Gythio, Lakonia	1994
M-17218	Seminatural	Voutiani, Lakonia	1994
M-17219	Seminatural	Voutiani, Lakonia	1994
M-17220	Seminatural	Arkasa, Karpathos	1994
M-17221	Seminatural	Diafani, Karpathos	1994

(iii) Foliage and total biomass was found to be strongly affected by the age of the plantation, management and edapho-climatic conditions.

(iv) Collected populations were found sensitive to frost but some of them were selected for cold resistance, especially from north Attica (Vaitsis and Konstantakis, 1994).

(v) Most collected populations drop their leaves in the summer but some of them have been selected for keeping their leaves longer.

(vi) *Dactylis glomerata* was a good species for intercropping with *Medicago*, but competition for water was found when density was high.

(vii) Establishment of *Medicago* under active grazing conditions was difficult unless plants were protected for 2 years and proper management was applied afterwards.

(viii) Cutting and grazing in the spring favoured plant recovery during the dry period.

Table 10. Experimental plantations for evaluation of the collected *Medicago arborea* indigenous populations in Greece

Title of experiment	Place	Year of establishment
Conservation of older maternal plants	Larissa 7a/k Larissa 7a/k	November 1983 October 1985
Seed multiplication and selection into the populations: M-15131, M-11237, M-14352, M-16442	Larissa 2/k Larissa 8a/k Larissa 15/k Larissa 12/k	November 1988 November 1988 November 1988 April 1990
Evaluation of 9 populations	Larissa12/k Messochori Rhodos	October 1991 November 1991 November 1991
Evaluation of 15 populations	Larissa 2/k	April 1993
Evaluation of 12 clones	Larissa 2/k	April 1993
Wild clones nursery	Rhodos	May 1993
Young shrubs establishment under active grazing	Messochori	November 1993
Evaluation of 43 clones	Larissa 12/K	April 1994
Evaluation of 14 populations	Larissa 2/K	November 1994

Robinia pseudoacacia

Progeny trial

Mean height and diameter for each family participated in the progeny test are presented in Figs 5 and 6 for four years (1991-1994).

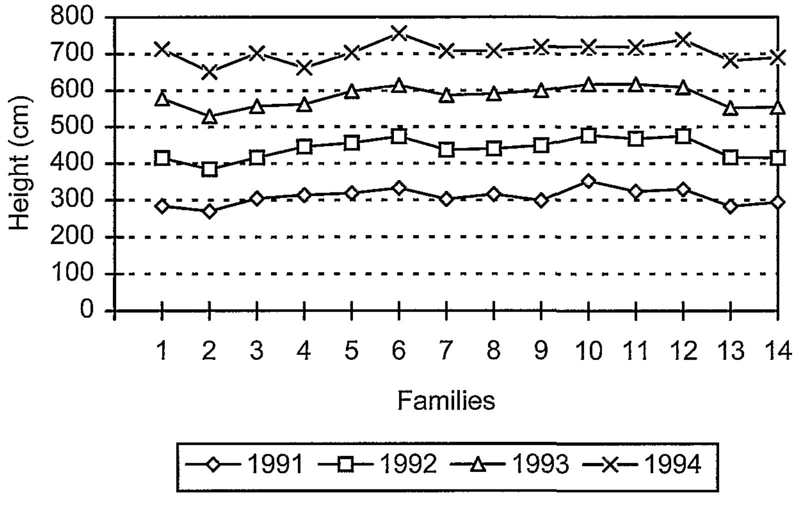


Fig. 5. Mean family height (cm) of *Robinia pseudoacacia* during four years (1991-1994) in northern Greece.

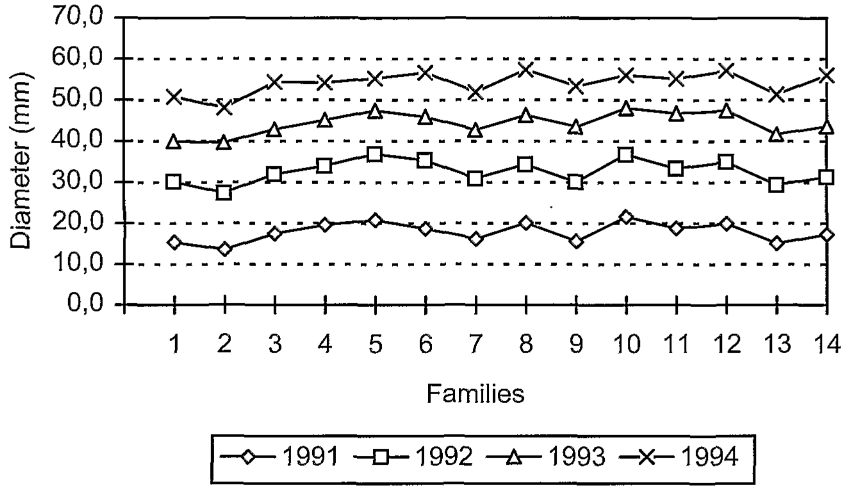


Fig. 6. Mean family diameter (mm) of *Robinia pseudoacacia* during four years (1991-1994) in northern Greece.

From these figures it is clear that while for the height the year increment was about the same during the study period, for the diameter there was a gradual decrease. This was expected considering the increasing crown density with time, which favours the growth of height but depresses the one of diameter (Dini 1990, 1993).

The analysis of variance for height indicated statistically highly significant differences among families for the 4 years of the study. For the diameter, the differences were highly significant for the first two years (1991, 1992) significant for 1993 and non-significant for the last year 1994.

It was decided the families which exceed the mean performance in height and diameter of the whole progeny test by 2σ to be selected (Selection differential = 2σ). Based on this criterion, families were ranked for mean height and diameter.

According to these rankings, all half-sib (HS) families were far from exceeding the mean performance in height and diameter of the whole progeny test by 2σ, and consequently none could be selected. On the other hand, the same HS families were found always on the upper half of the ranking table for both traits during the four years, suggesting that the family performance was not variable in different years.

The analysis of variance revealed no statistically significant differences among families for thorniness (for both approaches of thorn measurements: maximum thorn length in the upper 50 cm of each sapling; and scoring of thorniness, using a scale from 1 to 5) which means than no family could be selected using as selection criterion the mean length of its thorns.

Two major groups of trees were visually recognized on the basis of their number of leaflets per compound leaf: one with few leaflets, but larger and thicker (type I) and a second one with more leaflets, but smaller and thinner (type II). A third category of trees (very rare-just a few trees in the whole plantation) was one with very small leaflets, almost round, looking like a feather and a fourth (just three trees) very thorny, with small and round leaflets and sterile till now, while all the other tree types had produced flowers.

A t-test was applied between the two leaf morphology types of saplings (I and II) and the results are presented on Table 11. The mean maximum thorn length was smaller, as well as thorniness, in the group of saplings of type I compared to type II (highly significant statistical differences). This means that the group with fewer leaflets per compound leaf had fewer and smaller thorns than the other group. But also the same group (type I) had smaller mean annual current increment in both height and diameter during 1992 (H92-H91 and D92-D91) (highly significant statistical differences), while during 1993 there was a tendency for the differences to disappear. This is an indirect indication of a positive relation between thorns and growth rate, at least the first years after establishment of the plantation.

Table 11. t-test between type I and type II saplings for different traits of *Robinia pseudoacacia* in northern Greece

Trait	Mean±Std deviation		t-value	Degrees of freedom
	Type I	Type II		
Max. thorn length	5.72±4.7	9.3±5.5	-9.47**	745
Thorniness	3.12±1.47	3.6±1.13	-5.46**	745
D92-D91 (mm)	119.34±53.67	133.11±49.18	-3.66**	745
H92-H91 (cm)	103.98±49.5	117.51±45.9	-3.88**	745
D93-D92 (mm)	106.64±48.38	115.29±48.9	-2.42*	745
H93-H92 (cm)	121.96±53.97	127.72±52.64	-1.47NS	745

*P ≤ 0.05; **P ≤ 0.01; NS: non-significant

The time of bud break ranged from 30th of March to 14th of April with the majority of the trees concentrated at the beginning of this period. As far as the time of leaf emergence is concerned, it ranged from 7th of March to 21st of April, while the time of raceme appearance ranged from 6th to 23rd of April. The time of leaf drop ranged from 8th of October to 6th of December while the majority of trees dropping their leaves in the middle of November.

About 57% of the trees produced pods in variable quantities, from very few to abundant at an age of three years.

Vegetative propagation

The percentages of rooted hardwood cuttings are shown on Fig. 7 for both trees (A and B) which were used as sources of cuttings. It comes out that the root promoting chemicals utilized, namely IBA 2000-8000 p.p.m., KIBA 2000 p.p.m. and ALANINE 250 p.p.m., were very useful since the majority of the control plants failed to establish roots. Also, the one year-old thin cuttings with a diameter less than 5 mm failed to establish roots. The majority of the rooted cuttings produced were ready for transplanting after four to five months.

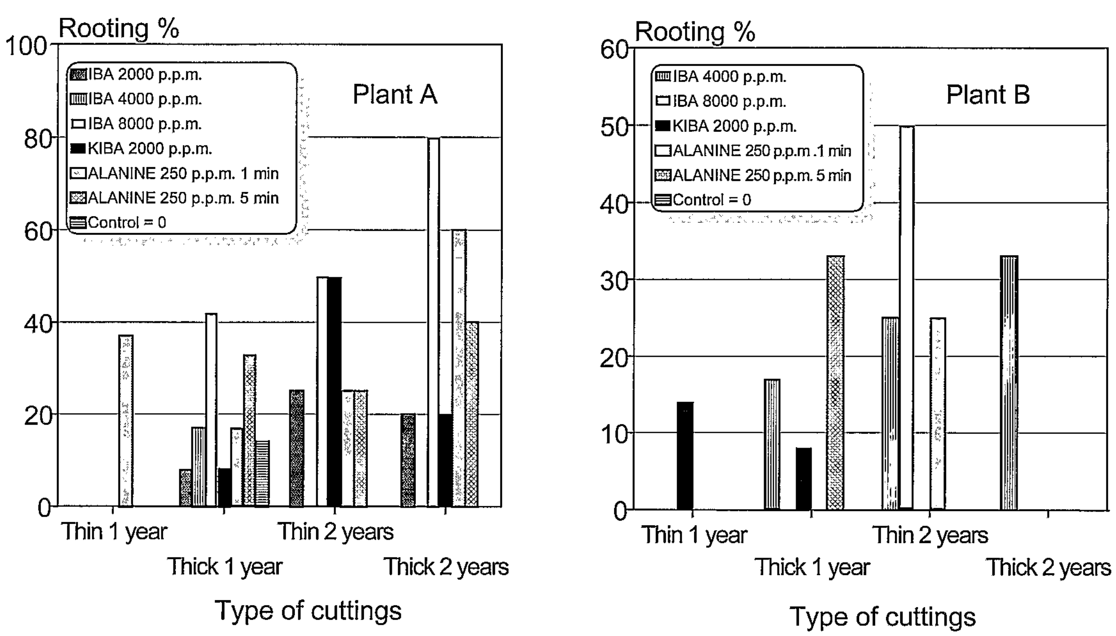


Fig. 7. Percentage hardwood rooting cuttings of two sizes and ages of *Robinia pseudoacacia* in northern Greece.

This method of propagation with hardwood cuttings was found to be expensive and not very effective. On the contrary, the second method tested, which employed softwood (green) cuttings was more successful no matter what rooting medium was used (Dini and Panetsos, 1994).

Clonal test

The main results of this test are presented on Table 12.

Table 12. Mean height, diameter, thorn length, biomass and crude protein contents of each HS family and clone of *Robinia pseudoacacia* included in the clonal test in northern Greece

HS families or clones	Mean height (cm)	Mean diameter (mm)	Range of max. thorn length (mm)	Mean total dry weight of sapling (g) (% leaf weight)	CP (%)
HS families					
8A or 10	139	16	4-18	203 (49)	14.1
2B or 3	131	14	4-15	197 (49)	14.8
A or 12	131	14	3-23	224 (47)	14.4
7B or 9	150	16	5-23	293 (48)	15.3
B or 13	154	18	6-27	288 (44)	14.6
3A or 4	153	18	5-25	361 (44)	15.3
6A or 7	161	18	3-21	376 (60)	14.4
Co*	139	16	6-23	245 (45)	15.1
Common *Robinia*	163	20	8-28	406 (38)	14.1
Clones					
A-8A(4)	144	15	4-13	237 (55)	18.2
A-8A(7)	183	18	0-1	295 (54)	16.7
A-8A(9)	123	12	0-0	118 (55)	16.2
B-2B(8)	208	21	5-5	491 (49)	16.4
C-2B(13)	168	15	3-3	345 (57)	16.7
A-2B(15)	125	13	0-3	161 (57)	17.2
A-A(7)	125	15	2-9	211 (64)	16.0
B-A(13)	77	8	0-0	80 (68)	18.9
A-7B(6)	166	23	8-9	486 (57)	16.9
A-B(3)	156	17	3-11	532 (49)	17.8
B-3A(7)	118	14	0-3	203 (48)	17.5
B-6A(8)	118	13	1-5	131 (68)	19.9
A-Strymon	139	15	0-1	163 (48)	17.2
Spherical	27	–	0-0	21 (81)	17.4

From this table the following points can be drawn:

(i) The HS families were in general established better than the clones.

(ii) The spherical clone showed a very different growth pattern compared with all the other clones, characterized by a prostrate form, dense branching and smaller leaves.

(iii) The mean height of families and clones ranged from 77 to 208 cm, while the mean diameter ranged from 8 mm to 23 mm. There were significant differences among the 9 HS families and among the clones as well (0.01 probability level) for both traits, while the combined analysis of variance for all HS families and clones together gave similar results. The highest sapling and the one with the largest diameter belonged to clones, but no final conclusion can be drawn.

(iv) The families in general were more spiny compared to clones. There were few clones, apart from the spherical one, which were quite thornless and also some others practically thornless. The mean maximum thorn length of clones was much lower than that of HS families, with differences being highly significant. However, it would be necessary to study the reaction of these thornless clones to the cutting before final conclusions are drawn.

(v) Analysis of variance for the biomass production indicated highly significant differences among different clones, among HS families and among HS families and clones. It seemed that biomass production was positively related with the other two growth parameters, height and diameter, as expected. The ratio of mean dried leaf weight to mean total dried weight of each HS family and clone could be an interesting index for forage production purposes. This percentage was more favourable for spherical clone (81%), while the opposite for common *Robinia* (38%).

(vi) A consistently higher CP content of clones versus HS families was found, which could be attributed to the selection made.

Ecological and agronomic evaluation

Gleditsia triacanthos

The two replications of the clonal test in Melgueil, Montpellier, established in 1992 at two sites, Masclac and Le Rouet, 25 km north of Montpellier, had different success due to the different soil types involved, sandy and clayish respectively for the two sites. The mortality rates and the trees emerged from the 180 cm tall plastic tubes (shelters) are shown on Table 13. They clearly suggest that grafted *Gleditsia* trees performed much better on the deep sandy soil than on the clayish soil.

Table 13. Mortality and tree emergence from the 180 cm tall shelters in July 1993 and December 1994 (% of the total number of planted and living trees) in southern France

Characteristic	Location			
	Masclac		Le Rouet	
	July 1993	December 1994	July 1993	December 1994
Mortality	8.2	10.3	25.2	21.0
Trees emerged	43.7	90.7	3.8	25.5

Different were the results obtained in the two replications with 10 selected clones which were established in northern Greece. The mortality rates were not as high but the height reached was much lower than in southern France. Also, the trees performed much better in the site with heavier (Loutra Thermis) than with lighter (Scholari) soils (Figs 8 and 9). These differences may be attributed to the fact that the trees in France were protected with tubex shelters which enhanced height at the first years (Dupraz, 1997) and that the climate in southern France is wetter than in northern Greece.

Medicago arborea

Variability in forage ability in Sicily

During the first year after plantation about 13% of the plants died (Fig. 10); very few plants died over the following years, but in autumn-winter 1993/1994 the percentage of survival fell to about 55% and only 35% were in perfect health. This high mortality occurred at an exceptionally rainy period (588.8 mm during September-February vs. the 381.5 mm of the pluri-annual average for the same period) that may have caused asphyxiating conditions in a soil with a very high clay content like that of the trial. It is possible to hypothesize that *Medicago* does not tolerate conditions of root asphyxia and/or that such conditions are favourable to growth of specific pathogens.

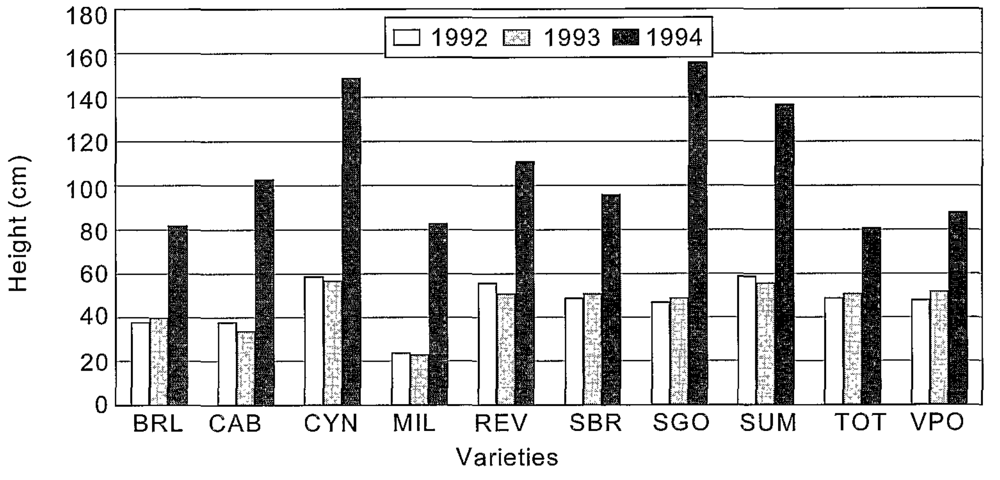


Fig. 8. Mean height (cm) of the *Gleditsia triacanthos* varieties for the years 1992-1994 in Loutra Thermis of northern Greece.

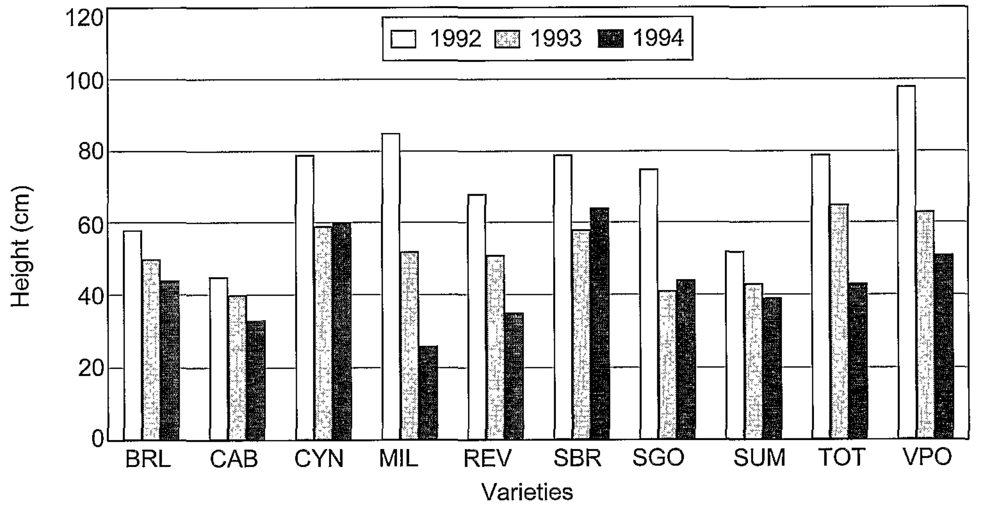


Fig. 9. Mean height (cm) of the varieties for the years 1992-1994 in Scholari of northern Greece.

