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Agronomic aspects of forage legumes: management and forage quality

V.P. Papanastasis[1] and T.G. Papachristou[2]
[1]Laboratory of Range Ecology, Aristotle University, 540 06 Thessaloniki, Greece
[2]NAGREF-Forest Research Institute (Rangeland Resources Laboratory), 570 06 Vassilika, Thessaloniki, Greece

Summary - Forage legumes are essential components of the Mediterranean grazing resources because they make 20% or more of the total number of species present. Several factors however such as adverse climatic and edaphic conditions as well as irrational grazing may substantially reduce or even eliminate them. In order to increase their presence in rangelands various management interventions are needed including fertilization, especially with phosphate fertilizer, seeding, planting, chiefly for woody species and prescribed burning. In most cases, however, best results can be achieved if proper grazing is combined with a balanced fertilization. The majority of legumes, especially the self-reseeding ones, can withstand heavy grazing but they need protection during the flowering period in order to produce seeds and replenish the seed reserves. The nutritive value of legumes is high thus contributing to a nutritious and balanced diet. Nevertheless, specific plant compounds such as tannins, saponins, isoflavones and cyanogenic glycosides, which are present in several legume species, may produce negative post-ingestive consequences in animals. Ruminants can overcome this problem by selecting different diets. This can be achieved if legumes are combined with other plant species or resources at the crop, farm and landscape level so that efficient production systems are developed and sustained.

Key-words: forage legumes, fertilization, grazing management, nutritive value, pastoral systems

Résumé *- Les Légumineuses fourragères représentent plus de 20% des espèces qui constituent les ressources fourragères des pâturages méditerranéens. De nombreux facteurs comme le climat, le sol ou le pâturage non raisonné peuvent réduire leur importance voire les éliminer. Plusieurs techniques ont été expérimentées pour accroître leur présence dans les parcours : fertilisation phosphatée, semis voire plantation dans le cas des espèces ligneuses, brûlage dirigé. En général on obtient de bons résultats en combinant un pâturage adéquat avec une fertilisation raisonnée. La majorité des Légumineuses et en particulier les annuelles, supportent une forte pression pastorale mais doivent être protégées pendant la période de floraison. Leur valeur nutritive est élevée mais certains composants secondaires comme les tannins, les saponines ou les isoflavones peuvent avoir des conséquences négatives sur la digestion de la ration; il est donc souhaitable de combiner les Légumineuses avec d'autres ressources fourragères à l'échelle de la parcelle, de l'exploitation agricole ou du parcours de façon à développer des systèmes de production durables.*

Mots-clés: *légumineuses fourragères, fertilisation, gestion pastorale, valeur nutritive,systèmes pastoraux*

Introduction

In the Mediterranean region, herbaceous legumes are part of the grassland flora while several woody leguminous species are also present in shrublands and woodlands. All these species have played significant role in animal production throughout the centuries and still are important elements ensuring a balanced feed to the animals. It was, however, only recently that their value was widely accepted and research was initiated to evaluate their role in the Mediterranean production systems. As a matter of fact, self-reseeding annual legumes were «re-introduced» from Australia, where extensive breeding work was carried out with germplasm collected from the Mediterranean region and huge areas were planted with them (Piano and Talamucci, 1996).

Compared to grasses, legumes are in general superior in feeding value because they have higher content of protein and minerals and for identical values of digestibility, their voluntary intake is considerably higher due to the higher levels of soluble cell content and a quicker microbial access to cell walls, which result in a faster rate of digestion (Van Soest, 1994). They are, however, less aggressive and competitive, less shade tolerant, less productive and some of them less resistant to grazing than grasses. On the other hand, their nutritive value should not be taken for granted since anti-quality factors may inhibit the digestibility of their high crude protein content.

Grazing resources in the Mediterranean region include agro-pastures, which are grown on cultivated land as well as rangelands and forests (Papanastasis and Mansat, 1996). The presence of forage legumes in these resources largely depends on the kind of management applied. In this paper the available information on management and forage quality of legumes is reviewed and suggestions are made for strengthening their importance in the Mediterranean production systems. Emphasis is given on rangelands, which include shrublands, open forests and especially grasslands, also known as natural or native pastures.

