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Pastoral systems dominated by fodder crops harvesting and grazing

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SUMMARY - In the Mediterranean environments, native pastures, directly influenced by climatic constraints, show a very high productive instability and this implies the necessity of an appropriate combination with forage crops and other resources, thus valorizing the existing contrasts, according to the wide variability of natural and socio-economic conditions. After a reminder of different typologies of pastoral systems, this paper presents a review of systems including fodder crops and sown or oversown pastures destined to harvesting or grazing. In the frame of the regularization of forage production calendar, the role and the genetic and agronomical control of different "strategic" resources, particularly perennial and annual legumes, are considered. The possibilities of their combination at crop, farm and territory level in order to implement and manage conventional and non conventional systems are discussed. Pasture-woody resources relationships in view of a multi-use of territory are also presented. Finally, the research requirements and perspectives on this subject are considered.

Key words: Sustainability, conservation, "strategic" resources, legumes, multipurpose systems.

RESUME - "Systèmes pastoraux caractérisés par la récolte et le pâturage de cultures fourragères". Dans les milieux méditerranéens, les pâturages naturels, directement influencés par le climat, montrent une très grande variabilité de leur production. Ce ci impose de les combiner de façon avec les prairies semées et les autres ressources, valorisant ainsi les contrastes existant suivant la variabilité des conditions naturelles et socio-économiques. Après un rappel sur les différentes typologies de systèmes pastoraux, on examine les systèmes incluant les prairies temporaires et les pâturages semés or sursemés destinés à la fauche ou à la pâture. Dans l'optique de la régularisation du calendrier de la production fourragère, on considère le rôle et la maîtrise génétique et agronomique de quelques ressources "stratégiques", en particulier les légumineuses pérennes et annuelles. Ensuite on discute de la possibilité de les combiner au niveau de la parcelle, de l'exploitation et du territoire, ainsi que des relations entre herbacés et ligneux en vue d'un multiusage de l'espace pastoral. Enfin on considère les besoins et les perspectives de recherche dans ce domaine.

Mot-clés : Durabilité, conservation, ressources "stratégiques", légumineuses, multiusage.

Introduction

The production of native pastures is influenced, more directly than any other crop, by meteorological variations, which represent the most important conditioning factor. In Mediterranean environments, which are characterised by the erratic nature of rainfall and by an alternance of a wet and relatively cold winter with a dry and hot summer, pastures present a very high production variability due to this strong seasonality. In these conditions, native pastures, even when they are the main resources (as in Spain or in Sardinia) can become vulnerable and aleatory; this imply the necessity of an appropriated combination with other native or, more suitable, cultivated resources (Talamucci, 1994a, 1995; Talamucci *et al.*, 1996).

In addition to the climatic constraints, the Mediterranean Basin presents some other difficulties, such as: high demographic pressure; edaphic constraints; difficulties of mechanisation; property fragmentation; market dispersion. All this leads to a wide variability of the environmental and socio-economic conditions and, consequently, of pastoral systems, ranging from transhumance or nomadism to intensive farming. (Le Houerou, 1980; Flamant and Cocks, 1989; Talamucci and Chaulet, 1989; Delgado, 1992; Piano, 1993; Papanastasis and Mansat, 1996; Crespo, 1997).

Typologies of forage and pastoral systems

This wide variability makes it very difficult to classify correctly the different forage and pastoral systems. Following an Italian classification proposed by Cereti and Talamucci (1991) based on the relative importance of temporary or permanent resources and of grazing or mowing (Table 1), we can consider nine great types of systems going from the exclusive mowing of sown forage crops, to exclusive grazing of permanent pastures. To these typologies we have to add the three types of "mixed" systems, i.e. cereal/fodder crops or fallow combinations; silvopastoral systems; and multipurpose systems. This paper considers only the typologies including fodder crops and oversowing pastures in different proportions. It takes also into account the seasonal evolution of the forage availability and of the animals requirements in the systems that can be represented in different graphic forms, as shown in Fig. 1.