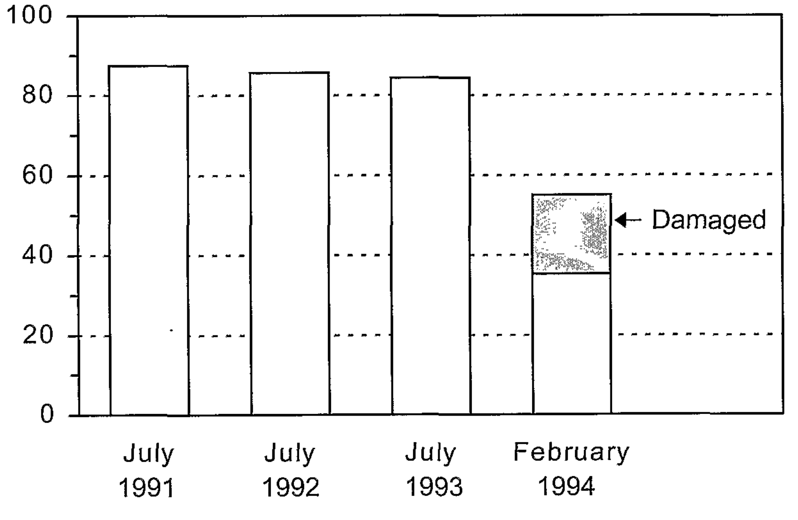


Fig. 10. Plant survival (%) of *Medicago arborea* in Sicily.

The main phenological dates were observed in the second year after plantation on 837 plants. On the average, the flowering period lasted for about five months from winter time until the end of spring (Table 14). However, a high variability was detected; in fact, some plants produced the first flowers in the middle of November and others at the end of March; flowering duration was also extremely variable, being slightly more than two months in some plants and about eight months in others.

Table 14. Main phenological dates observed on 837 two-year old plants of *Medicago arborea* in Sicily

Phenophase	Mean	Range	CV (%)
Beginning of flowering	2 January	18 November-27 March	45.3
End of flowering	13 June	6 May-21 July	8.7
Flowering duration (d)	162.1	68-234	20.4
Beginning of pod set	15 February	2 January-23 April	16.7
Beginning of pod ripening	25 May	3 May-1 July	4.3

Pod production may be considered useful for grazing, due to the high protein content of the seeds. Mean production of plants not used for grazing in 1991 and 1992, 18 and 30 months after plantation, resulted in 134.4 and 448.0 g per plant, respectively (Fig. 11). In both years the variability of pod production per plant was very high, thus giving good chances for selection.

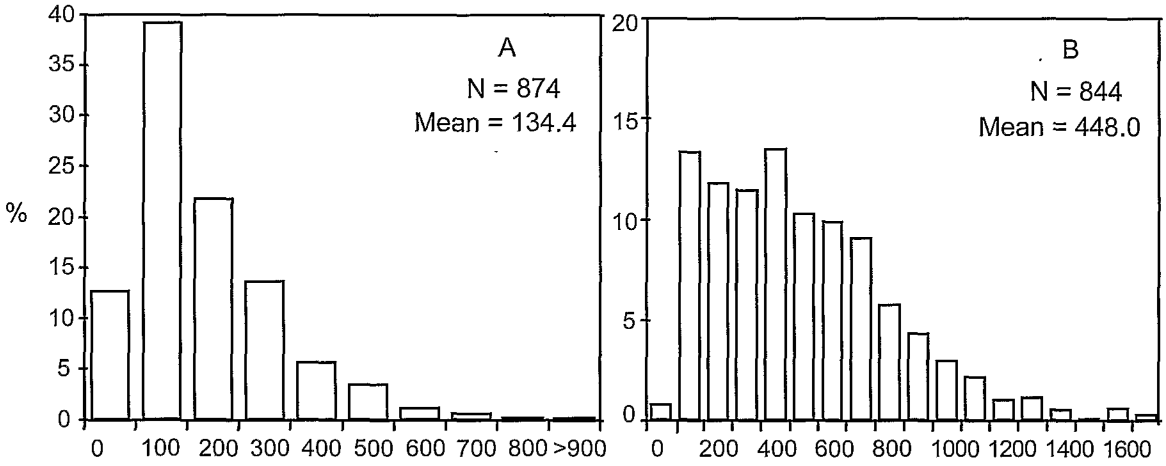


Fig. 11. Frequency distribution of pod yield (g/plant) of *Medicago arborea* in July 1991 (A) and 1992 (B) in Sicily.

In Fig. 12 the mean plant volumes calculated on the basis of mean diameter and maximum height of the canopy are reported. Undisturbed plants showed a slow growth during the first two years and a rapid one up to the cutting done during the third year. Afterwards, good regrowth ability was observed.

The production of edible biomass, made up of leaves, herbaceous twigs, flowers and pods, was measured during the third and fourth years after plantation. In the first case, it was measured by cutting at 70 cm and then by separating the edible portion; in the following year, in order to obtain a more accurate evaluation of the actual productive ability of the plants, edible biomass was measured by removing all the leaves and shoots by hand. As regards the estimation of productivity, the two methods seem accurate, particularly the second; however, they may induce different regrowth patterns compared to the actual grazed plants.

Mean plant production was 0.535 kg in undisturbed, three years-old plants and 0.836 kg in regrowth one year later (Fig. 13). The high variability of forage production observed in both uses seems interesting for selection purposes (Stringi *et al.*, 1993, 1994).

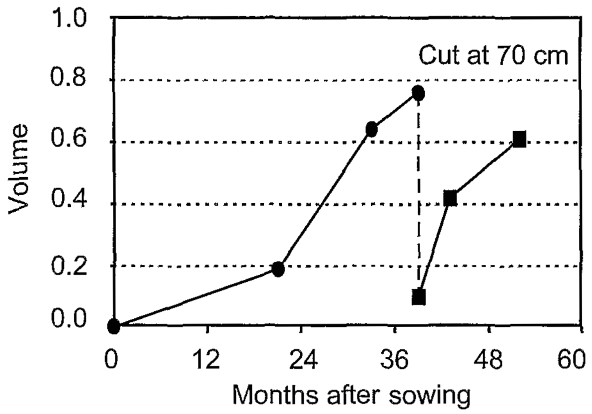


Fig. 12. Mean plant volume (m^3) of *Medicago arborea* in Sicily.

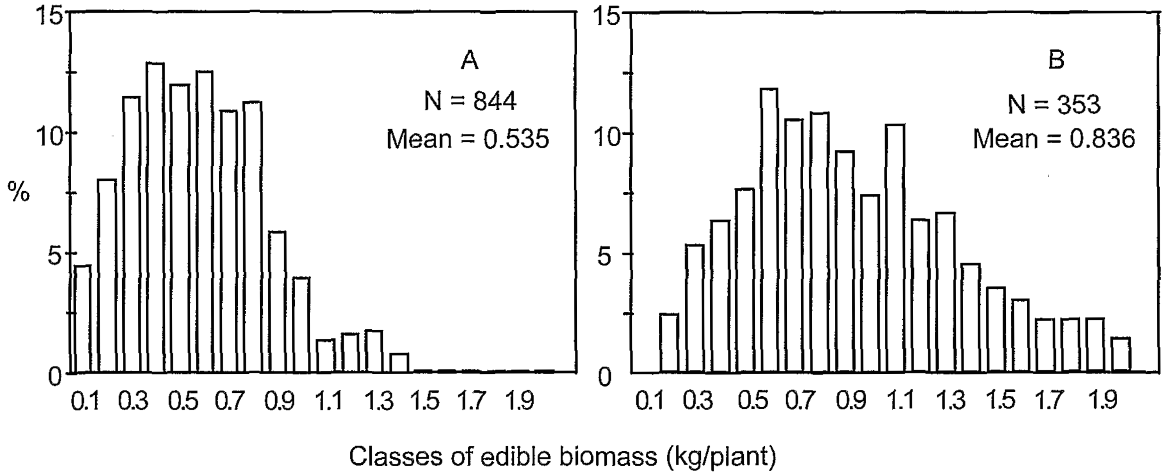


Fig. 13. Frequency distribution of edible biomass of *Medicago arborea* in January 1993 (A) and in February 1994 (B) in Sicily.

A study of the relationships among traits showed that it is possible to estimate, with a fair level of accuracy, grazable biomass production by means of plant volume. In Fig. 14, the regression curves of undisturbed plants and of the regrowth are shown. The coefficients of determination of the two regressions were both high; however, the kind of relationship changed markedly according to plant conditions (age and previous use).

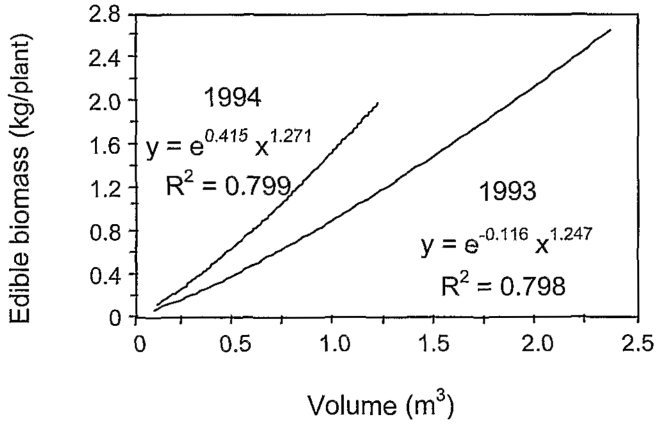


Fig. 14. Relationship between plant volume and edible biomass in *Medicago arborea* in Sicily.

By means of the relationship found for undisturbed and cut plants, edible biomass production per hectare was estimated on the basis of the dimensional parameters observed each year. The edible biomass production (mean of the different genotypes and related to the adopted density) was, on the whole, low (Table 15). In such conditions, the very low availability during the first year would exclude early utilizations, although the effects of grazing on regrowth should be taken into account.

Table 15. Measured and estimated mean edible biomass production and seed yield of *Medicago arborea* in Sicily

Months after transplanting	Edible biomass (t/ha)	Seed yield (t/ha)
18 (July 91)	0.28†	0.17
30 (July 92)	1.28†	0.57
36 (January 93)	1.70	
40 (May 93)	1.60††	
53 (February 94)	2.68	

†Estimated by the relation with volume in ungrazed plants
††Estimated by the relation with volume in cut plants

Productivity measured during the third year and in the fourth on regrowth may be considered acceptable mostly because it is available in a period of short supply of forage production in the trial environment.

A wide range in the hemolytic saponins content has been observed with individual means of the hemolytic index (hemolysis relative to the standard, HRS) ranging from 0 to 6.6 (Fig. 15) even if about 60% of the plants had HRS less than 1.0. The presence of saponin-free plants as well as those with a high saponin content is interesting for breeding for forage production and for the extraction industry respectively. The saponin content was not significantly related to any of the other observed traits.

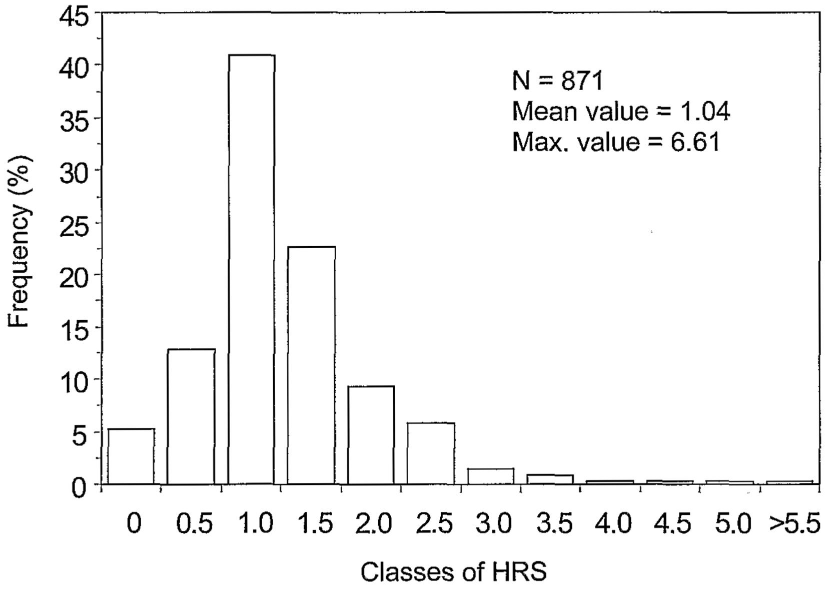


Fig. 15. Frequency distribution of HRS in *Medicago arborea* in Sicily.

On the basis of individual productive data, 15 phenotypes of each population were selected and 30 cuttings of each phenotype were made in January 1993 and put in outdoor bed for rooting. Five months later (June 1993) the number of rooted cuttings of each progeny was measured.

A high variability in the behaviour of the selected phenotypes, ranging from no rooting to 100% rooting (Fig.16), was observed.

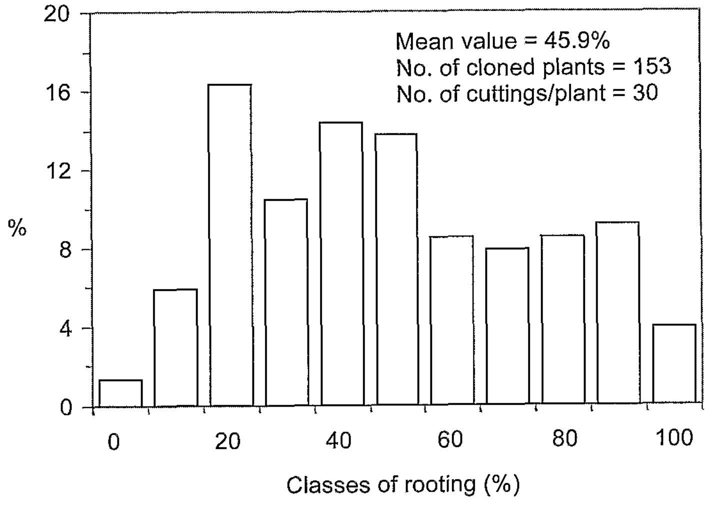


Fig. 16. Frequency distribution of rooting percentage in *Medicago arborea* in Sicily.

The rooted cuttings of the progeny clones were transplanted in the field in January 1994 in a randomized block design with four replications. On the basis of height, diameter and leaf density index measured during the first year of plantation it was possible to carry out a cluster analysis which grouped together the progeny clones in three statistically different groups. In Fig. 17, the mean heights of the three groups are reported; one group, composed of seven clones, although lower at transplanting, grew faster reaching a greater mean height than the other two groups.

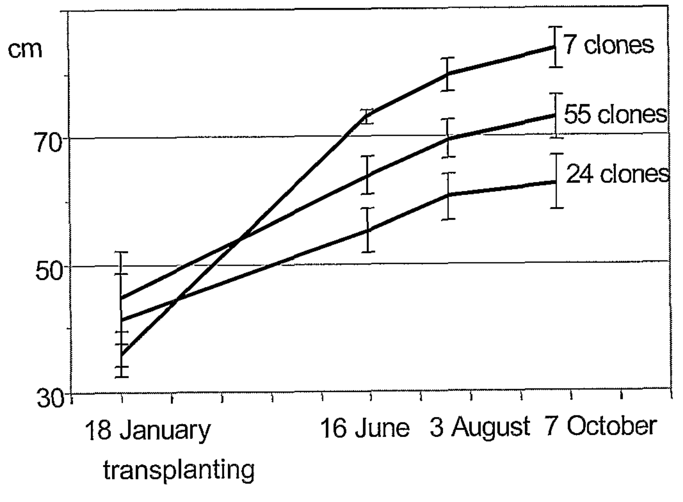


Fig. 17. Mean plant height of three cluster groups of *Medicago arborea* in Sicily (vertical bars represent std deviation).

Cold and grazing resistance in central Italy

The trials of *Medicago* established in north Lathium, central Italy (near Viterbo), have produced the following most important results:

(i) *Medicago* was found sensitive to strong winds which slowed or even stopped its growth.

(ii) Low autumn temperatures did not damage the shrub but stopped its growth. Winter frosts, on the contrary, damaged or even killed the plants.

(iii) Two year-old plants of *Medicago* since establishment were good enough for grazing by sheep but not for cattle thus indicating that initiation of grazing of *Medicago* plantations after their establishment depends not only on growth conditions but also on the animal species involved.

(iv) *Medicago* plants did not produce much fodder at the fourth growing period since establishment apparently due to the winter frosts which damaged them. In December 1994, production was found about 125 kg/ha at the Tessennano site and about 250 kg/ha at the Viterbo site. Herbaceous plants, spontaneous (Tessennano) or seeded *F. arundinacea* (Viterbo), contributed with 2030 and 320 kg/ha at the same period, respectively for the two sites.

Biomass estimation with photographic method

Harvested biomass from young *M. arborea* plants was found to be accurately calculated by taking photographs and analysing them in the computer with a special image analysis program. The same technique was also applied by the Viterbo team in estimating damaged *M. arborea* plants from frosts with satisfactory results (Cereti and Rossini, 1992, 1993).

Morus alba

Foliage production

Measured dry matter production of leaves of the Japanese cultivar ('Kokuso 21') of *Morus* varied considerably between sites, origin of plants, year of plantation and between years (Fig. 18) in southern France.