Management of forage legumes

Species composition

Before implementing any management intervention for legumes in rangelands, an evaluation of the existing species composition should be carried out. Mediterranean rangelands are usually rich in legumes. In semi-arid to sub-humid grasslands, legumes may make 20% or more of the total number of the species present and they are predominantly *Trifolium* and *Medicago* species (Papanastasis, 1981). Their contribution, however, to the total plant cover is much less and usually no more than 10% (Papanastasis, 1985). The same relation exists in the mountainous areas as well, although the number of legumes present there, are relatively less than in typical Mediterranean grasslands (Papanastasis, 1981). In the rangelands of Psilorites mountain of Crete, for example, 161 herbaceous and 14 woody species were recorded in 30 sites distributed in an elevation gradient from 750 to 1600 m a.s.l. (Abid, 1998). Of the herbaceous species, 23 were legumes thus making 14% of the total number while their ground cover was only 7.1% and their contribution to the plant cover was only 9.5% (Table 1).

Table 1. Contribution of legumes to the total cover and species composition in the rangelands of Psilorites mountain in Crete (Abid, 1998).

species groups	Mean cover (%)	Mean composition (%)
Vegetation	75.3	
Woody	24.6	32.7
Herbs	50.7	67.3
Legumes	7.1	9.5
Other	43.6	57.9
Litter	5.0	-
Bare soil	7.7	-
Rocks	12.0	-
Total	100.0	100.0

Nevertheless, several factors may intervene to reduce legume composition in rangelands. They include adverse winter and early spring temperatures which may lead to their partial or

complete elimination in a growing season (Koukoura and Papanastasis, 1997); too low soil acidity which may create nodulation problems in several species of legumes (Piano and Talamucci, 1996); and overgrazing particularly in spring which may lead to their substantial reduction in natural pastures (Osman *et al.*, 1999).

If overgrazing is combined with wildfires then the results may become devasting. For instance, in rangelands of the Psilorites mountain in Crete, it was found that the sites where only overgrazing was applied the number of legume seeds in the soil was increased while it was substantially decreased where both overgrazing and burning were combined (Table 2).

Table 2. Contribution of legumes in the seed bank (seeds m^{-2}) of rangelands in the Psilorites mountain of Crete (G. Kazakis, unpublished data).

Site	Total seeds	Legume seeds	
		Number	%
Only Grazing			
Grazed			
Grasslands	29,908	3,707	12.4
Phryganic areas	14,132	1,568	11.0
Ungrazed			
Grasslands	24,169	3,654	15.2
Phryganic areas	10,150	1,450	14.3
Burning and grazing[1]			
Burned and grazed	3,076	67	2.2
Unburned and grazed	14,132	1,569	11.0

[1] in phryganic areas

Fertilization

If legume composition in a grassland is low, it may be increased if appropriate fertilization is applied. In general, nitrogen fertilizer do not induce any significant response on pure legume pastures; but in mixed ones with grasses and other herbs legume composition is decreased, especially in favor of grasses, particularly if the legume species are low-growing and prostrate (Crespo, 1982). In several experiments carried out in grasslands of Greece, it has been found that pure nitrogen depresses legumes while a more balanced composition is achieved when phosphorus is also combined in the fertilization programs (Papanastasis and Koukoulakis, 1988). Similar results were also found in Italy by Martiniello *et al.* (1995) and Postiglione *et al.* (1989).

Since legumes have a greater requirement for phosphorus than other plant species, in soils deficient in this particular element, phosphate fertilization may be the best solution to increase legume participation in natural pastures. Several studies in a number of Mediterranean countries have shown that application of phosphate fertilizer increases the participation of legumes in native flora and consequently the herbage production since the nitrogen build up in the soil favors also grasses as well as other broad-leaved species (Dordio *et al.*,1991; Osman *et al.*, 1989; Dauro and Gintzburger, 1989; Moreno *et al.*, 1993; Papanastasis and Koukoulakis, 1988). If phosphorus is not deficient in the soil, a prolonged fixation of nitrogen by legumes may change completely the pasture composition because the increased nitrogen fertility will favor grasses and thistles (Piano and Talamucci, 1996).