Table 1. Forage systems typology. Intensification decreases from left to right and from top to bottom (modified from Cereti and Talamucci, 1991)

A) Forage systems			
Resource type	Utilization modalities		
	Only mowing	Mowing and grazing	Only grazing
Sown temporary resources (artificial)	1) Only mowing of sown resources	4) Mowing and grazing of sown resources	7) Only grazing of sown resources
Sown and permanent resources	2) Only mowing of temporary and permanent resources	5) Mowing and grazing of sown and permanent resources	8) Only grazing of temporary and permanent resources
Permanent resources (natural)	3) Only mowing of permanent resources	6) Mowing and grazing of permanent resources	9) Only grazing of permanent resources
B) Mixed systems			
10) Forage systems linked to intensive cereal cropping			
11) Silvo-pastoral and agro-silvo-pastoral systems			
12) Multi-use systems (vineyards, pastoral, protection, etc.)			

Features and role of the new pastoral systems

As a consequence of the recent socio-economic changes, the proportion of the four typical resources of European Mediterranean areas (i.e. wheat, grape, olive and rangelands) has radically changed, mainly for the collapse of cereal crops and for the saturation of vineyards. This fact has given more space to livestock and now it is possible to estimate that the area of pastoral interest in Mediterranean Europe is about 50 millions of hectares (65% of total surface). But this evolution has also given to livestock a fundamental ecological role for the conservation of areas threatened by degradation and for the safeguard of the territory. So, new forage-pastoral systems must integrate the aspects of production, based on quality, with those concerning the conservation of plant resources, wild animals and environment, the fire prevention and the limitation of soil erosion; they must reduce inputs and search for the stability of production throughout time and among seasons with an optimal temporal distribution. These new systems must also remain open to the international market, that is surely experiencing a positive trend due to the tourist flow from the north and to the migration of people in search of jobs from the south and the east. But they have also to keep a simple and easy management (by promoting grazing), to increase their biological efficiency (by valorizing legumes and animal restitutions) and to integrate different uses of land. In conclusion, these systems will have to appeal to the combination of diversified resources and to valorize at the best the existing contrasts.

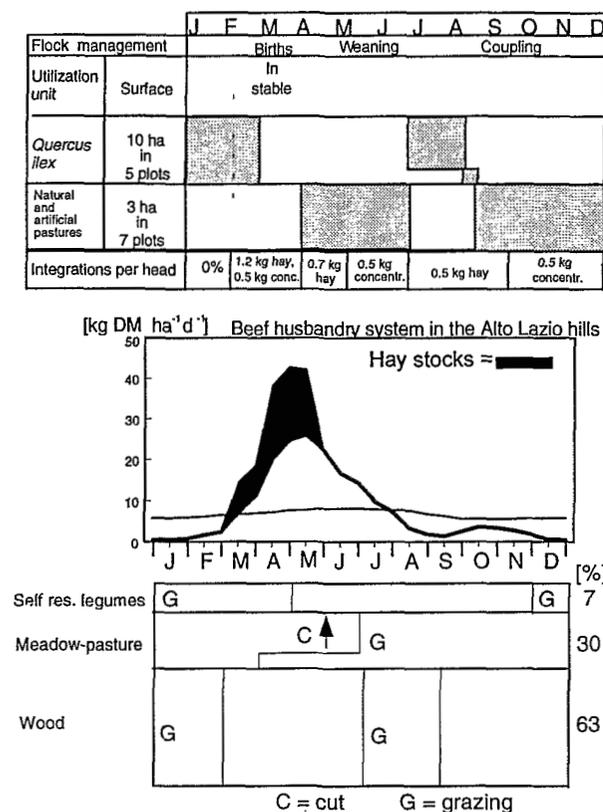


Fig. 1. Two forms of graphical representation in south France (modified from Bellon, 1995) and in central Italy (modified from Pardini and Rossini, 1997).

Under this scheme the most important problems concern: (i) the regularization of the forage production calendar by making resources complementary; (ii) the genetic and agronomic control of single resources; (iii) the combination of resources in integrated systems; and (iv) the relationship between pastures and woody resources, in view of multi-use of the territory.

The seasonal regularization of the forage production

In the Mediterranean environments there are two periods of gap in forage production: winter (short but not to be underestimated because of its coincidence with the periods of high animal requirements) and summer (intense and prolonged).