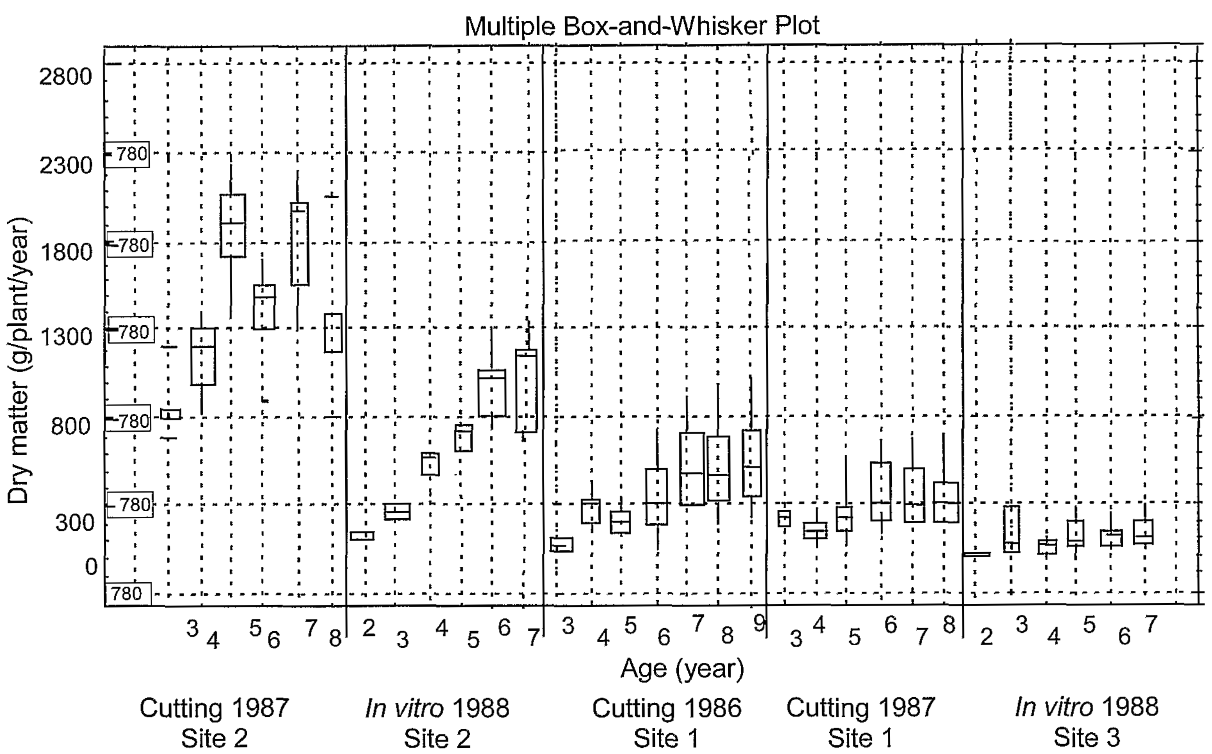


Fig. 18. Comparison of dry matter production of leaves in relation to the age, methods of propagation of plants and sites of *Morus alba* cv. Kokuso 21 in southern France.

In the best site (near Montfavet), it ranged from 500 to 2000 g DM leaves/plant as compared to the other two poorer sites in the pre-Alps where it ranged from 100 to 500 g DM leaves/plant (Armand and Meuret, 1993). Plants derived from cuttings did much better than *in vitro* plants, and cuttings planted in 1986 did much better than the ones planted in 1987. Also, foliage production was increased with the age of plantation although there were inter-annual variations, due to climatic variation. On an area basis, the annual dry matter production of leaves in plants derived from cuttings was 1.5 t/ha in the 1986 and 0.9 t/ha in the 1987 plantation in the site 1 during the last 3 years, while in the better site 2, the plantation of 1987 with similar plants reached 4.2 in the unfavourable and about 5.7 t/ha in the favourable years.

Comparison of the defoliation intensities

The two intermediate intensities 50 and 80% were abandoned in the fourth year since establishment because they were not able to be realized in practice by sheep. The remaining two intensities 0 and 100% started to get differentiated in 1990 when a severe summer drought affected the defoliated plants much more than the control. This difference became significant in the 5th year and it was maintained until the end of the project (Fig. 19).

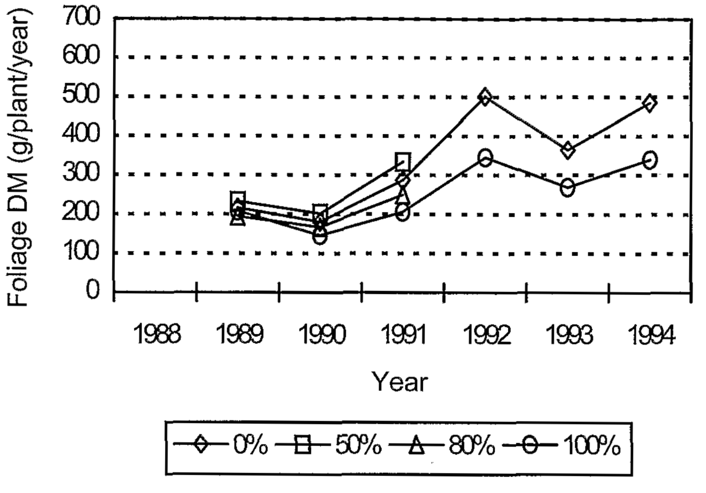


Fig. 19. Comparison of estimated dry matter foliage production of planted shrubs of *Morus alba* cv. Kokuso 21 in 1987 in the various defoliation percentages in southern France.

Cutting treatments

Among the three cutting schemes applied, clear cutting of shrubs at a height 30-35 cm resulted in much better growth and production than the other two treatments (cups and pollards) (Fig. 20).

Prediction equation of production

Dry matter production of leaves of each shrub was found to be highly correlated with its volume calculated from its dimensions (diameter and height) (Fig. 21). For this reason, all the data were analysed to find out the most appropriate linear equation for prediction of the dry matter production of leaves from the shrub volume (Armand, 1994). The analysis was carried out within each method of plant propagation, within each site, within different ages of plants and by considering the whole data or the whole data minus the extreme values. The best relation found was a Neperian logarithmic equation:

$\ln MSE = -1.852 + (1.040 \times \ln Vol)$; $n = 165, r = 0.94$

This equation means that the dry matter production of leaves can be predicted in *M. alba* cv. Kokuso 21 shrubs with a volume ranging from 180-9900 dm^3 for plants propagated with cuttings and from 640-6340 dm^3 for plants propagated *in vitro*.

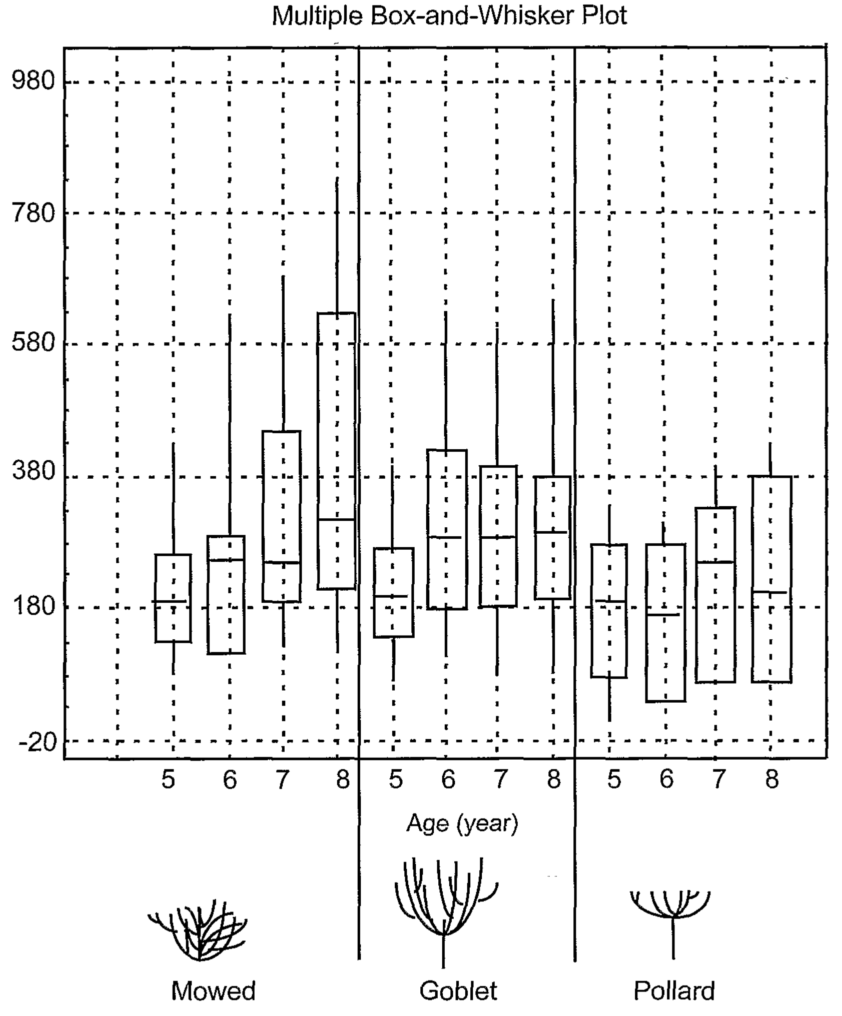


Fig. 20. Comparison of dry matter (g/plant/year) foliage production in relation to the age and methods of cutting of shrubs of *Morus alba* cv. Kokuso 21 in southern France.

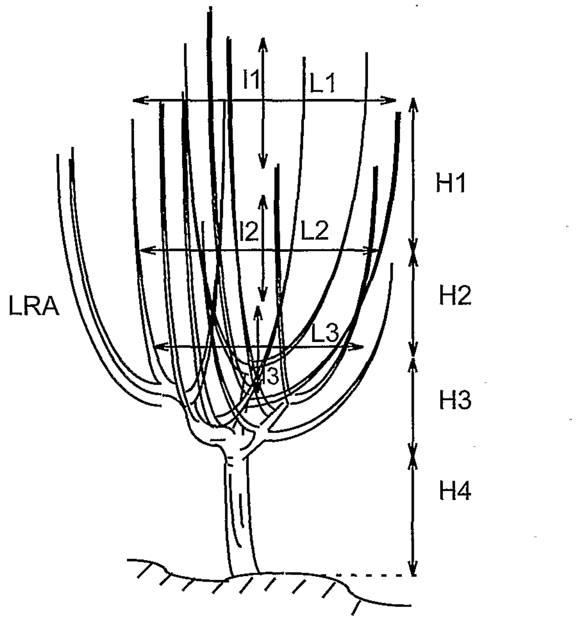


Fig. 21. Diagram of a *Morus alba* cv. Kokuso 21 shrub with the dimensions to be measured for estimating its volume in southern France.

Survey of Morus alba *utilization in southern France*

The survey of six farmers utilizing *Morus* foliage for feeding their animals (Fig. 22) has shown that:

(i) Five of them were using *Morus* foliage at the end of summer (August-September) to feed their sheep or goats in the form of green matter (GM) as quality supplement or as "dessert". The sixth farmer collected the foliage and fed it dry during the winter period.

(ii) Feeding was carried out at the end of the day in the barn after collecting the *Morus* branches earlier at the same day. It amounted to about 100-150 g/animal/day.

(iii) Four farmers collected the *Morus* branches with the foliage from ancient trees grown within or outside their farms. The remaining 2 had planted 'Kokuso 21' in their farm and practised also sericulture. The use of *Morus* by all farmers was integrated in the animal feeding and production calendars that they practised in their farms. The calendar followed by one of the surveyed farmers is shown on Fig. 22.

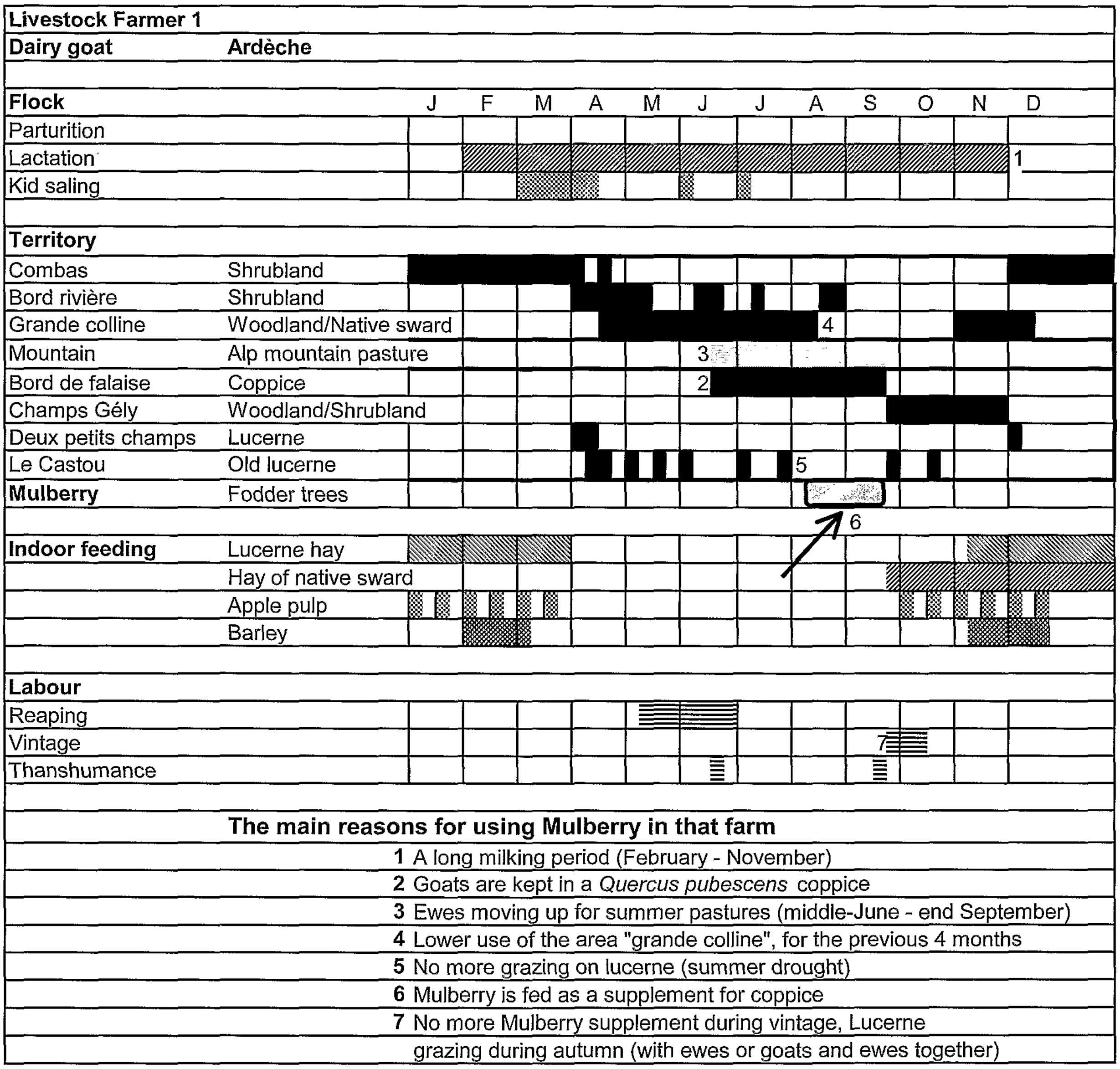


Fig. 22. Forage calendar of a farmer in pre-Alps of southern France.

Other species

Productivity of deciduous fodder trees and shrubs in Greece

The results of the annual aboveground production are shown on Table 16. It is clear that the most productive species all along was *Robinia* (both common and thornless) followed by the other two legumes *Amorpha* and *Colutea*. All the other species had much less production with the exception of *Ostrya*. Another interesting point is that the three leguminous species had a peak production at the third year since establishment while the other species peaked at the fourth year or later. During the third year, *Robinia* produced 12.4 t/ha, *Amorpha* 5.7 t/ha and *Colutea* 4.2 t/ha. Grazable biomass (leaves and twigs) as a percentage of the total biomass, ranged from 25% to 66% in *Robinia*, 24-54% in *Amorpha*, 36-74% in the *Quercus* species, 27-48% in *Pirus*, 25-47% in *Colutea*, 25-28% in *Ostrya*, 32-74% in *Carpinus*, 38-67% in *Corylus* and 29-63% in *Fraxinus* (Platis and Papanastasis, 1993; Papanastasis *et al.*, 1998).

Table 16. Annual biomass (g/plant) of eleven fodder trees and shrubs in northern Greece (Papanastasis *et al.*, 1997)

Species	Years								
	1987	1988	1989	1990	1991	1992	1993	1994	Mean
Amorpha fruticosa	23.4 c	18.3 c	469.5 b	511.6 ab	175.6 abc	219.0 a	114.9 b	273.0 b	223.2 b
Carpinus orientalis	1.5 d	3.2 f	74.2 d	90.6 e	41.6 e	48.5 c	63.4 cd	108.3 cde	47.4 de
Colutea arborescens	3.9 d	11.6 d	473.3 b	419.1 b	240.7 a	153.7 b	183.3 a	336.8 a	217.0 b
Corylus avellana	6.0 d	9.1 def	84.4 d	145.4 de	86.1 cde	79.7 c	69.8 bcd	158.1 c	79.8 de
Fraxinus ornus	0.9 d	3.1 f	66.9 d	88.1 e	46.0 e	40.9 c	65.4 cd	78.7 def	46.3 e
Ostrya carpinifolia	8.9 d	15.0 c	271.7 c	145.5 de	84.7 de	56.1 c	52.6 cd	123.3 cd	93.0 d
Pirus amygdaliformis	2.5 d	10.0 de	130.0 d	242.3 cd	89.9 cde	77.2 c	72.3 bcd	77.2 ef	87.7 de
Quercus pubescens	3.0 d	8.2 def	132.6 d	149.3 de	52.4 e	65.4 c	63.0 cd	52.3 f	66.8 de
Quercus sessiliflora	4.8 d	6.6 ef	136.4 d	120.3 e	41.0 e	28.3 c	33.4 d	76.8 ef	54.9 de
Robinia pseudoacacia (common)	66.3 a	45.1 a	923.5 a	572.5 a	216.5 ab	154.2 b	85.7 bc	100.8 de	284.4 a
Robinia pseudoacacia (spineless)	32.6 b	27.8 b	566.7 b	263.4 c	150.6 bcd	85.3 c	65.0 cd	117.7 cde	166.7 c

[a,b]Means within each year followed by the same letters are not significantly different at 0.05 level of significance

Height of shrubs varied widely among species and over the years (Table 17). Leguminous species and especially *Robinia* attained the tallest heights all along (more than 1 m high) while all the other species remained shorter (less than 1 m high). It is interesting to notice that some species increased their height with age while others started varying their heights since the fourth year (Platis and Papanastasis, 1993; Papanastasis *et al.*, 1998).

The forage value of the species is shown on Tables 18 (crude protein content) and 19 (IVOMD). Comparing the leguminous species (*Robinia, Amorpha* and *Colutea*) with the remaining species, the leguminous had on the average a higher content of crude protein (17-21% vs. 10.5-13.3%) and higher IVOMD values (56-60% vs. 47-53%). Also, *Robinia* had the highest relative acceptance index by goats while *Amorpha, Colutea* and *Corylus* the lowest (Table 20).

Productivity of fodder shrubs for summer grazing in France

Dry matter of edible parts of shrubs including leaves, buds and the apex of stems down to a 3 mm diameter at the beginning of August varied widely among shrub species and between years. This variation is shown in Fig. 23.