Legume growth is also affected by other nutrients. Deficiencies in calcium, sulfur and trace elements may limit nitrogen fixation and thus inhibit plant growth. Lourenco *et al.* (1990), for example, have found a clear increase of legumes by applying lime in a grassland

of Portugal. Also, in a cleared oak forest in Greece planted to subterranean clovers, application of molybdenum was crucial in order to ensure their good establishment (Papanastasis and Platis, 1989).

Seeding

If natural pastures are very poor in legumes then their introduction is needed by seeding appropriate species or cultivars. Sowing is also needed when new pastures are to be established. In this latter case, only legumes need to be sown since grasses and other species will soon come. In both cases two aspects should be considered: (a) the choice of the appropriate species and cultivars and (b) the method of establishment (Piano and Talamucci, 1996).

Annual self-reseeding legumes are the most widely used species in the Mediterranean region. There are, however, some regional differences. In northern Africa and Middle East attention has been given to annual medics for their better adaptation to alkaline soils and to the ley-farming production system which has been introduced in these areas as an alternative to the traditional cereal-fallow system. In northern Mediterranean, on the contrary, subterranean clovers have been mostly promoted due to the prevalence of acid soils and as better adapted to the continuous grazing system (Piano, 1993; Masson *et al.*, 1993; Masson, 1997).

In any case, the choice of the appropriate species or cultivar should be based on the existing species composition of the natural pasture, the soil characteristics, the land morphology and the climatic conditions (Piano, 1991; Spanu *et al.*, 1996). On the other hand, mixtures of annual legumes can some times perform much better than single species, especially if different growth habits are combined in the mixture. Fore example, Sulas *et al.* (1993) have found that a mixture of T. *brachycalycinum* and two annual medics (*M. rugosa* and *M. truncatula*) produced more herbage and seed yield in a pasture than when *T. brachycalycinum* was sown as a monoculture.

Perennial legumes are less popular species in the improvement of natural pastures or establishment of sown ones in rainfed areas. The reason is that there is a lack of appropriate species or cultivars on the one hand and on the other they are more difficult to manage. However, they are appropriate for hay production in order to feed the animals in the critical periods of the year. A good species for this case is lucerne (*Medicago sativa)* with its drought-resistant varieties, which can be used alone or in mixture with grasses to meet this particular objective (Delgado, 1992; Talamucci and Pardini, 1999). Other interesting species are sulla (*Hedysarum coronarium)* (Sulas *et al.*, 1995) for clay soils and sainfoin *(Onobrychis viciifolia)* for calcareous soils. Nevertheless, all these species can be also used for grazing (Talamucci and Pardini, 1999).

For establishment of legumes, oversowing on existing vegetation does not usually have good results. A "minimum tillage" of the soil is needed in order to minimize competition for water, light and nutrients from the existing vegetation (Piano, 1991). To achieve such a goal, special seeding machines could be used which drill the seed into soil. Removing the surface vegetation with a bulldozer and drilling legume seed with a chisel seeder can also result in successful legume stands.

In shrublands and woodlands, the woody vegetation should be removed before legumes are introduced. This removal can be done by machines or by prescribed burning. In the first case, a seed drill should be used to introduce the legumes while in the second case legume seed can be broadcasted on the ash right after the fire so that seeds are self-covered (Liacos *et al.,* 1980; Joffre and Casanova, 1983; Bullitta *et al.,* 1989).

Planting

Besides herbaceous species, woody legumes may be introduced into production systems so that emergency feed is ensured for the animals during the critical periods of winter and summer months. The significance of fodder shrubs as strategic resources in the Mediterranean region has been realized only in the last few decades. Among the several species tested, the leguminous ones such as *Medicago arborea* for the winter period and *Robinia pseudoacacia, Amorpha fruticosa* and *Colutea arborescens* for the summer period have been found the most productive (Papanastasis, 1999).