The traditional tools for overcoming this problem are represented by harvesting and storing fodder crops. Nevertheless sometimes this operation is too expensive, or difficult, or impossible due to excessive slope. Another alternative is the regularization of the seasonal distribution of forage production. Among the different methods, ranking in accordance to efficiency, the following can be taken into account:

(i) Rationalization in the use of native herbaceous resources: with the use of some "short transhumance" or some nomadism (even if presently highly reduced); with the use of standing hay or by deferred grazing or by the intake of the seeds produced by annual self-regenerating legumes; with diversified fertilizations (mainly nitrogen to anticipate the utilization or mainly phosphorus to postpone it); with the diversified utilization in the pre-winter period; with the improving of the pasture by overseeding species of different precocity in relation to the native flora.

(ii) Introduction of temporary pastures or meadows, or short term meadows of progressive earliness (grasses and mixtures) to constitute the so called "grazing chains".

(iii) Use of sown "strategic" resources (cool season and warm season grasses, annual self-regenerating legumes, forage shrubs) to be grazed right in the periods of maximum difficulty.

(iv) Utilization of the wood and the herbaceous understore in critical periods.

The efficiency of the two former suggestions is, unfortunately, limited and their management becomes more difficult in those cases of property fragmentation. On the contrary, the use of "strategic" species, even if more expensive, opens interesting possibilities. Finally, grazing in the wood, when properly conducted, valorizes at the maximum the environmental role of the forage species which are called to cover a place in the prevention against fire.

The use of "strategic" resources

Species to be used to fill the winter gap

In the winter period, some microterm grasses can be used like the Mediterranean varieties of *Festuca arundinacea* Shreb. or *Dactylis glomerata* L. characterised by summer dormancy and winter productivity, or adapted genotypes of *Phalaris aquatica* L., *Bromus willdenowii* Kunth, *Lolium rigidum* Gaud., *L. multiflorum* Lam.; or annual winter growing legumes (vetch, horsebean, crimson clover, bersim), or some annual self-regenerating legumes like subterranean clovers (*Trifolium subterraneum* L. sensu lato), medics (*Medicago* spp.) and others. Some types of planted shrubs can be used, like *Medicago arborea* L. or *Coronilla glauca* (L.) Batt. that have persistent leaves, or like *Gleditsia triacanthos* L. whose numerous and saccharine legumes fall to the ground right in winter (Dupraz, 1987).

Species to be used to fill the summer gap

Several C₄ grasses can be sown to fill the period of summer shortage, like *Cynodon dactylon* L. which is so well adapted to be a worst weed of the main crops, some species of the genus *Andropogon*, *Bouteloua* or *Buchloe*, or like *Eragrostis curvula* (Schrad.) Nees, whose Australian variety "Consol" could be interesting also for the Mediterranean Basin thanks to the improved palatability.

Other summer resources are represented by the regrowth of perennial legumes (like alfalfa, sainfoin and sulla).

An interesting different "strategic" resource for summer is represented by artificial plantations of forage shrubs, which are a little expensive in the management and late in good yields but they can also keep their leaves green even in the worst drought periods thanks to the deep root system and they lose nutritive value, digestibility and palatability slowly. Among several interesting species we can consider *Morus alba* L., whose varieties are selected for large leaves and good productivity. These were available from Japanese breeders at the beginning, are now used also in Europe, and is now raising some interest also for the agroforestry of tropical Africa. Among the legume shrubs or trees *Robinia pseudacacia* L., which is very fast growing, can be taken into account, as well as *G. triacanthos* L., *Colutea arborescens* L., *Coronilla emerus* L. and *C. glauca*, *M. arborea* whose many seeds are available right during summer while leaves can be used also in winter. For the worst drought environments some *Acacia cyanophylla* Lindley or *A. salicina* Lindl., *Camaecytisus proliferus* (L.f.) Link ssp. *Palmensis* (Christ.) Kunkel can be planted. Between the non-legume shrubs, *Opuntia ficus-indica* Mill. does not have a good chemical value but contains water which is useful for the animals; it also provides natural fences and helps in the consolidation of moving sands, *Atriplex halimus* L. and *A. nummularia* Lindl. are particularly suitable for salty places (Correal *et al.*, 1990; Giambalvo *et al.*, 1997).

Species to be used by harvesting

All the annual or perennial legumes and grasses mentioned above can be utilised, in pure stand or in mixture, for making hay or silage for conservation. Generally, they are utilised as animal feed during the winter period in stables, or transported into rangelands as balls for complementation in summer.