Table 17. Height (cm) of eleven fodder trees and shrubs in northern Greece

Species	Years							
	1987	1988	1989	1990	1991	1992	1993	1994
Amorpha fruticosa	53.5 c	56.6 b	100.7 c	90.5 c	117.5 d	146.0 d	126.8 d	143.2 c
Carpinus orientalis	16.4 ab	21.4 ac	38.2 a	47.8 ab	44.0 a	56.9 a	71.6 b	60.0 a
Colutea arborescens	29.0 ae	51.9 b	80.6 b	93.5 c	113.7 d	86.7 bc	116.8 d	106.0 b
Corylus avellana	30.9 ae	32.3 de	40.1 a	63.6 b	88.1 c	78.0 bc	87.8 c	106.7 b
Fraxinus ornus	10.8 b	18.9 ac	42.0 a	57.7 ab	75.3 bc	95.6 c	98.0 c	80.4 ab
Ostrya carpinifolia	36.6 e	35.4 d	57.6 a	68.3 b	90.2 c	94.2 c	101.8 cd	76.4 ab
Pirus amygdaliformis	21.3 abe	30.8 ade	52.5 a	64.3 b	64.5 ab	52.7 a	56.9 ab	73.6 a
Quercus pubescens	16.2 ab	17.8 a	40.2 a	41.1 a	52.7 ab	67.1 ab	54.1 a	50.1 a
Quercus sessiliflora	30.1 ae	22.9 ade	48.2 a	56.5 ab	62.9 ab	66.7 ab	61.5 ab	69.1 a
Robinia pseudoacacia (common)	82.1 d	81.3 c	168.8 a	158.7 e	189.4 e	192.7 e	177.5 e	162.4 c
Robinia pseudoacacia (spineless)	61.7 c	63.5 b	137.9 d	138.3 d	181.7 e	190.7 e	182.7e	162.3 c

[a,b]Means within each year followed by the same letters are not significantly different at 0.05 level of significance

Table 18. Crude protein (DM basis, %) of 11 woody fodder plants[†] during six stages of maturity in northern Greece (Papachristou and Papanastasis, 1994)

Species	May	June	July	August	Sept.-Oct.	Oct.-Nov.	Mean
Amorpha fruticosa	30.3 aαβ[††]	26.6 bα	22.8 cαβ	18.8 dα	15.3 eβγ	12.5 fα	21.0 β
Carpinus orientalis	16.8 aζ	12.5 bεζ	12.3 bεζ	10.6 cδ	9.8 cζ	8.7 dγδ	11.8 ζη
Colutea arborescens	26.7 aγ	23.2 bγ	18.7 cγ	11.8 dβ	11.7 dε	10.5 eβ	17.1 δ
Corylus avellana	18.1 aε	12.6 bεζ	12.2 bεζ	11.3 cγδ	9.9 dζ	9.1 dγ	12.2 ζ
Fraxinus ornus	20.6 aδ	14.8 bδ	11.7 dζη	11.9 dβγ	13.0 cδ	7.6 eδε	13.3 ε
Ostrya carpinifolia	17.5 aεζ	14.7 bδ	13.1 cδε	12.4 cβγ	10.5 dζ	10.6 dβ	13.1 ε
Pirus amygdaliformis	15.4 aη	11.9 bζ	10.8 bcη	10.2 cδ	8.0 dη	6.8 eε	10.5 θ
Quercus pubescens	18.6 aε	13.1 bε	11.0 cη	10.5 cδ	9.8 cζ	6.8 dε	11.6 η
Quercus sessiliflora	17.5 aεζ	12.5 bcεζ	13.7 bδ	12.9 bcβ	14.7 bγ	7.7 dδε	13.1 ε
Robinia pseudoacacia (common)	29.3 aβ	25.9 bαβ	22.2 cβ	18.8 dα	15.9 eβ	11.6 fαβ	20.6 γ
Robinia pseudoacacia (spineless)	31.0 aα	25.0 bβ	23.7 cα	19.1 eα	20.8 dα	10.8 fβ	21.7 α

[†]Data of two years (1991-1992)
[††]Means in the same row with different letter (a,b) or in the same column with different Greek letter (α,β) are significantly different ($P \leq 0.05$)

Morus was the most productive species on an individual tree basis. Rainy springs as in 1992 and 1993 induced very high *Morus* yields, resulting in high year to year variability. This ability to use any input of water, any time of the growing season, is a distinctive feature of *Morus*. No bud dormancy occurred throughout summer allowing the plant to regrow after any significant rainy episode. Both *Amorpha* and *Robinia* were less sensitive to spring and summer rains, possibly because of a deeper root system. Leguminous species seem to be able to produce high amounts of forage as soon as the third year after plantation (1990). *Morus* topped its yield in 1992, during the fifth growing season.

These production figures are based on a 2500 trees/ha density for *Morus* plants. At this density, *Morus* trees covered only half the field. Some plots with 5000 trees/ha show that this density is necessary for a full coverage of the field at the age of 5. In these conditions, *Morus* yields were almost doubled compared to 2500 trees/ha stands, indicating that the tree to tree competition remains low even at 5000 trees/ha. Such dense *Morus* stands would be more productive than the 10,000 trees/ha legume stands.

On a percent basis, dry matter of edible parts was also variable among the different shrub species; in 1994, it ranged from 35% in *Colutea* to 49% in *Amorpha* with *Morus, Coronilla* and *Robinia* being intermediate, 39%, 42% and 45% respectively.

Different was the performance of the species on different soil types, too. Higher yields of both *Amorpha* and *Morus* were achieved in Melgueil where soil fertility and water holding capacity of the site are more favourable than in Saint-Gély where soil fertility is relatively low. Moreover, *Amorpha* outyielded *Morus* in the Melgueil site (594 vs. 492 g of DM/shrub) while *Morus* outyielded *Amorpha* in the Saint-Gély site (149 vs. 53 g of DM/shrub) thus suggesting that *Amorpha* is more productive than *Morus* in good soils.

Table 19. IVOMD of 11 woody fodder plants† during six stages of maturity in northern Greece (Papachristou and Papanastasis, 1994)

Species	May	June	July	August	Sept.-Oct.	Oct.-Nov.	Mean
Amorpha fruticosa	74.9 aα††	55.5 bγ	56.2 bδ	50.5 dεζ	53.6 cβ	45.3 eβ	56.0 γ
Carpinus orientalis	66.3 aβ	51.9 cδ	55.1 bδε	49.6 dζ	41.4 eε	39.9 eγδ	50.7 εζ
Colutea arborescens	64.9 bβγ	65.4 abα	66.9 aα	65.1 abα	56.2 cα	41.3 dγ	60.0 α
Corylus avellana	53.5 aη	52.1 aδ	49.8 bη	50.1 bεζ	40.8 cε	38.4 dε	47.5 η
Fraxinus ornus	62.4 aδε	49.2 cε	54.6 bδεζ	54.7 bγ	49.4 cγ	39.4 dγδε	51.6 δε
Ostrya carpinifolia	60.8 aε	56.2 bγ	55.6 bδε	56.1 bγ	47.4 cδ	40.7 dγδ	52.8 δ
Pirus amygdaliformis	52.7 aη	50.6 bδε	50.4 bη	50.3 bεζ	41.5 cε	38.4 dε	47.3 η
Quercus pubescens	62.5 aδε	50.9 cdδε	53.8 bεζ	52.3 bcδ	49.8 dγ	38.3 eε	51.3 ε
Quercus sessiliflora	56.4 aζ	52.1 bδ	52.7 bζ	51.7 bδε	46.7 cδ	38.8 dδε	49.7 ζ
Robinia pseudoacacia (common)	63.2 aγδ	62.3 bβ	60.7 bβγ	60.5 bβ	52.1 cβ	48.3 dα	57.8 β
Robinia pseudoacacia (spineless)	63.0 aγδ	62.7 aβ	62.1 aβ	62.2 aβ	53.7 bβ	49.6 cα	58.9 β

†Data of two years (1991-1992)
††Means in the same row with different letter (a,b) or in the same column with different Greek letter (α,β) are significantly different ($P \leq 0.05$)

Table 20. RAI of 11 woody fodder plants† consumed by goats during summer in northern Greece (Papachristou and Papanastasis, 1994)

Species	RAI (%)		
	July	August	Mean
Robinia pseudoacacia (common)	15.8 bαβ††	23.4 aα	19.6 α
Robinia pseudoacacia (spineless)	16.1 aαβ	17.3 aβ	16.7 α
Fraxinus ornus	17.4 aα	4.6 bδεζ	11.0 β
Quercus sessiliflora	15.1 aαβ	6.8 bγδε	11.0 β
Carpinus orientalis	11.6 aβγ	9.4 aγδ	10.5 β
Quercus pubescens	8.0 aγδ	10.8 aγ	9.4 β
Ostrya carpinifolia	5.9 bδ	11.7 aγ	8.8 β
Pirus amygdaliformis	4.6 bδε	11.3 aγ	8.0 β
Colutea arborescens	4.8 aδε	3.1 aεζ	4.0 γ
Corylus avellana	0.8 aε	0.8 aζ	0.8 γδ
Amorpha fruticosa	0.1 aε	0.5 aζ	0.3 δ

†Data of two years (1991-1992)
††Means in the same row with different letter (a,b) or in the same column with different Greek letter (α,β) are significantly different ($P \leq 0.05$)

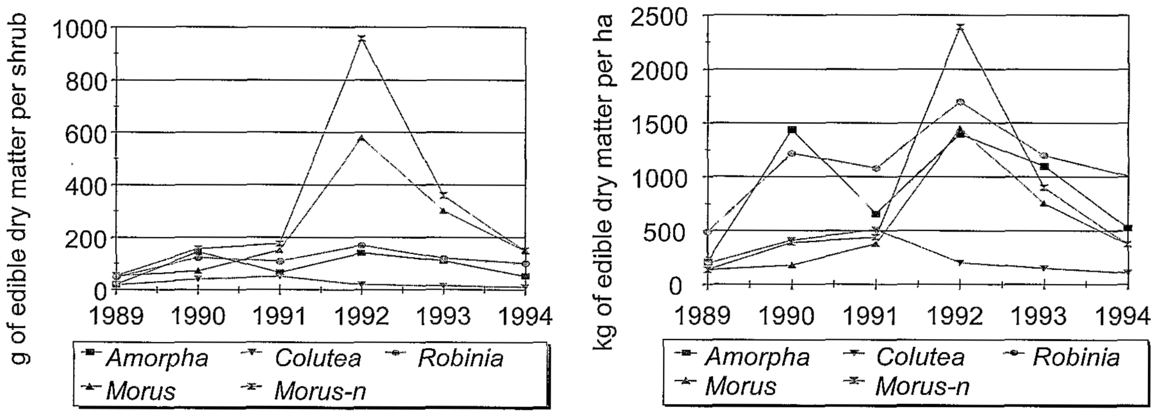


Fig. 23. Variation of fodder production per shrub and per ha during the first six years of a fodder shrub plantation in Saint-Gély du Fesc experimental farm in southern France.

The impact of the rainy pattern on summer biomass production was clear for *Morus* and *Amorpha* species. *Robinia* was the least affected species, while the leaf drop of *Colutea* was quite the same every year and resulted in poor August yields, irrespective of the rainfall (Table 21) (Lizot and Dupraz, 1993).

Table 21. Variability of rainfall totals for different periods of the years 1989-1994 in southern France†

Years	Period					
	January-June	January-December	March-August	October-March	April-June	July-August
1989	259	612	228	389	163	45
1990	258	678	208	307	164	29
1991	326	667	334	538	124	82
1992	385	739	399	282	276	97
1993	340	894	374	262	249	63
1994	345	983	186	579	116	59
Coefficient of variation	16	19	32	35	36	39

†All values in mm of rain, periods are ranked in increasing order of variability

A regression analysis was carried out between the August fodder yields and the rains occurred in the preceding months. Six different periods have been used in these calculations (Table 22). While the year to year variability of the annual rainfall was not very high, the year to year variability of the spring (April to June) rain was high.

Table 22. Linear regression coefficients between summer fodder shrub production and rainfall in Saint-Gély du Fesc of southern France

Fodder shrub	Period of rain					
	January-June	January-December	March-August	October-March	April-June	July-August
Amorpha	0.27	0.04	0.43	-0.67	0.62	0.13
Colutea	-0.33	-0.62	0.04	0.15	-0.36	-0.03
Robinia	0.69	0.22	0.62	-0.40	0.62	0.57
Morus	0.84	0.21	0.80	-0.45	0.83	0.79

The four species exhibited very different patterns:

(i) *Colutea* yields were not positively correlated to any rainfall total. On the contrary, they were negatively correlated with the annual rainfall. A very different result may have been expected if June yields of *Colutea* were available. This is because it drops its leaves in the summer whatever the rainfall pattern in winter and spring is.

(ii) *Amorpha, Robinia* and *Morus* yields were highly correlated with spring rainfall. April to June rainfall was the best predictor for *Amorpha* yields; this species takes little advantage of winter and summer rains. *Robinia* was the only species responding positively to winter rains. *Morus*, and in some degree *Robinia,* take advantage of summer rains.

Persistence and production of fodder shrubs in Spain

After testing 32 different species of shrubs in two sites of Extremadura, SW Spain, with semi-dry Mediterranean climate and mild winters, the best species adapted were found to be: (i) *A. nummularia, A. repanda, M. arborea, Ch. proliferus* ssp. *palmensis* and *M. alba* at "La Orden"; and (ii) *A. nummularia* and *M. arborea* at Valdesequera.

In the first site ("La Orden"), the production and nutritive value of the shrubs 2.5 years after transplanting in the field are shown on Table 23.

Table 23. Production (green or dry matter) of different shrub species at "La Orden", Spain

Shrubs species	GM (g/plant)	DM (g/plant)	DM kg/ha (2000 plants/ha)	DM (stem, %)	DM (leaves, %)	CP (%)
Atriplex repanda	2051	565	1130	24	76	9.1
Atriplex nummularia	1425	607	1214	19	81	11.4
Morus alba	2181	938	1876	5	95	11.4
Medicago arborea	1007	603	1206	35	65†	12.3
Chamaecytisus proliferus ssp. *palmensis*	1656	908	1816	28	82	11.6

†High seeds rate (≈ 60%)

From this table it comes out that the most productive species were tagasaste (*Ch. proliferus* ssp. *palmensis)* and *Morus*. The highest crude protein content was found in *Medicago*, while the most leafy species were *Morus* and tagasaste (Olea *et al.*, 1993b).

In the second site (Valdesequera), the production of *A. nummularia* reached 498 g/plant or 996 kg/ha in a plantation with 2000 plants/ha, 20 months after establishment in the field. In the same period, the production of *M. arborea* was much less (274 kg/ha). If plants of *A. nummularia* are harvested 20 months after plantation and three more harvests are done up to 32 months or 2.5 years, then the cumulative production may reach 1616 kg/ha. (Olea *et al.*, 1994).

Establishment and management of plantations

Establishment of fodder shrubs

The establishment trial with *Medicago* in Tessennano, central Italy, has shown that all methods employed (direct drilling, transplanting of 4 months-old seedlings or 5 months-old rooted cuttings) were successful but the seedlings produced by both direct seed drilling and transplanting were both destroyed by hares (*Lepus europaeus*). Plants from cuttings were more resistant. Therefore, the advantages of the low cost of direct drilling are offset completely by the hare damages which can be avoided only if plants are protected with wire nets for at least one year, until the stems are lignified (Cereti and Rossini, 1994).

Of the several methods tested by the Badajoz team to increase the germination capacity of seeds, it was found that the best pre-treatments were (Olea *et al.*, 1994):

(i) For *Atriplex* species → washing with running water for 24 hours and scarification with sulphuric acid.

(ii) For leguminous species → mechanical scarification.

On the other hand, good seedling establishment was obtained after seeding into plastic bags and then transplanting in the field in the autumn when seedlings were 20-30 cm tall. For *Medicago* specifically, good results were also achieved by using stem cuttings directly in the field in the autumn after the rains. In all cases, protection of young seedlings from wild animal damage was needed with wire nets.

Cultivation and management schemes

Weeds are strong competitors to fodder shrubs particularly in the spring and summer. Cultivation to remove the weeds was found necessary by all participants in this project. This removal however was very expensive. As an alternative to this costly operation, the Montpellier team applied winter grazing when shrubs were still dormant. Although the winter weeds were controlled, several summer weeds appeared (e.g. thistles) which also competed with shrubs. Some other teams intercropped perennial grasses (e.g. *F. arundinacea* and *D. glomerata*). These grasses controlled the weeds and increased forage production but also competed with shrubs. Annual legumes such as subterranean clover may be better companion crops with shrubs than perennial grasses.

Fertilization of *M. alba* cv. Kokuso 21 with 120 kg N/ha applied by the Montpellier was found very effective in increasing the production of this shrub.

Cutting back of shrubs in the winter so that they develop new growth in the spring was found necessary by all teams but the height of cutting back was different for the different species of shrubs.

Early spring grazing (leaf collection by hand) applied by the Montpellier team on *Amorpha* and *Colutea* in the Melgueil experimental area was found very effective in improving leaf quantity and quality in early summer. On the contrary, mowing at 30 cm aboveground affected negatively shrub growth. However, the two shrub species had differential response to grazing/browsing. *Amorpha* was not affected by grazing in 1990, which was a normal year, but it was significantly affected in 1991 which was a relatively dry year. On the other hand, *Colutea* was affected in both years. The difference may be attributed to the fact that *Amorpha* keeps its leaves longer in the summer than *Colutea*. The latter species suits better on early summer browse while the former could be used later. Pod production limitation by spring browsing delays but does not prevent mid-summer leaf fall of *Colutea*. Finally, spring grazing improves summer fodder quality by increasing the digestibility of organic matter of both species.

The results of the experiment on the shrub age at first cut are shown on Table 24. It comes out that with the exception of *Robinia* which peaked at the third year as well as *Colutea* and *Fraxinus* which peaked at the fifth year, all the other species peaked at the fourth year since establishment thus suggesting that the deciduous fodder trees and shrubs tested need to be cut for the first time when they are 4 years-old since establishment or 5 years-old since germination. On the other hand, the fact that all shrubs produced their highest aboveground biomass in 1994, a very favourable year in terms of spring air temperature and precipitation, indicates that aboveground production is very much affected by weather parameters and especially air temperature (Papanastasis *et al.*, 1997).

Spacing and grazing of fodder shrubs

Shrub growth, production and quality

Height of the shrubs tested in Greece varied between grazing treatments and spacings and especially among shrub species. At the fourth year of the experiment (1994), it ranged between 30 cm in *Gleditsia*, the poorest and 139 cm in *Robinia*, the best among the four species tested. Over the four years, these two species produced significantly different results with the other two being intermediate. Grazing significantly reduced shrub height while only the open spacing having produced significantly taller heights than the other two spacings (Table 25), apparently due to the lack of competition.

Table 24. Aboveground biomass (g/plant) of deciduous fodder trees and shrubs at the year of first cut in northern Greece (Papanastasis *et al.*, 1998)

Species†	Years							
	1987	1988	1989	1990	1991	1992	1993	1994
Amorpha fruticosa	23.4 c	53.2 c	656.5 c	783.3 c	580.8 b	392.9 de	627.2 cd	1222.9 d
Carpinus orientalis	1.5 d	6.7 d	72.3 g	268.2 d	194.5 c	190.1 de	393.4 d	718.4 d
Colutea arborescens	3.9 d	18.2 d	306.2 de	320.4 d	551.8 b	543.0 cd	1113.9 bc	2296.2 c
Corylus avellana	6.0 d	18.9 d	171.9 defg	638.0 cd	191.0 c	264.9 de	950.1 bcd	1035.5 d
Fraxinus ornus	0.9 d	5.2 d	107.8 fg	195.8 d	254.9 c	184.1 e	456.8 d	1061.6 d
Ostrya carpinifolia	8.9 d	42.8 c	555.7 c	1249.9 b	685.5 b	798.7 c	1464.8 b	3239.4 b
Pirus amygdaliformis	2.5 d	10.5 d	325.2 d	375.6 d	205.9 c	242.5 de	483.9 d	812.9 d
Quercus pubescens	3.0 d	16.2 d	281.2 def	514.2 cd	225.2 c	228.8 de	368.3 d	762.9 d
Quercus sessiliflora	4.8 d	13.4 d	205.5 defg	458.0 d	173.4 c	224.5 de	437.4 d	777.2 d
Robinia pseudoacacia (common)	66.3 a	136.2 a	3007.0 a	2241.9 a	1495.2 a	2039.2 a	2726.7 a	4173.6 a
Robinia pseudoacacia (*monophylla*)	32.6 b	82.1 b	2163.4 b	1411.5 b	1296.6 a	1450.6 b	2367.8 a	3125.4 b

†Species were planted as one-year old seedlings in the spring of 1987
[a,b]Means of the different species within each year followed by the same letters are not significantly different at the 0.05 level of significance

Table 25. Effects of grazing, plant species and spacing on shrub height (m) (1991-1994) in northern Greece

Grazing treatment	
Grazed	0.46 a
Ungrazed	0.67 b
Plant species	
Robinia pseudoacacia	1.02 a
Gleditsia triacanthos	0.25 c
Amorpha fruticosa	0.54 b
Morus alba	0.45 b
Spacings (m)	
1.5 × 1.5	0.54 b
2.5 × 2.5	0.55 b
3.5 × 3.5	0.58 a

[a,b]Means in the same treatment followed by the same letter are not significantly different at the 0.05 level

Relative growth rate of leaves (LGR) was not affected by spacing during the season (Fig. 24). In general, it was increased from mid-April to mid-May and decreased thereafter. *Robinia* presented the highest and *Morus* the lowest LGR. Grazing affected LGR: *Robinia, Gleditsia* and *Amorpha* attained their maximum values in late May but *Morus* in early July (Fig. 25). It comes out that grazing in early July and late August favours LGR in all species.