The best way to introduce woody legumes in natural pastures is by planting of at least one-year old bare-rooted or, preferably, containerized plantlets produced from seeds or cuttings. Spacing of the plantation depends on the particular species used and the objective sought. In general, a dense plantation of fodder shrubs can produce higher amounts of woody forage but its cost of establishment is also higher than of a sparse plantation (Papanastasis, 1999).

Burning

Annual legumes are favored by burning for several reasons. One is the reduction of competition for light due to the destruction of the aboveground vegetation. This reduction gives an opportunity to legumes to utilize the free space available after burning since they can not withstand shade and their competitive ability is less compared to grasses and other forbs. The second reason is the increase of pH of the surface soil due to the deposition of minerals after burning, such as calcium, potassium, etc. The third reason is the break of seed dormancy due to heating. All these factors result in an increased legume composition in burned-over pastures.

In a burned maquis shrubland in Greece, herbaceous vegetation covered 13% of the ground at the end of the first growing season after the fire and only 1% at the end of the second growing season, while it was completely disappeared in the third growing season (Papanastasis, 1978). However, 52% of this vegetation consisted of annual legumes in the first season while in the second season two annual legumes were making 100% of the herbaceous cover (Table 3). Similar results were found in phryganic communities (Papanastasis, 1976) and in kermes oak shrublands (Papanastasis and Platis, 1990). All these studies as well as others carried out in other Mediterranean countries (Le Houerou, 1981) have shown that annual legumes are behaving as anthracophytes by making use of the favorable light and nutrient conditions created after the fire to soon disappear (in 2-3 years) as these conditions change due to the recovery of the burned perennial, herbaceous or woody, species.

Since all these annual legumes appearing after fire are very preferable by livestock, especially sheep, shepherds have traditionally used fire to improve the grazing capacity of Mediterranean rangelands, a practice that it is still used in several parts of Greece as well as in Sardinia and Corsica.

Grazing regulation

Very often, the key to increasing legumes in natural pastures or maintaining them in sown pastures is the application of proper grazing. Annual legumes are particularly associated with the early successional stages of vegetation because they can not withstand competition with perennial species, which tend to dominate in advance successional stages. As a result, heavy grazing is often necessary in order to maintain a good legume stand. On the other hand, application of a continuous heavy grazing may not allow plants to flower and produce seed thus leading to a progressive depletion of the seed bank in the soil. According to Piano (1993), a compromise must be found in the continuous grazing system between the needs to

safeguard legumes from competition and not to deplete seed reserves, particularly in medics, which do not bury their pods.

Table 3. Species composition of herbaceous vegetation in a burned maquis shrubland three years after the fire (Papanastasis, 1978).

	Composition (%)		
Species	1974	1975	1976
Grasses			
Aira capillaris	20.7	-	-
Vulpia myuros	1.7	-	-
Arena sterilis	1.7	-	-
Legumes			
Trifolium campestre	20.7	-	-
Trifolium glomeratum	13.8	-	-
Trifolium arvense	5.2	39.8	-
Vicia lathyroides	1.8	-	-
Ornithopus compressus	8.6	-	-
Melilotus meapolitana	1.7	-	-
Lathyrus sativus	-	60.2	-
Other forbs			
Fumaria thureffi	10.3	-	-
Convonvulus elegantissimus	3.4	-	-
Viola tricolor	5.2	-	-
Other species	5.2	-	-
Total	100.0	100.0	-

In a research carried out in Sardinia, where two treatments involving continuous grazing and no grazing were applied in a natural pasture for two years, it was found that legumes were increased by more than 3 times in the former as compared to the latter treatment (Caredda *et al.*, 1996). Similar results were also found in Greece (Tsiouvaras *et al.*, 1996). However, in an experiment carried out in Lebanon where freely grazed pastures were compared with protected ones, it was found that the legume component was increased almost twice in the protected treatment, while the seed yield of legumes in the soil was increased by almost 3 times (Table 4). These results suggest that partial protection from grazing for one or two months in late winter and spring facilitates seed production and the build up of seeds in the soil compared with open grazing.

Table 4. Yield of legume and total herbage in April 1994 and legume seed in June 1995 in freely grazed and protected pastures in Lebanon (adapted from Osman *et al.*, 1999).