The role of the herbaceous legumes

As we can see, in all the categories of the above mentioned resources, legumes play a very important role for the conservation of fertility, for reducing the inputs, for maintaining soil cover to prevent erosion and for increasing the biological efficiency of meadows and pastures. The positive effects of the legumes on soil fertility are direct and indirect (Bonciarelli, 1992). The direct effects come from: the symbiotic nitrogen fixation and its release in short or medium periods; the mobilization of nutritive elements stored in the deep layers of the soil thanks to its powerful root system; the improvement of the physical conditions of the soil (structure, drainage); the control of weeds. The indirect effects are due to the presence of animals and to litter.

In addition to shrubs, herbaceous legumes potentially adapted to be incorporated in the Mediterranean systems belong to three main groups: (i) perennial legumes (alfalfa, sainfoin and sulla); (ii) annual winter growing legumes (vetch, horsebean, crimson clover, bersim); and (iii) annual self-reseeding legumes (subclovers, medics and others).

Perennial legumes

Among *perennial legumes*, alfalfa (*Medicago sativa* L.) still today maintains the main role with the only exceptions of those areas where particular edaphic conditions have given more importance to other species, like *Onobrychis viciifolia* Scop. in the calcareous soils of central or southern Europe, or like *Hedysarum coronarium* L. in the heavy clay soils of the warm areas (Talamucci, 1995, 1996). The utilization of alfalfa can be as green forage (grazing with attention to the problems of bloating), as conserved forage (hay or silage) or as concentrated (dehydrated); nowadays it is rising in importance also as an industrial plant.

Utilization of alfalfa by *grazing*, is surely the practice that shows the highest possibility of improvement. According to Grignani (1991), the reduction of reserves due to frequent grazing can cause up to the 30% of reduction of its production but, according to Delgado *et al.* (1992) this does not happen necessarily. Alfalfa can assure a good summer contribution to the animals. Usually the sprouts are used by grazing only after the first cut but, as is done in Argentina and parts of the United States of America as well as, in certain cases, in Europe like in Aragon (Delgado *et al.*, 1992) it can be grazed all through the year. A wider diffusion of grazing of alfalfa can be considered also because the risks of poisoning by estrogens are very limited and bloating can be avoided by a correct management of the flocks. There is a high level of variability concerning the risk of bloating either due to the plants (Bouton *et al.*, 1993; Tava *et al.*, 1993) or due to the animals (Morris and Wilkins, 1993), and this gives a good motivation for the work of genetic selection of the legume and of the animals. When grazed, alfalfa increases the leaves/stems ratio and reduces the number of stems per surface unit (Delgado, 1994) and this can reduce competitiveness with weeds. The breeding of Alfalfa, especially in Mediterranean environments, should be based on the local population, like the Spanish "mielgas", and could lead to change *Medicago sativa* from a typical meadow plant into a new type adapted for grazing either in pure stands or oversown in pastures.

Up to this moment, *hay-making* remains the most common utilization of *M. sativa* L., nonetheless this use can be considered the worst because of the large amount of mechanical loss of leaves, especially at the first cut that usually is done with the more unstable climatic conditions which causes a longer persistence on the ground and more frequent mechanical interventions. Even if the conditioning reduces the times of hay making, alfalfa is one of the slowest species to lose water (Ciotti, 1992). The loss of leaves can become higher when alfalfa is stored in bales. These motivations explain the trend to abandon hay-making in several European regions, except where cheese of very high quality (like the Italian Parmigiano) is produced.

At the moment, *silage* represents the most interesting technical solution to conserve alfalfa. Silage is recommended at first cut but it is useful also for the following utilizations. Prewilting should be applied up to values of 35-36% DM. The moment of reaching this value can be predicted using mathematical models (Acutis *et al.*, 1994). The technique of bale silages, that requires the 40-50% of DM and that takes about two days to be reached after drying up in the field, favours conservation (Ciotti, 1988; Le Gall, 1993). The addition of lactic micro-organisms is technically very easy and is recommendable (Ciotti *et al.*, 1993; Mader, 1993) because it allows operation with a level of 30% of DM and permits a very rapid dropping of pH.