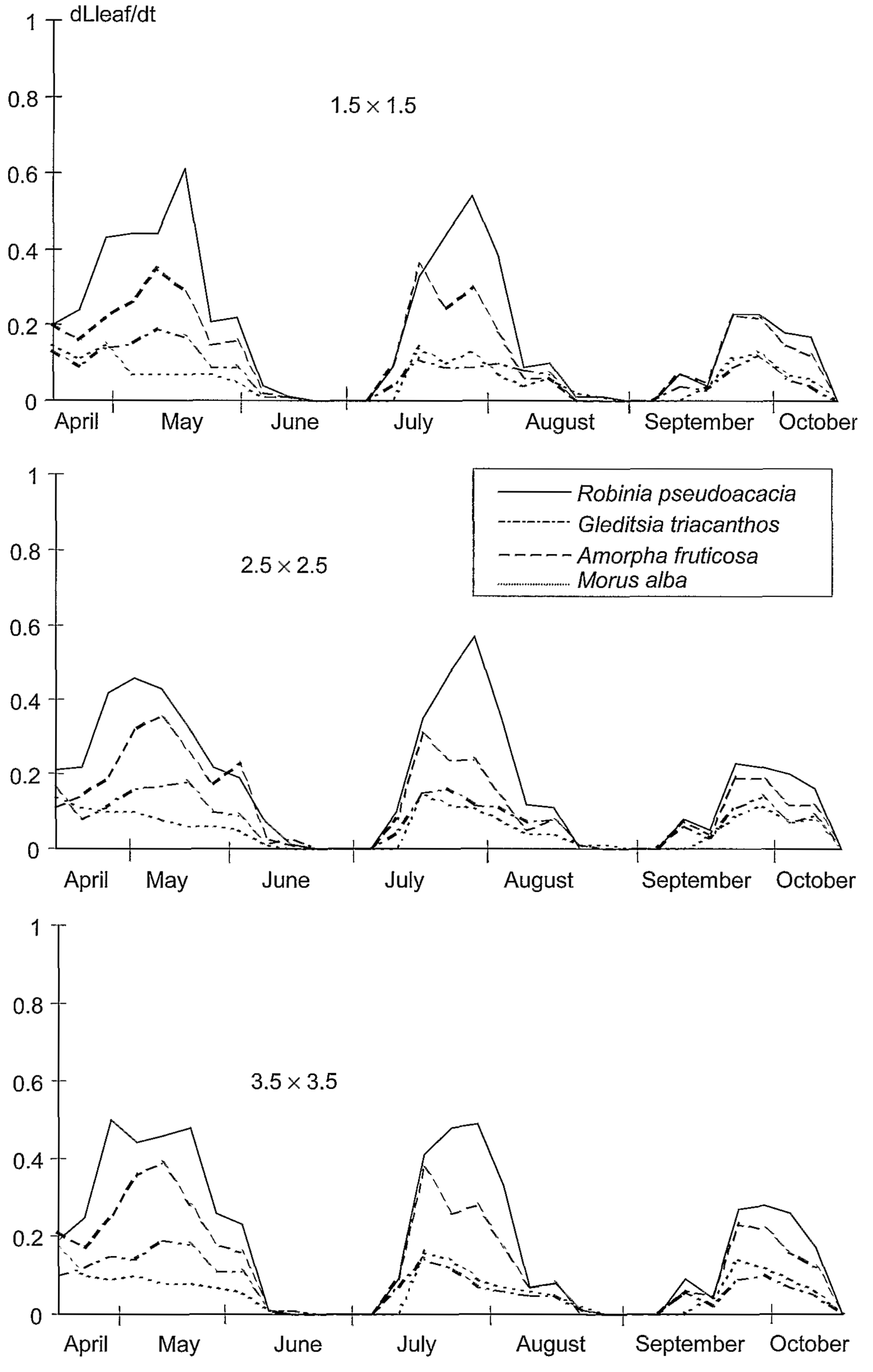


Fig. 24. Relative growth rate of leaf (change of leaf length over time, dLleaf/dt) in ungrazed fodder shrubs in northern Greece (average of 1992, 1993 and 1994).

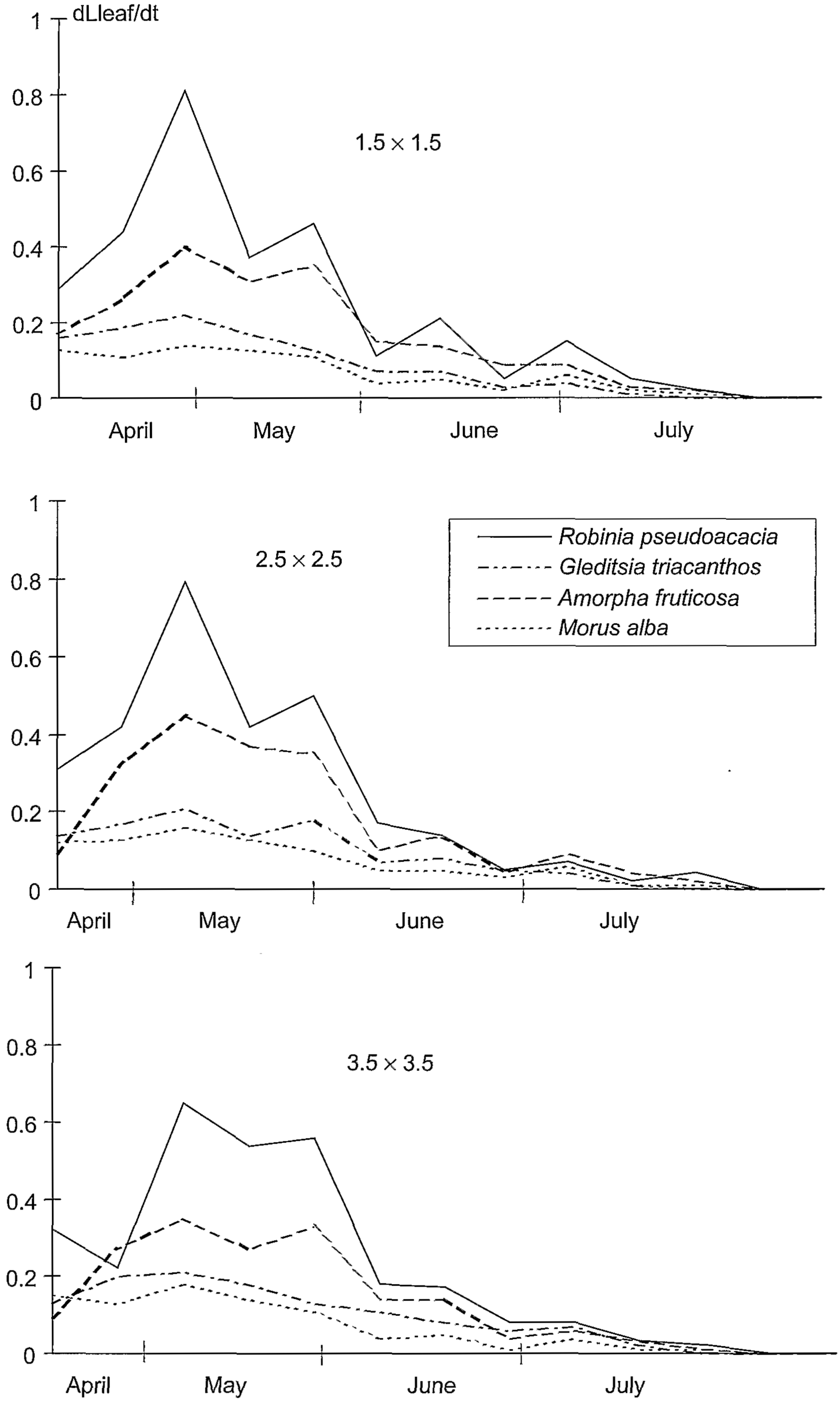


Fig. 25. Relative growth rate of leaf (change of leaf length over time, dLleaf/dt) in grazed fodder shrubs in northern Greece (average of 1992, 1993 and 1994).

Both ungrazed and grazed plants of *Robinia* had higher leaf water potential than the other species with second best being *Morus* (Fig. 26). This suggests that both species and especially *Robinia* are better adapted to the warm season than *Gleditsia* and *Amorpha*.

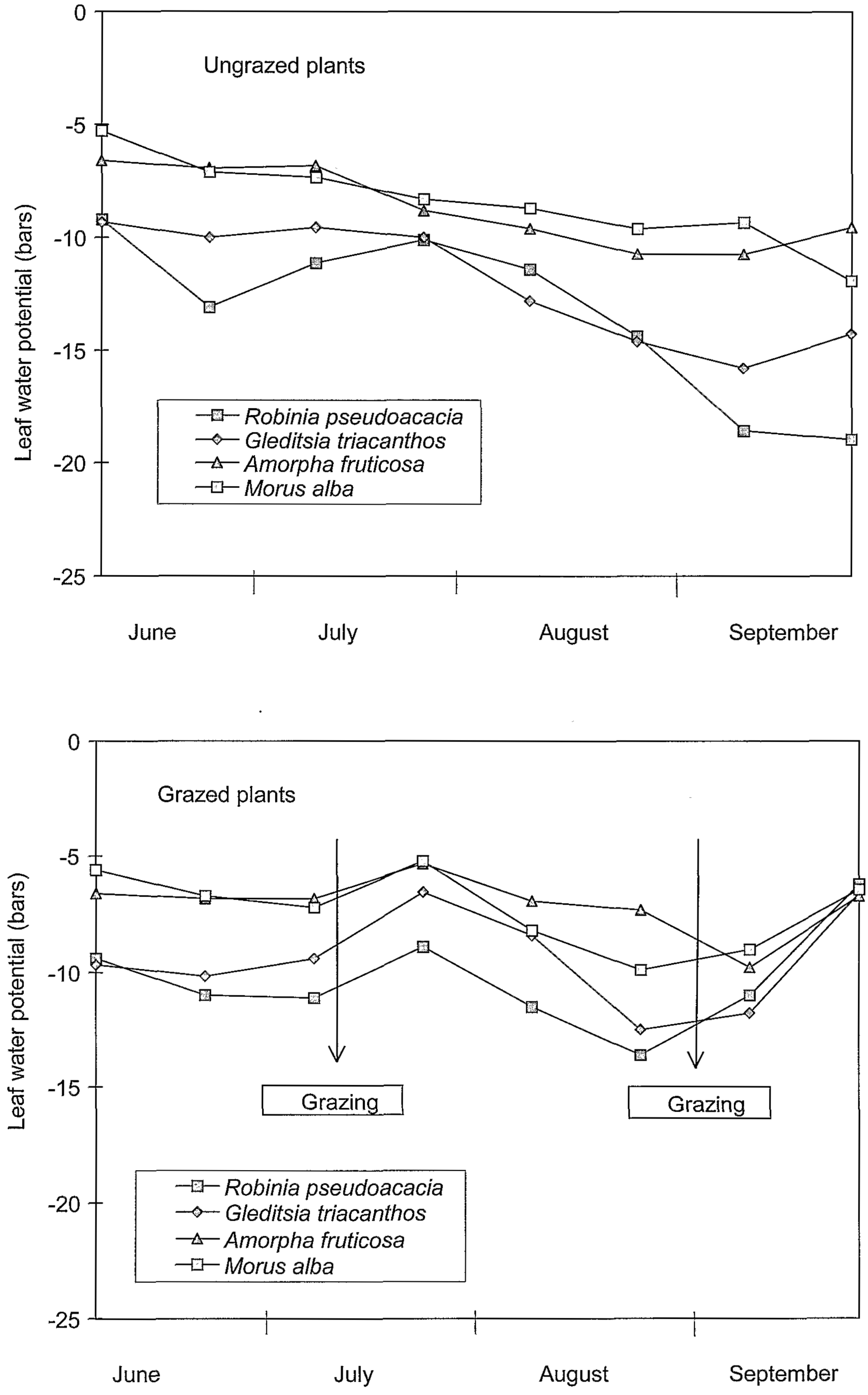


Fig. 26. Changes of leaf water potential (average of 1992 and 1993) in the ungrazed and grazed fodder shrubs during the growing season in northern Greece.

Browse production varied considerably between the different species, spacings and grazing treatments. Over the 4-years period, *Robinia* produced significantly higher production than the other species and *Gleditsia* the lowest. Also, the dense spacing (1.5 × 1.5 m) had significantly higher production per unit area than the other two spacings (2.5 × 2.5 and 3.5 × 3.5 m). Finally, grazing significantly reduced browse production (Table 26) (Ainalis and Tsiouvaras, 1998).

Table 26. Effects of grazing, plant species and spacing on browse production (kg/ha) (1991-1994) in northern Greece

Grazing treatment	
Grazed	113.35 a
Ungrazed	172.02 b
Plant species	
Robinia pseudoacacia	344.98 a
Gleditsia triacanthos	23.60 c
Amorpha fruticosa	137.32 b
Morus alba	64.84 b
Spacing (m)	
1.5 × 1.5	255.92 a
2.5 × 2.5	105.36 a
3.5 × 3.5	66.77 a

[a,b]Means in the same treatment followed by the same letter are not significantly different at the 0.05 level

Crude protein content tended to decrease from July to August in all the species except *Morus* which indicated an opposite trend. *Robinia* and *Amorpha* were the species with the highest and *Morus* with the lowest content. On the other hand, leguminous species, especially *Robinia* and *Amorpha*, had higher neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) but lower IVOMD (Table 27). Grazing did not affect considerably the chemical composition of all the shrubs.

Herbaceous vegetation

The mean cover of the herbaceous vegetation is shown on Table 28. It is clear that forbs were dominating the experimental area, especially the grazed plots, followed by perennial grasses (*Cynodon dactylon*), and annual legumes, while bare soil was also quite important.

Herbage production was not different among the three spacings apparently because shrubs were too young to affect understory vegetation. Grazing, however, reduced significantly herbage production (Table 29).

Chemical composition of herbage production is shown on Table 30. It is clear that this composition was not affected by shrub spacing while grazing seemed to have slightly changed it. Compared to shrubs (Table 27), herbaceous plants had lower crude protein content but higher *in vitro* organic matter digestibility.

Feeding value of pods of *Gleditsia triacanthos*

Chemical composition and in vitro *digestibility*

The chemical composition and *in vitro* digestibilities of the four *Gleditsia* varieties tested separately for pods and seeds are presented on Table 31. It is clear that pods had lower dry matter digestibility, crude protein content, ADF, NDF and *in vitro* digestibility as compared to dehydrated alfalfa, while seeds had higher crude protein content and *in vitro* digestibility than alfalfa. Overall, the whole pods were considered as a protein rich diet of a good digestibility and forage value comparable to those of oat and alfalfa (Foroughbakhch *et al.*, 1996).

Table 27. Chemical composition and *in vitro* organic matter digestibility of browse production in July and August over the years 1992-1994 in northern Greece

Species	CP (%)		NDF (%)		ADF (%)		ADL (%)		IVOMD (%)	
	Grazed	Ungrazed	Grazed	Ungrazed	Grazed	Ungrazed	Grazed	Ungrazed	Grazed	Ungrazed
July										
Robinia pseudoacacia	19.20	19.40	42.80	47.20	24.50	29.90	12.50	16.10	40.80	40.00
Gleditsia triacanthos	17.60	17.30	43.90	45.30	23.50	24.90	11.50	12.90	58.70	54.00
Amorpha fruticosa	19.50	18.90	41.00	48.30	24.90	29.60	9.40	13.50	39.80	39.00
Morus alba	12.20	12.40	30.00	33.60	17.40	18.90	4.30	4.20	76.00	74.00
August										
Robinia pseudoacacia	19.10	18.90	40.70	46.50	24.60	28.10	13.40	17.30	46.20	40.40
Gleditsia triacanthos	16.10	16.90	33.60	40.30	21.60	24.20	9.90	12.10	63.70	55.90
Amorpha fruticosa	18.10	17.80	38.30	39.30	25.00	26.80	10.50	12.80	50.10	46.50
Morus alba	15.70	14.40	29.90	32.80	17.40	19.70	5.30	5.80	73.00	74.90

Table 28. Mean cover (%) in the ungrazed and grazed treatments over the period 1991-1994 in northern Greece

Plant species	Ungrazed	Grazed
Annual grasses	7.90	8.57
Perennial grasses	20.90	17.53
Annual legumes	17.58	12.93
Forbs	53.73	47.50
Shrubs	0.90	0.93
Litter	1.48	1.87
Bare soil	15.51	10.67
Total	100.00	100.00

Table 29. Effects of grazing and spacing on herbaceous production (kg/ha) (1991-1994) in northern Greece

Grazing treatment	
Before grazing	1420.10 a
After grazing	786.14 b
Spacing (m)	
1.5 × 1.5	1055.56 a
2.5 × 2.5	1166.58 a
3.5 × 3.5	1087.21 a

[a,b]Means in the same treatment followed by the same letter are not significantly different at the 0.05 level

Table 30. Chemical composition and *in vitro* organic matter digestibility of herbage production in early June in grazed and ungrazed plots over the years 1991-1994 in northern Greece

Treatment	Spacing	CP	NDF	ADF	Lignin	IVOMD
Grazed	1.5 × 1.5	12.00	58.90	41.40	10.00	49.80
	2.5 × 2.5	13.10	59.80	39.90	9.50	51.90
	3.5 × 3.5	14.20	53.80	40.60	9.30	50.30
Ungrazed	1.5 × 1.5	12.20	56.50	42.70	10.60	52.10
	2.5 × 2.5	13.20	56.20	42.00	10.00	51.40
	3.5 × 3.5	14.10	55.90	43.00	9.70	49.80

In vivo *digestibility*

The pods were readily eaten by sheep. It took two days for the animals to eat thoroughly their daily pod allowance. This ration was only 1000 g per day at the beginning of the experiment, but was raised to 1380 g on the 14th day when it was realized that they could eat much more.