	Herbage yield (t ha^{-1})		Legume seed	
Type of pasture	Legume	Total	Yield (g m^{-2})	Number m^{-2}
Grazed	0.26	1.06	3.66	3,065
Protected	0.48	2.44	11.63	9,696

Maintaining an adequate seed bank in the soil is the key factor in the persistence of self-reseeding annual legumes in pastures. At least 1000 plants/ m^2 are required for an adequate

regeneration (Puckridge and French, 1983). The quantity of germinating seeds at the beginning of the season is the result of the amount of seed produced at the end of the previous season minus the amount grazed during summer and the amount not able to emerge due to coat impermeability. Since most annual legumes have a high level of hardseedness, it is necessary to ensure a high seed yield carried over from one season to the next so that legume persistence is ensured. This can be largely controlled by proper stocking combined with a balanced fertilization (Piano and Talamucci, 1995).

In the Mediterranean region, instead of employing a fixed stocking rate in rangelands, threshold stockings should be applied which integrate the ecological potential of the site, the climatic variability and the socio-economic conditions (Narjisse, 1998).

Special attention should be given on grazing management of woody legume plantations. Continuous heavy grazing may result in complete destruction of the plantation, particularly if the species is of high preference (e.g. *Medicago arborea*). Since the cost of establishing a pasture with woody legumes is much higher than with herbaceous species, the best way to manage fodder shrub plantations is to utilize them as reserves for supplementary feeding for a few hours per day during the critical period either directly by the animals or by the cut-and-carry system (Papanastasis, 1999; Papachristou *et al.*, 1999).

Forage quality of forage legumes

Nutritive value

Alibes and Tisserand (1990) have summarized reports from various Mediterranean countries concerning chemical analyses of various herbaceous legumes; some of these reports for specific species and some others (recently appeared in the literature) as well are shown on Table 5. As expected, the CP of herbaceous legumes is very high (>168 g kg^{-1} DM) throughout their growing period. There is, however, a seasonal variability depending on the particular plant species and the bioclimatic zone where it grows. Generally, the herbaceous legumes start to dry out by late spring when their CP content declines. In Greece, for instance, it was found that the forage abundance of vetches *Vicia tenuifolia* and *V. cracca* lasts form May to August in the sub-humid zone, but their crude protein content begins to decline by June (from 247 to 100 g kg^{-1} DM) (Papachristou and Nastis, 1993). On the contrary, Sulas (1999) reported that the CP content of sulla was extremely high in a pasture of Sardinia during the grazing period ranging from 216 (late spring) to 305 (winter) g kg^{-1} DM. Also reports from different countries (see Alibes and Tisserand, 1990) demonstrate that lucerne maintains high values of CP (≈200 g kg^{-1} DM) from spring to autumn. Moreover, herbaceous legumes (especially leaves) reach their potential extent of digestion much more quickly than other forages (e.g. grasses).

Woody fodder legumes such as *Amorpha fruticosa*, *Colutea arborescens* and *Robinia pseudoacacia* can ensure forage of high quality during summer while *Medicago arborea* during winter. The advantage of woody fodder legumes is that they provide foliage during critical periods when herbaceous plants are either dormant (summer) or have limited growth (winter). The CP content of foliage of these species (Table 5) is much higher than other non-leguminous woody species, which are also used as forages (Papachristou and Papanastasis, 1994).

Use by ruminants

Usually, the nutritive value of plants is estimated by laboratory techniques. Such results can serve only as a guide in assessment of their true nutritional value to particular animals. This is partly explained by the fact that some animal species may avoid eating certain legumes because they contain compounds such as secondary metabolites that affect the diet

selection and intake of grazing ruminants (Provenza and Malechek, 1984). Some compounds may be toxic and when they are ingested in high amounts they can cause injuries to animals or even death.