Conservation by silage is also recommended for sainfoin and sulla (Stringi *et al.*, 1997). Of course, the evolution of machinery for treatments of forage remains a very important means for the diffusion of alfalfa silage in different regions.

In intensive areas, alfalfa can be utilized by dehydration for preparing concentrate feeds, meals for humans and industrial products. But in Mediterranean areas it can also improve the stability of pastoral systems based on different resources, increasing and securing yields, assuring stocks during critical periods and, mainly, lengthening the grazing season. An example is given in Fig. 2, which represents graphically a pastoral system based on four resources (alfalfa, subclover, shrubs and oak forest) investigated in Tuscany (central Italy). The lower part of the graph represents the proportions of resources with the utilization periods and modalities (grazing or cutting); the upper part shows the curves of DM availability and animals requirements. This graph indicates quite well the function of alfalfa in the system: to assure the forage stocks, to provide grazing in a critical period and, more importantly, to overcome the interannual fluctuations with its good flexibility (Talamucci, 1994b). So, if the season is bad, alfalfa can be grazed; if stocks are needed, alfalfa can be mowed; if weather is favourable, alfalfa can be used as a seed crop, in this way assuring an additional income. This flexible management of legumes is also adopted for sainfoin (Bellon, 1992) and requires new genetical studies in order to obtain more flexible cultivars.

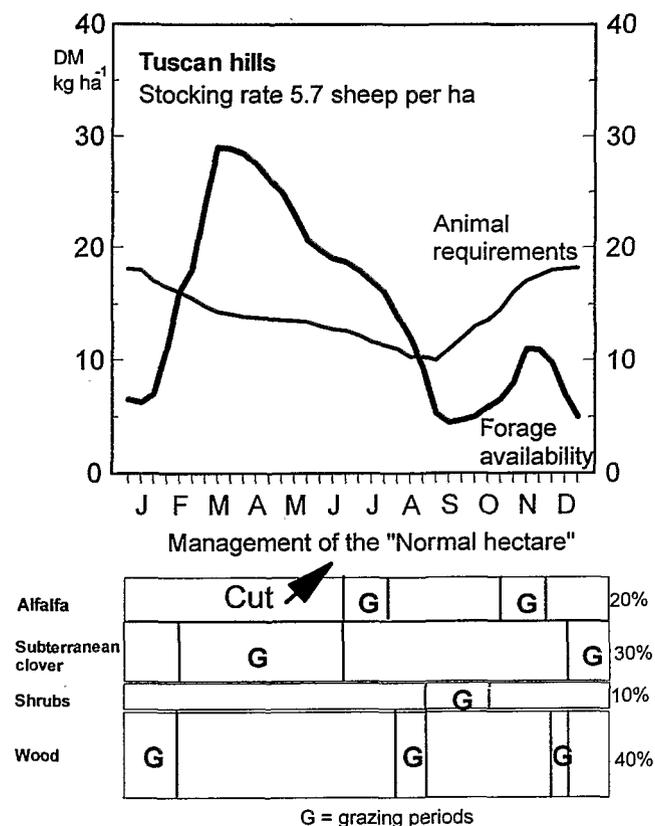


Fig. 2. Representation of a four resources pastoral system for sheep in Tuscany hills (central Italy), with the seasonal distribution of forage availability, animal requirements and management of the "normal hectare".

This necessity of flexibility, justifies the increasing interest for sainfoin (*O. viciifolia*) that can provide a good grazing also in autumn in the form of "standing hay" with the consequence of a lengthening of the grazing period and of the persistency of the crop, due to the pods dissemination. A similar role is

played by the sulla (*H. coronarium* L.) particularly suitable for clay soils. Both these legumes, up to now used only for hay, have to be transformed, with appropriate breeding programmes exploiting their wide variability, into some grazing species.

Annual winter growing legumes

A group of very useful crops in the Mediterranean areas is represented by annual winter growing legumes, traditionally cultivated in pure stand or in mixture with grasses, as fodder sources in addition to the natural pastures contribution. Vetch (*Vicia sativa* L.) and horsebean (*Vicia faba* L.) are always mixed with cereals; crimson clover (*Trifolium incarnatum* L.) presents a large adaptability but it is not so productive; bersim (*Trifolium alexandrinum* L.) is valuable for its fast regrowth and its great flexibility in use (grazing and cutting for hay or seed cropping in different sequences according to the climatic and marketing conditions).