A mean pod ingestion of 68 g/kg$^{0.75}$ was achieved during the experiment. Alfalfa was preferably eaten at the beginning of the experiment, but after some weeks some animals clearly preferred *Gleditsia* pods to alfalfa.

During the *ad libitum* phase, daily ingestions of 2.3 kg of pods were recorded (Fig. 27).

Table 31. Chemical composition and *in vitro* digestibility of *Gleditsia triacanthos* pods and of the alfalfa supplement used during the *in vivo* digestibility experiment in southern France

Variety	Chemical composition (%)						*In vitro* digestibility (% DM)	Feed units
	DM	OM	CP	ADF	NDF	Lignin		
MIL								
Pod	90.7	95.1	12.3	25.6	44.0	10.0	67.7	1.02
Seeds	90.2	94.3	29.7	13.4	29.2	1.5	94.7	1.48
TOT								
Pod	90.7	94.7	11.6	22.0	37.6	7.1	72.1	1.07
Seeds	90.4	94 8	28.4	13.8	36.3	1.5	94.7	1.49
VFMG								
Pod	90.9	95.4	10.5	24.5	39.9	9.3	68.4	0.96
Seeds	90.2	95.2	27.7	14.8	40.6	2.0	90.8	1.42
SUM								
Pod	90.9	95.3	13.0	22.2	47.3	7.0	71.9	0.85
Seeds	90.6	95.6	23.3	12.6	46.9	1.2	94.9	1.45
Alfalfa	93.4	88.8	18.4	33.2	51.1	9.1	62.3	

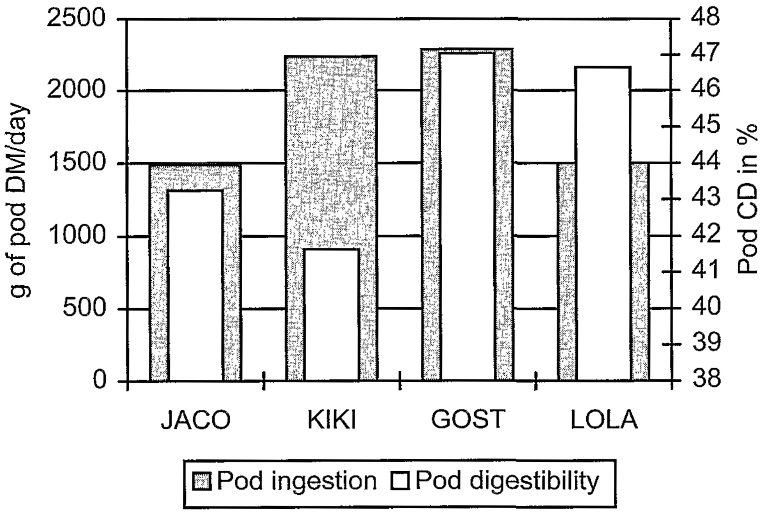


Fig. 27. *Gleditsia triacanthos* pods intake by sheep during the *ad libitum* phase of the feeding trial with four varieties in southern France.

During the 4 weeks trial with a daily allowance of 1380 g of pods per day, average daily liveweight gains ranged from 153 to 203 g/day. During the 7 days *ad libitum* phase, values ranging from 260 to 820 g/day were recorded. Although such results lack accuracy, the trend is obvious: sheep thrived on selected *Gleditsia* pods. The net weight gained ranged from 8 to 14 kg/animal in 7 weeks (Fig. 28). From these results, we can conclude that selected *Gleditsia* pods are a valuable feed that could provide animals not only with maintenance requirements but also with production requirements as well.

Dry matter and organic matter digestibilities as well as ADF and NDF were different among the four varieties tested (VFM and SUM varieties with high sugar content had significantly lower values than the other two) as well as among the 6 castrated animals which participated in the trial (Table 32).

Compared to dry matter, crude protein digestibility was much lower (Table 33). No significant differences were found among the 4 varieties but the differences among the animals were striking.

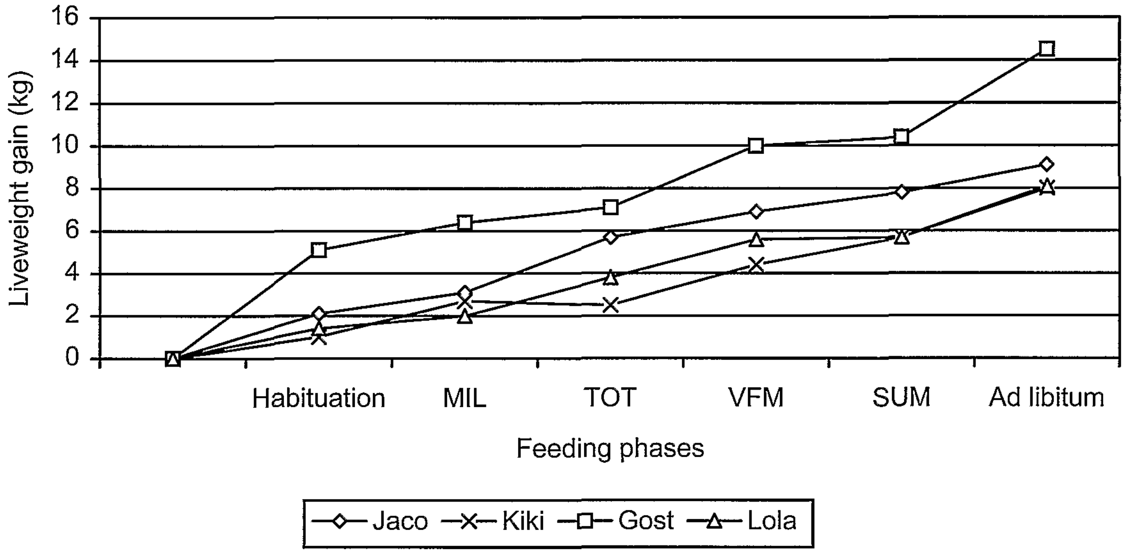


Fig. 28. Liveweight gains during the feeding trial with *Gleditsia triacanthos* pods in southern France.

Table 32. Coefficients of variation in digestibilities among varieties of *Gleditsia triacanthos* and animals tested in southern France

Variety	DM	OM	ADF	NDF
MIL	58.3 a	60.8 a	34.5 a	51.8 a
TOT	58.7 a	61.0 a	37.7 a	51.5 a
VFM	54.0 b	55.9 ab	25.8 a	38.5 a
SUM	48.6 b	50.1 b	8.6 b	45.8 a

Animal	DM	OM	ADF	NDF
Jaco	58.8 b	61.5 b	34.8 b	53.3 ab
Kiki	50.5 b	50.3 c	24.5 b	39.0 b
Gost	49.3 b	51.8 bc	18.0 b	37.3 b
Mimi	66.7 a	69.0 a	51.0 a	64.0 a
Tuti	53.5 b	56.6 bc	18.5 b	47.5 ab
Lola	55.3 b	57.3 bc	23.8 b	45.0 b

[a,b]Means in the same row followed by the same letter are not significantly different at the 0.05 level

Table 33. *Gleditsia triacanthos* pods' crude protein coefficients of digestibility (CPCD): variety and animal sources of variation (Southern France)

Variety	CPCD
MIL	37.3 a
TOT	20.7 a
VFM	20.5 a
SUM	16.8 a

Animal	CPCD
Jaco	50.5 a
Kiki	18.5 ab
Gost	22.0 ab
Mimi	51.7 a
Tuti	-10.5 b
Lola	29.5 ab

[a,b]Means followed by the same letter are not significantly different at the 0.05 level

The digestibility of pods seemed to be conversely related with the intake of pods. Animals which ate less pods had better coefficients of digestibility than animals which ate them readily. This suggests that *Gleditsia* pods should not be given as a sole feed. More research is needed to clear this point.

The seed budget during the feeding trial is presented in Table 34. From this table it comes out that a relatively high proportion of seeds in some varieties and by some animals is rejected in the faeces without being able to be digested due to their hard coats. For this reason, varieties of *Gleditsia* with soft seed coats should be preferred in the selection programmes (Dupraz and Newman, 1997).

Table 34. *Gleditsia triacanthos* seed budgets during the feeding trial in southern France†

Variety	Animal	1	2	3	4	5	6	7
MIL	Jaco	447	2	445	6	439	99	0
	Kiki		0	447	61	386	86	0
	Gost		0	447	159	288	64	0
	Mimi		81	366	1	365	99	12
	Tuti		105	342	12	330	97	20
	Lola		25	422	66	356	84	5
TOT	Jaco	558	49	509	19	490	96	0
	Kiki		19	539	235	304	56	1
	Gost		12	546	215	331	61	1
	Mimi		177	381	6	375	98	37
	Tuti		356	202	14	188	93	163
	Lola		148	410	64	346	84	15
VFM	Jaco	422	24	398	143	255	64	1
	Kiki		17	405	271	134	33	0
	Gost		6	416	169	247	59	0
	Mimi		59	363	14	349	96	7
	Tuti		275	147	39	108	73	168
	Lola		65	357	187	170	48	15
SUM	Jaco	665	190	475	76	399	84	4
	Kiki		87	578	296	282	49	0
	Gost		18	647	221	426	66	0
	Tuti		460	205	19	186	91	145
	Lola		156	509	176	333	65	13

†All values are in number of seeds per day and per animal unless noted
1 Seeds in the ration distributed
2 Seeds not swallowed + seeds spitted during rumination
3 Seeds ingested down the rumen
4 Seeds in the faeces
5 Numbers of seeds disappeared in the intestine
6 % of ingested seeds disappeared in the intestine
7 % of spitted seeds as compared to disappeared seeds

In sacco *degradability*

The pods of the four *G. triacanthos* varieties tested were found to have high *in sacco* degradability values, far above the standard nitrogen enriched straw (NES). The potential degradable fraction varied from 77 to 82%. Pod diet had a significant impact on straw digestibility: two varieties improved the degradability by more than 10% while the other two had no impact (Table 35). Such improvement of the valorization of low quality feed is a very interesting by-impact of the *Gleditsia* pods. By using a disappearance rate of the feed in the rumen kp = 0.06^{-1} the theoretical degradability of the proteins is deduced from the Orskov and McDonald model ranging from 59 to 65% for the four varieties tested.

Comparison of in vivo, in vitro *and* in sacco *degradability*

Comparing *in sacco* values with *in vitro* and *in vivo* digestibilities, it comes out that they were higher by 8% of the former (*in vitro*) and by 5-10% of the latter (*in vivo*). The lower *in vivo* values, which differ considerably among the four varieties contrary to the other (*in sacco* and *in vitro*) values

(Table 36), suggest that the retention time of pod particles in the rumen may be much shorter than 48 hours as used in the *in sacco* technique. It seems that it can be obtained an *in sacco* degradability up to 55% with a 10 hours retention time. In a more realistic diet, however, *Gleditsia* pods could contribute to 25 to 50% of the daily organic matter allowance.

Table 35. Influence of the diet on the *in sacco* protein degradability of *Gleditsia triacanthos* pods and NES (measured after 48 hours in the rumen) in southern France

Variety	Pods		Nitrogen enriched straw	
	Pod diet	Standard diet	Pod diet	Standard diet
MIL	77.6	76.4±3.7	47.3±1.7	50.2±0.9
TOT	78.7	76.4±2.1	64.6±4.6	
VFM	77.7	73.9±1.7	59.4±5.2	
SUM	77.6	77.2±2.2	48.9±2.4	

Table 36. Coefficients of digestive uses of the dry matter of pods of *Gleditsia triacanthos* measured with three different techniques in southern France

Variety	*In vitro*	*In sacco*	*In vivo*	
	Ground pods	Ground pods	Ingested pods	Crushed part
MIL	67.7 a	77.6 a	58.0 a	60.3 a
TOT	72.1 a	78.7 a	58.7 a	63.0 a
VFM	68.4 a	77.7 a	54.0 b	60.5 a
SUM	71.9 a	77.6 a	48.6 c	55.9 a
Mean	70.0 b	77.9 a	54.8 d	60.0 c

[a,b]Means in the same row followed by the same letter are not significantly different ($P \leq 0.05$)

The question that arises after making the pod digestibility trials is whether *Gleditsia* pods should be used raw or ground. The answer is that whole pods should be preferred as feed provided that they are selected to be sugar-rich. Ground pods in the form of flour have a short transit time from the animals' rumen thus resulting in poor degradabilities. Moreover, grinding of pods is very expensive and, therefore, non-economic (Dupraz and Newman, 1997).

To achieve a better use of *Gleditsia* pods by sheep, they should be mixed with bulky feed and varieties with soft seeds should be used. Such seeds are early broken at ingestion or rumination and result in high protein digestibilities.

Fodder shrubs as a summer feed supplement

Fodder shrubs for sheep

The first experiment on supplementation of sheep with fodder shrubs in the summer conducted by the Montpellier team in 1991 produced the following results (Ouattara, 1991):

(i) Fodder shrubs were very attractive to sheep, especially *Colutea, Coronilla* and *M. alba* cv. Kokuso 21.

(ii) Shrub supplementation resulted in clear improvement of the animal performance, although climatic conditions were very difficult in the summer (high temperatures and drought).

(iii) Sheep supplemented with fodder shrubs changed their behaviour while grazing in the rangeland by preferring woody plants instead of herbaceous species which were mostly preferred by the control (non-supplemented with shrubs) animals.

(iv) Shrub supplementation changed impressively the rumination behaviour of sheep and consequently body metabolism.

During the second experiment in 1994, different but also interesting results were produced.

Liveweight was reduced in all treatments, even in sheep supplemented with alfalfa pellets. This may be attributed to a variety of reasons including the probable low level of supplementation.

The species composition of the intake was different in the supplemented and non-supplemented animals. The former were selecting quite a few shrubs, while the latter were almost exclusively fed with grasses while grazing in the rangelands. The alfalfa-supplemented sheep were interestingly preferring *Quercus coccifera* and *Rosmarinus officinalis* (Table 37).

Table 37. Composition (% of DM) of the diet of sheep browsing freely in the rangelands at Saint-Gély du Fesc (19-23 July 1994) in southern France

Supplement	Graminaceae	Kermes oak	*Rosmarinus*	Miscellaneous†
No	72.5	3.7	1.8	14.1
Alfalfa	66.6	18.7	3.8	12.8
Morus	73.0	7.8	1.7	11.5
Legume shrubs	75.5	7.9	5.2	7.5

†*Thymus officinalis, Pinus halepensis, Dorycnium suffriticosum, Rubia peregrina, Rosa canina, Pistacia terebinthus* and *Phyllirea latifolia*

The production of faeces collected from the animals was increased from July to August indicating an increase of intake and/or a decrease in the digestibility of the diet (Fig. 29). The lignin content of the faeces was not affected by the supplements. But in August, non-supplemented animals had lower lignin content in their faeces indicating a poor degradation of cellulose in their rumens. This suggests that supplements and especially shrubs clearly improved feed digestion.

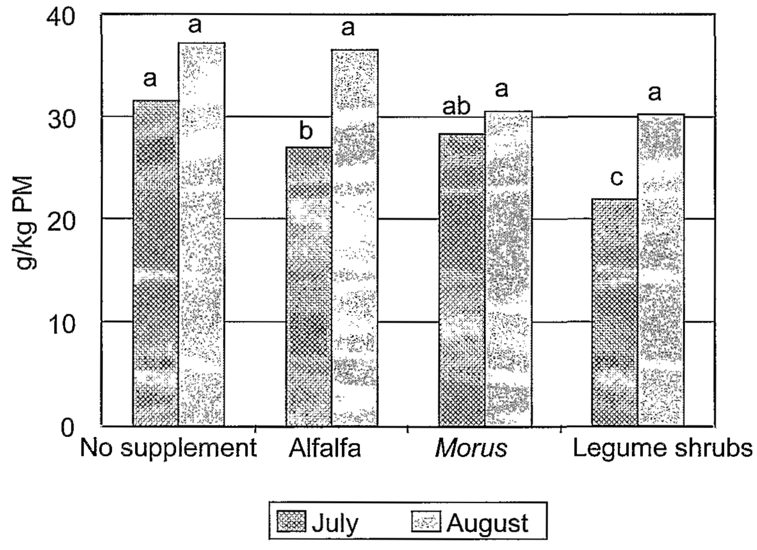


Fig. 29. Faeces production during the feeding trial with fodder shrubs in southern France.

By using the lignin budget based on lignin content of faeces, supplements and the main species found in the rangelands the feed intake by each animal was computed (Table 38). These computed values, however, turned out to be overestimations as compared to intake values thus indicating that the lignin budget is not a reliable method for feed intake determination (Table 39).

Both alfalfa and fodder shrubs improved significantly the *in sacco* degradability of a common feed with alfalfa having the highest impact while legume shrubs and *Morus* had equal effects (Table 40).

Table 38. Dry matter budget deduced from the lignin budget for sheep with different supplementations in Saint-Gély du Fesc in southern France

Supplement	Period	Outflow			Inflow						
		Faeces			Supplement			Range			
		DM	Lignin		DM	Lignin		DM		Lignin	
		g/day	%	g/day	g/day	%	g/day	g/day	g/day/kgMW[†]	%	g/day
No	July	689	21.5	148	0	0.0	0	2297	105	6.5	148
	August	762	16.6	126	0	0.0	0	1961	93	6.5	126
Alfalfa	July	522	19.2	100	92	3.0	3	1115	56	8.7	97
	August	728	19.7	143	92	3.0	3	1609	81	8.7	141
Morus	July	616	21.8	134	82	5.2	4	1605	74	8.1	130
	August	665	20.8	138	82	5.2	4	1655	79	8.1	134
Legume	July	384	19.7	76	125	13.3	17	745	42	7.9	59
Shrubs	August	529	19.3	102	160	12.8	20	1032	58	7.9	82

[†]MW: metabolic weight

Table 39. Overestimation of the intake by the lignin budget: a comparison with the values deduced from likely digestibility values for the main species

Supplement	Period	Digestibility budget	Lignin budget	Ratio
No	July	1255	2297	1.83
	August	1388	1961	1.41
Alfalfa	July	810	1115	1.38
	August	1187	1609	1.35
Morus	July	995	1605	1.61
	August	1084	1655	1.53
Legume shrub	July	459	745	1.62
	August	656	1032	1.57

Table 40. Impact of fodder shrubs supplementation on the cellulolytic activity in the rumen: *in sacco* measures on a common feed ("foin de Crau") in southern France

Supplement	Degradability (%)	SNK test
No	65.0	a
Morus	67.1	b
Legume shrubs	68.1	b
Alfalfa	70.0	c
Reference	63.6	

[a,b]Means followed by the same letter are not significantly different at 0.05 level

Recording the sheep behaviour in rangelands has shown that animals rest during the hot part of the day, feed at dawn and twilight and ruminate during the night. The rumination is stimulated by the supplements, especially in August, when the rangeland was used up. The impact of *Morus* is stronger than the one of the legume species. Also, supplementation increased the feeding time with *Morus* again having a stronger impact than legume shrubs (Fig. 30).