Condensed tannins, a major group of plant secondary compounds found in a wide range of legumes, commonly consumed by grazing animals, are regarded as affecting digestive and metabolic processes. In Greece, for example, it was found that while the foliage of *Amorpha fruticosa*, *Robinia pseudoacacia* and *Colutea arborescens* was of the same quality, only *Robinia* significantly contributed to the goat performance (Papachristou *et al.*, 1999). The limited intake of *Amorpha* and *Colutea* was the reason for the unconventionality between forage quality and animal performance; an effect that was partially illustrated by the presence of anti-nutritive factors, such as condensed tannins. A similar result has been found in France with sheep fed on *Amorpha* (Dupraz, 1999), promoting the view that when animals browse on *Amorpha* acquire an aversion and reduce intake (Papachristou *et al.*, 1999). Another explanation of the reduced intake of the *Amorpha'* s forage may be the high nitrogen degradation resulting in high amounts of ammonia, which passes into peripheral circulation thus becoming toxic. Generally, the value of *Amorpha* and *Colutea* as animal feed is much less than that suggested by their relatively high forage production and the results of their chemical analyses (Table 5). On the contrary, the usefulness of *Robinia*'s forage as animal feed has been established (Papachristou, 1999; Papachristou *et al.*, 1999). Findings from these studies suggest that *Robinia* promotes a similar increase in the live weight gain of goats to that of lucerne.

It is also known that substances found in several legume species consumed by ruminants form stable viscous foam in the rumen preventing the eructation of gas thus holding the gases in large pockets (free gas bloat) or small pockets (foamy bloat) (Reid and James, 1985). Stable foam production in bloating animals is generated by a complex interaction among environment, animal/ plant species, and microbial factors (Van Soest, 1994). The saponins were the first substances to be considered as the main causal agents of bloat. There is also evidence that a plant protein known as 18S and pectin methylesterase (PME, a growth enzyme) cause bloat, when they are present in high levels (Church, 1975; Wright, 1984; Van Soest, 1994; Taylor and Barczewski, 1998). For example, lucerne, *Trifolium pratense*, *T. repens*, *T. hybridum*, and *Melilotus officinalis* contain 4.5 to 5% 18S protein that causes bloat. On the contrary, legumes that do not cause bloat (e.g. *Lotus corniculatus* and *Onobrychis* spp.) and the grasses contain less than 1% 18S protein. Regarding pectin methylesterase, it has been reported (Wright, 1984) that on high bloat-incidence days, legumes contain 34 to 47% more PME than on low bloat-incidence days. An important finding is that the non-bloating legumes contain large amounts of certain tannins (Jones and Lyttleton, 1971). These tannins are capable of precipitating the proteins found in bloat-causing foam. Therefore, a combination of pasture management and the use of anti- foaming agents may achieve bloat prevention. The proportion of bloat-causing legumes in a pasture should be less than 40% (Vallentine, 1990). Before introducing an animal into a pasture containing a high proportion of a bloat-causing legume (>30%), it is wise to graze either a grass pasture or a woody fodder stand (i.e. forages containing tannins).

Of particular importance is the estrogenic activity of several isoflavones present in several subterranean clover cultivars (e.g. Trikkala and Larissa). These substances have a low but variable level of estrogenic activity that causes problems in grazing animals on legume pastures (e.g. reduced fertility in male sheep and sterility in females) (Crespo, 1982;Van Soest, 1994).

Cases of animal poisoning by *Vicia* species have been also reported (Enneking, 1995). These can be grouped into those caused by *V. sativa* and its related species (cyanogenic glycoside vicianine: HCN poisoning; and anti-nutritive effects of cyanoalanine) and those

caused by canavanine containing species such as *V. villosa* and *V. ervilia*. These harmless compounds are present in high levels in the seeds of vetch. It is known that vetches are used as grain legumes in ruminant diets in the Mediterranean region; therefore livestock people need to be made aware concerning the concentration of seeds among different vetch species or cultivars in such compounds.

Table 5. Average nutritional quality of common herbaceous and woody legumes presented in Mediterranean pastoral systems during their growing period.