All these annual legumes can produce considerable quantities of seed, also for export abroad (including non Mediterranean countries, like Germany and Switzerland, where they are used as summer growing species). The risks of soil erosion connected with the requested frequent drillings, suggest a prudent use of these annual crops in extensive contexts and, where possible, their substitution with the annual self-regenerating legumes that can represent the key of the improvement of Mediterranean forage system.

Annual self-regenerating legumes

The annual self-regenerating legumes have experienced a major agronomic role in southern Australia where, accidentally introduced in the XIX century, they have later become the key component of the ley-farming system, expanding over millions of hectares. In the last twenty years, annual medics and clovers have risen to a new importance also in the mother region of the Mediterranean Basin (Piano, 1993).

As already mentioned, the species of major agronomical importance pertain to subterranean clovers (*Trifolium subterraneum* L., *T. brachycalycinum* Katzn. et Morley; *T. yannicum* Katzn. et Morley and, rarely, *T. israeliticum* D.Zoh. et Katzn.) and annual medics (including 7 commercial species i.e. *Medicago littoralis* Rhode; *M. Murex* Willd.; *M. polymorpha* L.; *M. rugosa* Desr.; *M. scutellata* Mill.; *M. tornata* Mill.; *M. truncatula* All.; and other species with an interesting agronomical potential such as: *M. rigidula* All.; *M. orbicularis* Burt.; *M. noeana* (Boiss.). Other self-regenerating legumes are: *Trifolium hirtum* All.; *T. michelianum* Savi; *T. vesiculosum* Savi; *Ornithopus compressus* L. and, less important, *Trifolium nigrescens* Viv.; *T. glomeratum* L.; *T. cherleri* L.

A recent review by Piano and Talamucci (1996) has underlined the adaptive advantage, in Mediterranean environments, of annual self-regenerating legumes that combine the agronomical profit of a perennial-like stand, where costly reseeding operations are excluded, with the adaptive advantage of the annual cycle. The increasing interest in the annual self-regenerating legumes is justified by several reasons. We can mention:

- (i) The growth rhythm synchronous to Mediterranean climate.
- (ii) The adaptability to poor and acid soils, to heavy stocking rates and to severe intensities of grazing, mainly by sheep, typical of Mediterranean environments.
- (iii) The efficient nitrogen fixation.
- (iv) The persistence due to the self-regeneration mechanism and to the hardseededness.
- (v) The considerable amount of edible pods offered to animals in summer (Cocks, 1988; Carter, 1992; Pardini, 1993).

(vi) The buffering function played by the seed bank and, consequently, the high plasticity of response to seasonal fluctuations within and among years and to diversity of management practices.

Because of their wide adaptation and flexibility of utilization, self-regenerating legumes can participate in a wide range of farming systems, i.e.:

(i) *Crop-pasture rotation systems* (ley-farming, widespread in Australia, rather interesting in west Asia and north Africa, but very limited in southern Europe, where more intensive systems can be adopted because rainfall often exceeds 600 mm).

(ii) *Continuous pasture systems* (sowing of self-regenerating legumes as permanent stands or their oversowing into a native degraded sward).

(iii) *Non conventional systems* (where extra-productive targets are predominant in order to achieve significant environment protection objectives, such as: protective action by legume cover crops in intensive farming (Caporali *et al.*, 1993); soil erosion control in disturbed areas; fire and erosion control in firebreak lines by biomass reduction and limited combustibility of the canopy during summer due to the shallow and compact plant layer (Etienne, 1989; Etienne and Vleix, 1995; Pardini *et al.*, 1995).

(iv) *Multipurpose systems* (generally integrating annual self-regenerating legumes with ligneous resources such as cultivated trees or shrubs and forests).