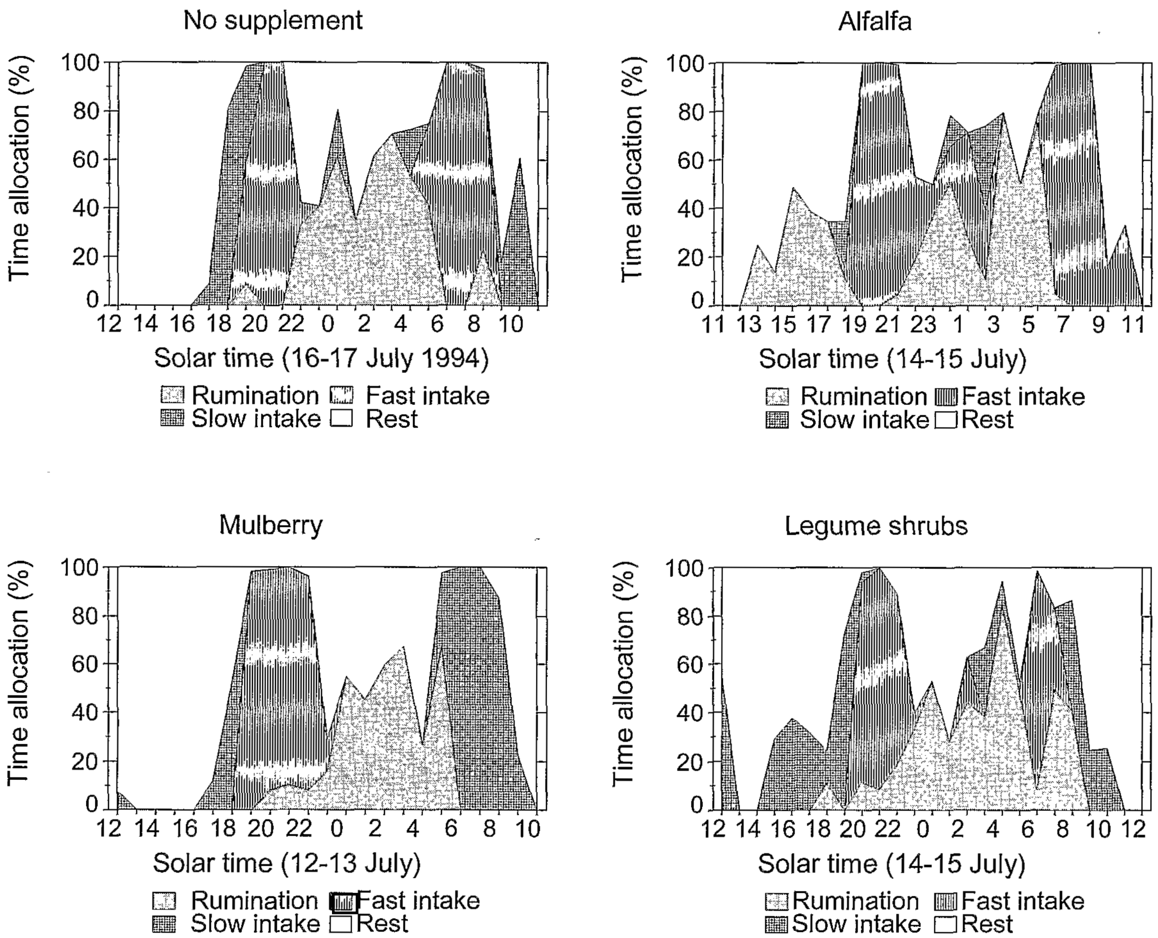


Fig. 30. Time tables of sheep with different supplementations in southern France.

The main conclusions of these two experiments were the following:

(i) The supplements increased the rumen efficiency, extended the rumination activity, but lowered the daily intakes on the range, and induced an increase in the browse of woody plants. Few direct observations of the intake were done, but they suggest that fodder shrubs supplemented animals browsed more (woody species) and non-supplemented animals grazed more (herbaceous species). These observations were done after the sheep were moved to a new fold with plentiful of dry herbaceous species, and may explain that all sheep focused on the dry grasses they had been looking for in the previous fold. The close observation of the rumen content did confirm these visual observations, but the time chosen for the sample collection of the rumen content may have not been adapted: the range was used up, and the animals had little choice.

(ii) The daily allowance of 10% of the organic matter needs applied in the 1994 experiment was inadequate. It was too little to induce a maintenance of body condition.

(iii) In 1991, an evening delivery resulted in a body weight maintenance. In 1994, a morning delivery resulted in a body weight loss. But the levels of supplementation were different (30% versus 10%). Control sheep without any supplement lost more weight in 1994 than in 1991, indicating more severe conditions in 1994. A new trial with the time of delivery as the only variable may be necessary to clarify this point.

(iv) Legume species were the best for rumen activity, and *Morus* the best for maintaining the intake on the range. A significant reduction in the intake on the range was evidenced for any supplement, but was very impressive with the legume shrubs supplement. This reduction did not induce worse body weight conditions, and it may be explained by a better use of the intake.

(v) As a final remark, it should be added that the supplementation was readily eaten, even the *Amorpha* supplement (but after a two week adaptation period) and although fodder shrubs did not improve the body weight condition, they matched alfalfa in this regard; and alfalfa is the obvious top quality challenger for fodder shrubs.

Fodder shrubs for goats

The results of the experiment in Greece with fodder shrubs as a supplement to goats were the following:

(i) Dry matter intake of supplements was higher in September than in July apparently because green forage was still available in the rangelands during July. Intake of *Amorpha* and *Colutea* was significantly lower than of the other feeds. In September, the feed with the highest intake was *Fraxinus* (513 g/animal/day) which did not differ significantly from *Robinia* (424 g/animal/day), while alfalfa was significantly lower (398 g/animal/day) than *Fraxinus* (Table 41).

Table 41. Daily intake of fodder trees and alfalfa used as supplements by free grazing goats and its effect on body weight in northern Greece

Diets	Intake DM (g/animal/day)		Body weight gain (g/animal/day)	
	July	September	July	September
Amorpha	78.3	284.7 c	2.5 a	12.5 bc
Carpinus	221.4	398.6 b	32.5 a	175.0 a
Colutea	125.4	233.2 c	0.0 a	50.0 bc
Fraxinus	245.1	513.3 a	37.5 a	112.5 ab
Ostrya	183.4	388.0 b	12.5 a	-12.5 c
Robinia	199.9	424.3 ab	37.5 a	112.5 ab
Alfalfa	356.5	397.9 b	50.0 a	187.5 a
Control	–	–	47.5 a	-25.0 c

[a,b]Means in the same column sharing the same letter are not statistically different ($P \leq 0.05$)

(ii) Body weight of animals (g/day) was not affected during the July experiment but in September some shrubs (*Carpinus, Robinia, Fraxinus*) resulted in significant increase (112-188 g/animal/day) as much as alfalfa while the control animals lost weight as well as those fed with *Ostrya* (Table 41).

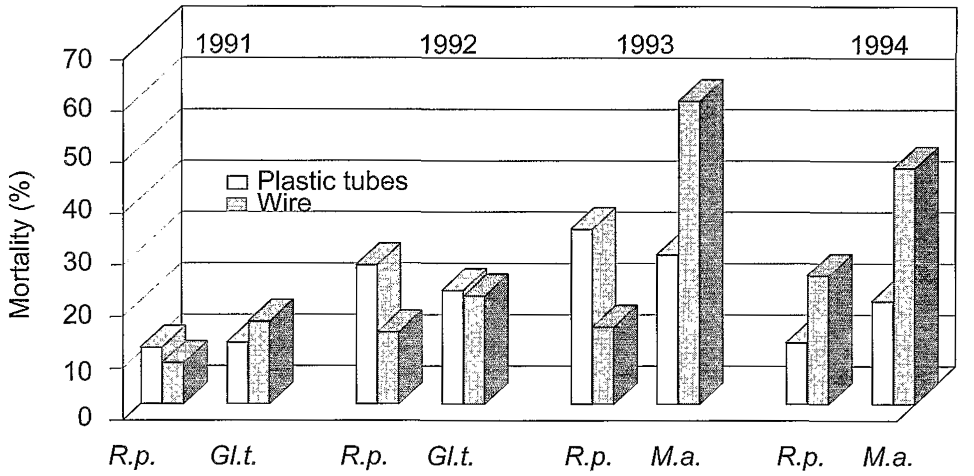
(iii) Nitrogen intake ranged in relatively high amounts, especially in the September trial when *Fraxinus* and *Robinia* even exceeded alfalfa pellets (Table 42).

Table 42. Daily supplemented nitrogen (N) consumed by grazing goats fed with six fodder trees and alfalfa in northern Greece

Diets	Consumed N (g/animal/day)	
	July	September
Amorpha	2.4	7.0
Carpinus	3.8	6.3
Colutea	3.0	4.4
Fraxinus	4.7	10.7
Ostrya	3.6	6.2
Robinia	6.1	12.2
Alfalfa	8.8	9.8

Wide spacing of protected fodder trees

Despite the irrigation of all the species during the summer period, the fodder trees in the Scholari experiment, northern Greece, suffered from the drought which resulted in the death of several plants. The mortality percentages are shown on Fig. 31. It is obvious that *Gleditsia* on the average presented higher mortality than *Robinia*. The mortality of the latter was higher for the protected with plastic tubes trees than for the ones protected with the wire nets. The mortality rates were opposite in *Morus* which means that plastic tubes had a beneficial effect on the survival of this species (Platis and Papanastasis, 1996).



Robinia pseudoacacia L. *(R.p.), Gleditsia triacanthos* L. *(Gl.t.), Morus alba* L. *(M.a.)*

Fig. 31. Percentage mortality of fodder trees planted with various protection measures in northern Greece.

The tree height of all the species during the 4 year-period, where trees were planted at various spacings and under two protection measures, is shown on Table 43. *Robinia* was taller than the other two species as it was expected. This fact illustrates the great adaptability of the species in the different environments during the first years of establishment.

The three spacings did not produce any significant differences in plant height in *Robinia*. Protection measures, on the contrary, affected significantly tree height. Trees in plastic tubes were 44%, 36%, 38% and 14% taller than the ones protected with wire nets or freely grown in fenced plots respectively in the four years (1991-1994). The reduction of the difference in the last years, especially the fourth, may be explained by the fact that the plastic tubes ceased to affect the plant growth with time, as trees grew out of their tops (Dupraz, 1997). Among the other species, *Gleditsia* did not show statistically significant growth between spacings and the two protection measures. Its poor growth even within the plastic tubes indicates that it is not a suitable species for semi-dry environments with sandy soils and justifies its replacement with *Morus*. *Morus* did not present significant differences between spacings and the two measures in the first year; in the second year, however, trees protected with plastic tubes were 134% taller than the plants grown freely in the fenced plots (Platis and Papanastasis, 1996).

The ground cover of the herbaceous layer was not significantly different between the species and the three spacings (Table 44). Forbs were the dominant plant group in the 4 years of the study followed by perennial grasses, which were almost exclusively dominated by *C. dactylon*. This composition indicates a high grazing pressure on the communal grassland. This is also derived from Table 45 where herbage production in grazed and protected plots for the four years of the study is presented. By comparing the two values in each year, it comes out that the utilization percentage of the herbaceous production at the end of the growing period (middle of May) ranged from 52% in 1993 to 86% in 1991, relatively dry and wet years respectively.

Table 43. Average tree height (cm) at different years of *Robinia*, *Gleditsia* and *Morus* planted at various spacings and protection measures in northern Greece (Platis and Papanastasis, 1996)

Year	Plant species	Spacing (m)	Protection measures	
			Plastic tubes	Wire
1991	*Robinia pseudoacacia*	4 × 4	160.3 a	111.9 b
		8 × 8	172.1 a	117.0 b
		12 × 12	162.2 a	111.7 b
	Gleditsia triacanthos	4 × 4	60.1 a	43.0 a
		8 × 8	54.6 a	42.0 a
		12 × 12	56.0 a	38.2 a
1992	*Robinia pseudoacacia*	4 × 4	211.8 a	126.9 b
		8 × 8	208.7 a	182.9 b
		12 × 12	204.2 a	111.6 b
	Gleditsia triacanthos	4 × 4	51.9 a	44.1 a
		8 × 8	51.2 a	41.3 a
		12 × 12	50.1 a	45.0 a
1993	*Robinia pseudoacacia*	4 × 4	166.6 a	136.7 b
		8 × 8	191.7 a	155.5 b
		12 × 12	207.5 a	118.7 b
	Morus alba	4 × 4	72.9 a	51.1 b
		8 × 8	63.5 a	47.0 a
		12 × 12	62.7 a	53.0 a
1994	*Robinia pseudoacacia*	4 × 4	161.6 a	158.3 a
		8 × 8	208.4 a	190.2 a
		12 × 12	180.4 a	131.7 a
	Morus alba	4 × 4	113.7 a	33.9 b
		8 × 8	87.6 a	26.6 b
		12 × 12	90.9 a	37.3 b

[a,b]Means followed by different letters in the same species denote significant differences at 0.05 level

Table 44. Ground cover (%) changes through the years (1991-1994) in the grazed communal grassland of northern Greece

Plant groups	Years			
	1991	1992	1993	1994
Annual grasses	10.3	8.0	6.0	18.1
Perennial grasses	23.4	19.2	23.5	13.5
Annual legumes	19.1	6.6	15.0	34.3
Forbs	24.7	33.2	36.6	22.1
Shrubs	0.0	0.5	0.1	0.1
Bare soil	22.5	32.5	18.8	11.9
Total	100.0	100.0	100.0	100.0

Table 45. Herbaceous production (kg/ha) changes through the years (1991-1994) in the grazed communal grassland of northern Greece

1991		1992		1993		1994	
Protected	Grazed	Protected	Grazed	Protected	Grazed	Protected	Grazed
1195	165	1471	588	1111	532	1679	612

Discussion

The two main objectives of this project, namely (i) the exploitation of genetic material and (ii) the application of modern techniques in establishment of fodder tree and shrub plantations were fully met by its results produced during the 4 year long (March 1991-February 1995) experimental period. More specifically, the collected results confirmed the great potential of fodder trees and shrubs for filling up the feed gaps in the critical periods of the Mediterranean climate and thus efficiently supporting the extensive ruminant production systems.

On the other hand, it is well documented that using fodder trees and shrubs in the Mediterranean production systems is not without problems which are related with their great variability, low digestibility, difficulties in propagation, biomass estimation and management as well as with the high cost of establishment (Papanastasis, 1991, 1993a,b). Most of these problems were encountered in this project, and it was found that not all species of fodder trees and shrubs present the same problems nor the problems are uniform in all environments.

At any rate, the results of this project should not be considered as conclusive in all cases because fodder trees and shrubs are perennial woody species. This means that four years of experimentation are not enough to reveal their full range of advantages and limitations as sources of feed for animals in highly diversified conditions where Mediterranean extensive livestock production systems operate.

The discussion is structured along the three actions of the project and followed by the economic assessment of the results.

Germplasm collection, screening and multiplication

The germplasm collected during the course of the project constitute an invaluable source of genetic material to be further screened and multiplied so that special varieties are developed for a wide range of Mediterranean conditions.

Chamaecytisus proliferus is a very palatable ("ice-cream"), winter growing and summer dormant fodder shrub species which grows spontaneously in the Canary Islands. There, it is found in a variety of environments but mostly in relatively acid soils, and always in areas free of winter frost and with abundant annual rainfall (more than 400 mm). The selection programme of the Badajoz team has succeeded in identifying three lines which are very promising for the semi-arid conditions and the acid soils of Extremadura (SW Spain).

Medicago arborea is also a very palatable winter growing and summer dormant fodder shrub species naturally grown in the Aegean islands of Greece. Compared to *Chamaecytisus*, *Medicago* grows in drier Mediterranean environments and in slightly acid to alkaline soils while it can tolerate cooler but also frost-free winters. The selection programme of the Larissa team has succeeded in identifying lines resistant to winter frost as well as lines keeping their leaves in the summer longer than the normal species does.

Gleditsia triacanthos is considered as a valuable fodder tree for its pods which fall from the trees in the autumn and are available to the animals through the winter period. The selection programme carried out by the Montpellier team has clearly shown, however, that not all *Gleditsia* trees produce pods of high nutritive value and that selected varieties for that particular purpose are needed, which have been already produced. The grafting technique developed by the same team seems to have been very successful and it resulted in the production of certified true copies of the parental trees. On the other hand, pod production of the grafted trees was found to be affected not only by genetic factors but also by management practices including the competition of trees by the established pasture in the understory.

Robinia pseudoacacia is also a very valuable and productive fodder tree but for its foliage rather than for its fruits. For this reason, maintaining it in a shrubby form is advantageous if it is going to be used directly by the animals. The selection programme carried out by the Vassilika team has clearly shown its high variability in morphological and growth parameters and has resulted in the production of clones with few thorns, few but large leaflets per compound leaf and higher crude protein content than the common *Robinia*.

As far as the multiplication of the collected and selected germplasm of the above four species is concerned, the results have shown that the easiest method to use is seeds, although pre-treatment is usually needed to increase their germination capacity. However, seeds do not ensure the maintenance of the selected characters. For this reason, vegetative propagation through cuttings (softwood or hardwood) should be preferred. For *Gleditsia* especially, cuttings seem not to be the appropriate propagation method and grafting of the selected clones on wild trees is needed.

Ecological and agronomic evaluation

Environmental considerations

Environmental factors seem to play a significant role in the performance of most of the fodder tree and shrub species studied. *Gleditsia* for example was found to grow better on deep sandy than on heavy soils in southern France while in northern Greece the opposite was true. This may be attributed to the wetter Mediterranean climate prevailing in the former than in the latter region, thus suggesting that there is a strong interaction between soil and climate. On the other hand, *Medicago*, which is adapted to relatively dry climates, suffered from root asphyxia in Sicily when too much rain fell during the winter (growing) period.

In general, the performance of winter growing fodder shrubs such as *Medicago* seems to be mostly affected by the winter temperatures with negative impacts if they are relatively low and prolonged. On the other hand, the performance of summer growing (or winter deciduous) species in southern France is mostly affected by rainfall, especially in late spring and summer. This means that yearly variations in the amount and distribution of annual rainfall are closely related with the yearly changes in shrub productivity, a fact that it should be further explored in future studies. In northern Greece on the contrary, where winter and spring are colder than in southern France, the climatic factor mostly affecting the growth of the deciduous species is air temperature, especially in the early spring (Papanastasis *et al.*, 1997).

Biomass estimation

Proper utilization of fodder shrubs requires the knowledge of the biomass produced which is often very difficult to estimate with direct and destructive methods. The results of this project suggest that there are alternative indirect methods, less expensive and much easier to use. Such methods include the photographic method employed by the Viterbo team which makes use of modern technologies (computers and image analysis) as well as the dimensional method employed by the Avignon and Sicily teams which are based on the easily measured shrub dimensions. The accuracy of these methods, however, depends on detailed measurements beforehand so that predictive models for specific shrub species are developed.

Productivity

Productivity was found to be related with the particular species of shrubs or their cultivars involved, the environmental conditions where they grow, and the age of plants. For *Medicago* which was studied both in Sicily and central Italy, winter production was found higher in the former (about 500 g/plant) than in the latter site (about 250 g/plant) apparently because Sicilian environment is closer to the optimum growth conditions of *Medicago* than the environment in central Italy.