Forage legumes	CP	Digestibility *in vivo* (a) *in vitro* (b)	NDF	ADF (a) or ADL (b)	Reference
	..... g kg^{-1} DM				
Herbaceous[1]					Adapted from:
Hedysarum Coronarium	272	857 (b)	492	160 (b)	Sulas, 1999
Medicago sativa	204	690 (a)	393	300 (a)	Alibes and Tisserand, 1990[3]
Onobrychis spp.	168	679 (a)	343	300 (a)	Alibes and Tisserand, 1990
Trifolium Subterraneum	178	790 (a)			Alibes and Tisserand, 1990
Trifolium spp.	185	702 (a)	398	270 (a)	Alibes and Tisserand, 1990
Vicia faba	177	832 (a)	447	281(a)	Alibes and Tisserand, 1990
Vicia spp.	168	600 (b)	506	76 (b)	Papachristou and Nastis, 1993
Woody plants[2]					
Amorpha Fruticosa	210	560 (b)	450	83 (b)	Papachristou and Papanastasis, 1994; Papachristou *et al.*, 1999
Colutea Arborescens	171	600 (b)	352	91 (b)	Papachristou and Papanastasis, 1994; Papachristou *et al.*, 1999
Medicago Arborea	178	649 (b)	441	90 (b)	Bouzid, 1990; Ventura *Et al.*, 1999
Robinia Pseudoacacia	206	598 (a) 578 (b)	432	94 (b)	Papachristou and Papanastasis, 1994; Papachristou *et al.*, 1999; Papachristou,1999

[1]Entire plants and fresh material were used for the nutritive value determination.
[2]Nutritive value concerns browse material (i.e. leaves and twigs of up to 2-mm diameter).
[3]Data after Alibes and Tisserand were extracted from more than one reference and stages of maturity.

Strategies in Mediterranean pastoral systems

Grazing animals select diets from an array of plant species combining different resources. The role of legumes is important since their presence in the production systems may be used as a management tool. Legumes are a nutritious feed that seems to offer more advantages

when offered to animals as monospecific diet. However, sheep repeatedly grazed white clover (*Trifolium repens*) chose to graze an alternative grass diet *(Lolium perenne*) (Newman *et al.*, 1992). This must be considered in the planned grazing systems allowing the animals to graze variable diets and not too frequently the same ones. The above knowledge was used to improve foraging conditions during grazing trips in France (Hubert, 1993; Meuret *et al.*, 1994). Meuret *et al.* (1993) reported that a legume pasture involved in a production system of combined resources improved the preference of the rougher constituents of the diets. This happened because legumes a) promoted intake of rougher diets during grazing rounds, b) complemented previously eaten forages, and c) stimulated the intake of herbage of mixed swards by creating motivated grazing competition among the herd.

On the basis of the importance of variable diets, a combination of specific legumes that deter grazing animals and other forages, which also negatively affect preference and intake may enhance animal performance because they contain different kinds of chemical compounds (Provenza, 1996). For example, the combination of white clover, which contains cyanogenic compounds, and grasses, which contain alkaloids, gives a good result by increasing animals' intake. According to Provenza (1996), the combination also of woody species that contain tannins with legumes that contain saponins may also be beneficial because tannins and saponins interact in the intestinal tract, reducing their negative effects.

Legumes, therefore, should be combined at various levels of the Mediterranean pastoral systems (Talamucci and Pardini, 1999). At the crop level, they can be combined with grasses in synchronic or asynchronic associations, namely with species which have the same (C_3 grasses) or different (C_4 grasses) growth rythms. For example, lucerne can be combined with *Festuca arundinacea* or *Dactylis glomerata* and subterranean clover with *Lolium rigidum* in the first case and subterranean clover with *Eragrostis curvula* in the second case. At the farm level, seeded pastures or planted with leguminous shrubs can be combined with natural resources by rotational grazing. At the landscape level, finally, legumes can be combined with other herbaceous or woody species as parts of the agro-pastoral or silvo-pastoral systems.

Conclusions

Legumes are essential components of the Mediterranean grazing resources for ensuring a balanced feed to ruminants. Their presence can be enhanced by appropriate management including proper grazing combined with a balanced fertilization. Additional measures involve seeding, planting, and prescribed burning. The main strategy should be to increase the efficiency of the production systems at the crop, farm and landscape levels. However, their feeding value and the determination of the nutritional relevance for each animal species should be further investigated and explored.

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