The average production of edible biomass for the 10 populations of *Medicago* in Sicily was about 1.78 t/ha in the third year since establishment, but some populations such as the French Cap Ferrat and the Algerian Melagon gave higher values, 2.80 and 2.26 t/ha respectively. Such productions are about 6-7 times higher than those observed during the autumn-winter period in some representative Sicilian natural pastures and still higher than the winter forage production achievable from a vetch-berseem (*Vicia sativa-Trifolium alexandrinum*) mixture (Amato *et al.*, 1991) or from a short rotation meadow crop of sulla (*Hedysarum coronarium*) (Stringi *et al.*, 1991) in a representative area of the arable land of inner Sicily.

Comparable to the results obtained in Sicily were also the productivity values of *Medicago* found in the island of Rhodes by the Larissa team while the values found in central Greece by the same team were closer to the ones obtained in central Italy. In Extremadura, SW Spain, finally, values were again closer to the results obtained in central Italy and Greece but lower than the ones given by tagasaste (*Chamaecytisus*) thus suggesting that the latter species is more suitable in that particular area than *Medicago*.

The annual production of edible biomass was also high in the summer growing species of fodder shrubs but the values obtained were again different depending on the particular species and year involved. For example, the Japanese variety of *M. alba* cv. Kokuso 21 gave annual production values ranging from 100 to 2000 g/plant in Provence of southern France. Relatively high values were also achieved for the same species in Montpellier (149-600 g/plant).

Other species of deciduous fodder shrubs produced variable annual edible biomass as well. In Greece, the most productive species was found to be *Robinia* with 584 g/plant at the third year since establishment while in southern France it produced less than 200 g/plant. *Amorpha* produced up to 233 g/plant in Greece while in southern France it ranged from 53 to 594 g/plant. *Colutea* in Greece produced up to 160 g/plant while in southern France less than 100 g/plant. Other deciduous shrubs, finally, which were tested only in Greece had lower than 150 g/plant of annual edible biomass.

As far as the evergreen but summer growing fodder shrub species, such as *Atriplex*, their annual production of edible biomass was found relatively high in SW Spain and ranging from 430-500 g/plant.

All these results suggest that productivity of shrubs is relatively high compared to herbaceous plants grown in the same environments but it varies widely among species, cultivars, years and sites.

Establishment and management

Establishment and cultivation schemes

The results of the project have shown that establishment of fodder trees and shrubs is not always easy nor without significant cost. Increased seed germination needs to be enhanced in most species, especially in legumes, with several pre-treatment methods. Direct seed drilling in the field is not always successful while the young seedlings may be damaged by wild herbivores. It seems that the classical method of containerized seedlings or rooted cuttings is the most reliable to use, although quite expensive.

Young plantations suffer not only by herbivore damages but also by competition from weeds. Therefore, companion or cover crops, which can keep weeds out without competing too much with the saplings, are needed to be intercropped. Although perennial grasses such as *F. arundinacea* and *D. glomerata* are a solution, other more suitable species should be found so that the most appropriate associations between woody and herbaceous forage plants are established in each environment and production system.

Coming to the question of the proper spacing of fodder tree and shrub species, the only clear answer that it has come out of this project is that spacing is related to the objective of the plantation to be established. Dense plantations tend to produce more biomass per unit area but less per plant as compared to open plantations. Also, dense plantations have higher cost of establishment and restrict the understory herbage production. All these aspects plus the specific shrub or tree species should be taken into account before deciding about the right spacing in each case.

Forage value and grazing management

Forage value of fodder trees and shrubs was found to be different among the species tested while in all of them it declined with maturity. In general, leguminous species had on the average higher crude protein content and *in vitro* organic matter digestibility than non-leguminous species. No matter which group they belonged, however, deciduous fodder tree and shrubs tested in this project maintained a satisfactory level of crude protein content during the critical summer period which can be an effective protein supplement to animals, more than other forage resources, especially herbaceous plants (Fig. 32). The question is whether this protein is digestible, something which is not fully known yet. A digestion trial with goats for two of the species tested, namely *C. orientalis* and *F. ornus*, has shown that their *in vivo* digestibility was 68% and 64% respectively during summer while they declined to 53% and 54% respectively during autumn (Papachristou and Nastis, 1990).

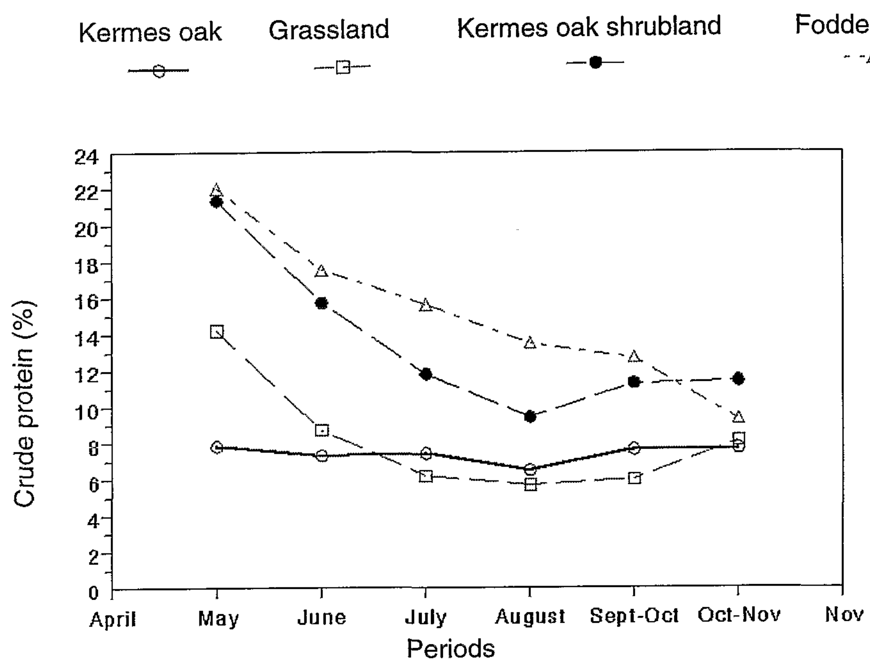


Fig. 32. Crude protein content (%) in forage of kermes oak, grassland, kermes oak shrubland and deciduous fodder plants studied from May to November in northern Greece (Papachristou and Papanastasis, 1994).

Of high feeding value are also the leguminous species *Medicago* and *Chamaecytisus* as well as of the non-leguminous species of *M. alba* cv. Kokuso 21. The latter compares favourably with many other resources available in an average farm in Provence, southern France where it has been studied (Fig. 33).

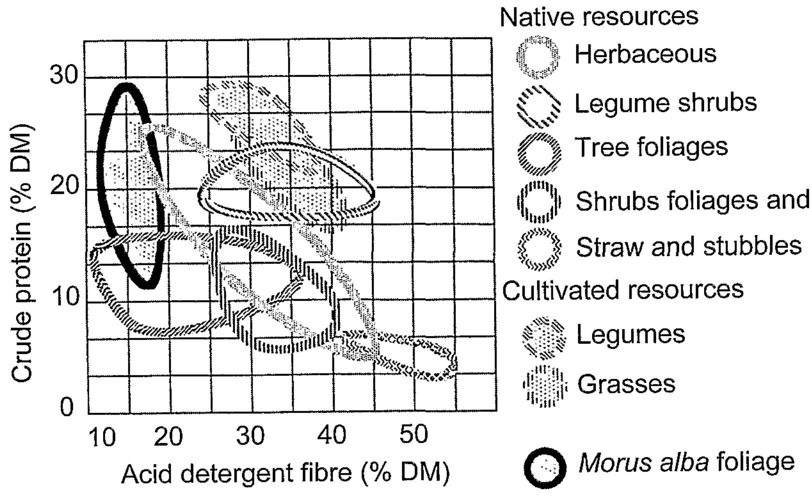


Fig. 33. Fodder resources in a diversified farm in Provence, southern France with relative rank of *Morus alba* cv. Kokuso 21 foliage (M. Meuret, unpublished data).

Of special interest are the pods of *Gleditsia*, intensively studied in this project, which have favourable chemical composition and relatively high *in vitro* and *in vivo* digestibilities, especially their seeds.

As far as the grazing management of fodder trees and shrubs is concerned, it seems that most species are safe to be grazed only at the third year after their establishment, while the height of cutting them back differs from one species to the next. It appears that although some species can withstand close grazing or clearcutting to the ground level, the most usual case is to graze or to cut them back at a height of about 30 cm aboveground. On the other hand, some species can stay green for a longer period in the summer if grazed in late spring. Finally, certain shrub species drop their leaves in the summer earlier than others, which means that grazing season should be adapted to the phenology and growth pattern of each species involved. In case that more than one grazings are applied during the season, the distance between two successive treatments should be long enough to allow shrub regrowth.

Integration in the production systems

The results of this project clearly suggest that fodder trees and shrubs cannot substitute other forage resources. They can only serve as strategic crops or fodder supplements to animals already fed with another apparently poorer fodder resource. The supplementation can be provided either in the morning (breakfast) or in the evening (dessert), indirectly (by lopping the branches of fodder trees and shrubs and bringing them to the animals as in the case of *Morus* in Provence, southern France) or directly by browsing. This means that fodder shrubs should be established in one or more parts of a farm and serve as reserve feed for the critical periods of the year.

Special mention should be made of the fodder trees which can be established as an overstory in a pasture or in a farm with wide spacing to provide fruits (e.g. pods in the case of *Gleditsia*) directly to the animals or foliage (e.g. *Morus* or *Robinia*) indirectly by lopping the branches. In this case, fodder trees can be planted in large areas to establish a sylvo-pastoral system which will also ameliorate the environment, in addition to the production of fruits or foliage for the animals.

Economic assessment of the results

The results of the project have clearly shown that fodder trees and shrubs are a viable solution to ensuring stability in the extensive ruminant production systems in the Mediterranean region.

The selected genetic material of *Chamaecytisus, Gleditsia, Medicago* and *Robinia*, if propagated and certified, can be commercialized and released to the market. Such a development can:

(i) Substitute other germplasm imported outside the Mediterranean basin thus saving precious exchange for the benefit of the European Union (EU).

(ii) Replace protein-rich feedstuffs produced in the irrigated areas thus reducing the cost of production and making the production systems more viable.

(iii) Reduce the amount of subsidies already paid by the EU to the Mediterranean farmers to buy protein-rich supplements from intensively cultivated areas within or outside the EU (e.g. maize).

(iv) Ameliorate the environment since most of these species are leguminous which improve the soil fertility besides stabilizing it against erosion.

(v) Meet the objectives of EU in creating more extensive and environmentally friendly production systems.

On the other hand, the results of the project are likely to have significant economic impacts on the farmer's level as well. This is because they indicate that the farmer can plant some of these species in his farm in order to ensure feed reserves for the critical periods of the year. Such an intervention will maintain an increased production level of his system without having to buy feed supplements from the market or to apply expensive alternatives such as transhumance. In addition, the results suggest several alternatives on how to establish, cultivate and manage the shrub plantations so that the farmer can use these resources without needing extra technical assistance.

Finally, the results have socio-economic impacts on regional level since they open new roads on how neglected indigenous plant resources can be put to production for the benefit of the rural people. They also provide new ideas or alternative ways for management of open space so that it becomes environmentally safe and harmoniously integrated with human activities and the production systems in the Mediterranean marginal areas.

Conclusions

The most important conclusions drawn from the project were the following:

(i) A great variation in morphological, growth and nutritional characters was found in all species of fodder trees and shrubs studied indicating their high potential for selecting individuals or populations with desirable characteristics for establishment and management purposes.

(ii) *Chamaecytisus proliferus* is a very productive and palatable fodder shrub. Two lines of the sub-species *palmensis* (tagasaste) and one of the sub-species *canariae* were found very promising for semi-arid environments with mild winters and acid soils.

(iii) *Gleditsia triacanthos* is a very interesting fodder tree for its fruits (pods).

- Its growth and performance is strongly affected by soil type and weed competition. Deep soils with a high holding capacity seem to be preferred to sandy soils. Also, weed competition affects tree growth and pod production. Apart from these factors, however, pod yields of *Gleditsia* are variable among varieties and between years (fruit bearing alternates every second year). In an orchard with 400 grafted, 4-5 years old, trees/ha, pod yields ranged from 0 to 376 kg/ha or 117 kg/ha on the average for the 17 varieties tested. At least 4 varieties had pod yields more than 200 kg/ha. This production is expected to increase as the age of the trees increases, too.
- The great importance of pod production in *Gleditsia* lies on two facts.
  . Pod production is on top of the ground production provided by a companion crop such as *F. arundinacea* which may produce up to 2 t/ha of dry matter although there is a trade off between pod and herbage production due to competition.
  . Pods are available to the animals in the winter months, when herbage growth and production is very low.
- Sheep thrive on *Gleditsia* pods which may result in a net liveweight gain of about 178 g/animal/day. This is because pods have very favourable chemical composition and high *in vitro*, *in vivo* and *in sacco* degradabilities (70, 78 and 60% on the average respectively). In a realistic diet pods can contribute from 25 to 50% of the daily organic matter allowance to sheep. On the other hand, in order to achieve an efficient use of *Gleditsia* pods, whole pods should be preferred instead of ground ones and varieties with soft seeds should be used in a mixture with bulky feed.

(iv) *Medicago arborea* is a very palatable winter growing shrub but sensitive to winter frosts and dormant in the summer.

- Some germplasm collected in Attica and the Aegean islands was found to withstand prolonged winter frosts as well as keep green leaves in the summer for a longer period than the normal species does. This germplasm can now be propagated and used to expand *Medicago* cultivation in Mediterranean areas with cold winters.
- There is a high correlation between plant dimensions and edible dry biomass. Such a correlation may be used to develop mathematical relations for estimating or predicting edible biomass based on easily measured parameters, such as height and crown diameter, thus avoiding destructive methods of biomass estimation.
- Establishment of *Medicago* in the field is successful by direct seeding. This technique can replace the traditional method of planting grown seedlings in plastic bags produced in a nursery which is very expensive and time consuming. The only problem is the damage caused to the young seedlings by wild animals, especially hares. An alternative could be the use of protection measures or rooted cuttings which are not debarked by hares.
- Grazing of *Medicago* in the third year since establishment is unsuitable for cattle in relatively poor sites because the growth is not enough and plants may be damaged. Sheep, on the contrary, are much more suitable but grazing intensity should be low.
- Haemolytic saponin content which affects the nutritive value of *Medicago* is different among populations originated from different parts of the Mediterranean thus suggesting that this characteristic should be considered as a selection criterion is future breeding programmes of the species.

(v) *Morus alba* is a very productive and palatable fodder tree for its foliage, especially if shrubby varieties such as the Japanese cultivar 'Kokuso 21' is used.

- Production of *M. alba* cv. Kokuso 21 increases as the age of plantation increases but this increase is affected by the particular year involved and especially by the summer drought. However, this particular cultivar never exceeds the height that sheep can reach (up to 1.60 m). The impact of summer drought is more pronounced on defoliated than on non-defoliated plants.
- An exponential equation of high correlation between dry foliage and shrub volume was developed for 'Kokuso 21'. This equation is a very important finding because it permits the fast estimation of foliar biomass with reduced cost and without destruction of the shrubs. The practical benefits of such a method are obvious.
- Year of establishment, intensity of defoliation and method of shrub cutting at the end of growing season significantly affects growth and productivity of *M. alba* cv. Kokuso 21. Moreover, aged plants seem to develop different crown shape and dimensions than younger plants indicating that for developing predictive equations of the foliage biomass based on crown dimensions the full picture of shrub development over the life span of the species should be known.
- Farmers in southern France (region of Provence) utilize *Morus* foliage cut from ancient trees to feed their animals (sheep or goats) at the end of summer (August-September) as a "dessert" at the end of the day. Therefore, they are willing to establish plantations with improved varieties of this species (e.g. 'Kokuso 21') so that more and of better quality foliage is ensured.

(vi) *Robinia pseudoacacia* is a very productive fodder tree for its foliage rather than its fruits. For this reason, it is advantageous to maintain it in a shrubby form.

- *Robinia* is the most productive species compared with other indigenous species of fodder trees and shrubs grown in comparable environmental conditions. Its vegetative propagation is more successful with softwood (green) than with hardwood cuttings. Since the former are less expensive than the latter, this result makes an important contribution to the fast, safe and inexpensive propagation of *Robinia*.
- *Robinia* presents a high variability in growth parameters, namely height and diameter, phenology and thorniness; the latter characteristic is not recorded only in a small percentage of trees, while the majority of them have quite a few and strong thorns. A clone with few thorns will be well suited for grazing by sheep.
- Thorniness and leafiness (particularly the number of leaflets per compound leaf) of *Robinia* are related with its productivity and forage value. The fewer thorns measured in the ramets of the clonal test in Greece clearly show that the selection for no or a few thorns may be successful, which means that such clones can be released.
- *Robinia* has high stomatal conductance with low seasonal variation thus indicating its adaptation to the warm conditions. Its forage quality is the highest among other species of deciduous fodder trees and shrubs and it is the first species to be preferred by goats during the summer period.

(vii) Weeds affect very much the growth of fodder trees and shrubs in their plantations. This problem can be overcome by intercropping herbaceous plants, grasses or legumes. In *Medicago* plantations, the grasses *D. glomerata* and *F. arundinacea* may be successfully used. The advantages of such a mixed system are: saving money for controlling of weeds and increasing the grazing capacity of plantations. However, since perennial grasses are very competitive, other more suitable species such as annual legumes should be also tried so that the most appropriate associations between woody and herbaceous forage plants are established.

(viii) Productivity of fodder trees and shrubs is related with the particular species of shrubs or other cultivars involved, the environmental conditions where they grow and the age of the plants. In general, *Medicago* produces at its optimum environment about 500 g/plant of edible biomass while in less favourable environments its production is about half (250 g/plant) at the third year since establishment. Other species of shrubs such as cv. Kokuso 21 of *Morus* and *Robinia* produce higher quantities of edible biomass than *Medicago* in good sites while in poor sites the production is lower than 500 g/plant. On the other hand, the majority of deciduous fodder shrubs tested had productions ranging from 100 to 200 g/plant. Even such low quantities, however, calculated on an area basis, outyield in most cases other resources while they have the benefit of being available in critical periods of the year.

(ix) Spacing does not affect shrub or tree growth at the early years of a plantation. As a result, the more plants per hectare are established the higher the production is on an area basis. However, this has to be considered in relation to the cost of establishment too, which was not studied in this project.

(x) Total annual rainfall and especially its distribution throughout the growing season significantly affect productivity of fodder shrubs with spring rainfall being a decisive factor in shrub growth of several species (e.g. *Amorpha, Robinia, Morus*). Also, air temperature greatly affects productivity of deciduous fodder shrubs, particularly in semi-arid to sub-humid Mediterranean environments with cold winters. Mild and rainy springs increase browse production by more than 50% as compared to cold and dry springs. Also, summer rainfall play a crucial role in extending the availability of green biomass during the critical dry period.

(xi) The majority of deciduous fodder trees and shrubs tested in the project seems to retain relatively high levels of crude protein and satisfactory levels of neutral detergent fibre contents in the summer. As a result, fodder shrubs can be used as a feed supplement to sheep and goats during the summer period, when herbaceous plants are dormant, to maintain or even increase the body weight because they can be favourably compared with standard feeds such as dehydrated alfalfa. Special emphasis should be given, however, on how and when such shrubs should be integrated into the specific production systems involved in each region.

(xii) Fodder trees protected from animal damage with plastic tubes seem to be the ideal solution for the communal systems where control of grazing is difficult or impossible.

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