Genetic and agronomical control of single resources

The plant material to be introduced in the pastoral systems must be genetically adapted to the Mediterranean environments. Taking a step from the present situation, it can be said that few varieties (belonging to *F. arundinacea*, *D. glomerata*, *L. rigidum*, *L. multiflorum*, *M. sativa*, *O. viciifolia*, *H. coronarium*, *T. incarnatum*, *T. alexandrinum*, *T. subterraneum*, *T. brachycalycinum*, *T. yanninicum*, *M. polymorpha*) obtained in Mediterranean basin are available, even if selection programmes activated in Mediterranean countries are promising (Crespo, 1970; Gomez Pitera, 1975; Abdelguerfi, 1989; Olea *et al.*, 1989; Piano, 1989; Bounjemate *et al.*, 1992; Prospero *et al.*, 1992; Volaire *et al.*, 1992; Mansat, 1993; Vaitsis, 1993; Ben Chaabane and Delgado, 1995; Chakroun *et al.*, 1995; Farinha *et al.*, 1996; Piano and Pecetti, 1996). In spite of these efforts, much work remains to be done. Generally speaking, we can say that, up to this moment and excepting some few cases, only two types of germoplasm are available: adapted but not improved (ecotypes and native populations, mainly concerning legumes) and improved but not adapted (commercial varieties coming from areas climatically very different from the Mediterranean, still a common case for the grasses). In this situation, the local material should be selected with a maximum valorization of those characteristics which favour the adaptation to the Mediterranean environments i.e.: summer dormancy, winter production, aptitude to grazing, fast settling, resistance to drought and shadowing, high hard seeds rate to keep a good seed stock in the soil in the case of the annual self-reseeding legumes (Piemontese *et al.*, 1997). In the case of alfalfa, the most important criteria for selection are still the growth in spring and in summer, the long persistence, the capability of sprouting, and the adaptation to competition.

Of course, together with the availability of adapted germoplasm a perfect agronomic control of its utilization is fundamental. From this point of view the simplification of seeding and overseeding modalities is very important; fertilization must be based on little amounts of phosphates thus to favour the legumes and permit the sustainability of pastures (Granda, 1991); but, above all, in Mediterranean areas, the most efficient tool continues to be animal management and therefore it should become more rationalized by paying attention to the equilibrate stocking rate, to the grazing modalities, and to the distribution of restitutions. Livestock management (based on early, continuous and intense grazing and sometime also conducted by different animal species in succession) must take into account also the utilization of standing hay or annual legumes pods during summer.

Resources combinations

The combination of different resources can be implemented at three different levels: at the crop level (in the form of associations); at the farm level (in the form of separated crops to be utilized in succession) and at the territory level (in the form of multipurpose or complex systems).

At the crop level, in order to simplify the utilisation and to secure the grazing, grass-legume association represents a good technical solution. The grasses more suitable for the association with alfalfa (and sometime with sainfoin) in Mediterranean areas are: *F. arundinacea*, *D. glomerata*, *B. willdenowii* and, more rarely, *Ph. aquatica*, while the annual self-regenerating legumes can be mixed with *Ph. aquatica* and *L. rigidum* (Delgado, 1997). Generally growth rhythms of the partners of the mixtures are "synchronic", but in order to simplify the utilization, to lengthen the grazing period and to reduce the interference between partners, it has been proposed to associate species of complementary growth rhythm. Two of these "asynchronic" associations, i.e. subterranean clover associated with a warm season grass such as *E. curvula*, or with a deciduous fodder shrub such as *M. alba*, gave promising results in southern Tuscany, assuring a grazing period of 8-9 months (Talamucci and Pardini, 1993; Piemontese *et al.*, 1994). Similar periods of grazing, up to the whole year, can be reached in the complex optimal associations of oaks that give shadow, acorns and pasture, typical of the Spanish "Dehesas" and the Portuguese "Montados" (Fernandez de Mesa and Olea, 1979; Granda, 1981), systems whose very good balance suggests that exploitation should be carried out still today in accordance with traditional patterns (Gomez and Pérez, 1996).

At the farm level, it seems possible to utilize in sequence, by rotational grazing, the different sown or natural resources, that present great variations in the levels of productivity, growth rhythms and periods of availability; if considered all together they can cover the animal requirements all through the year.

An example concerning central Italy is presented in Table 2. On the basis of these data, it has been possible to choose hypothetical systems aimed at a lengthening of the grazing period. So, Table 3 shows that, using natural pastures alone, it has been possible to assure a grazing period of only 4.5 months; utilizing two different resources (for instance, adding a warm season grass) we have obtained a period of availability of 7 months; with three resources (addition of subclover), 9 months; with four resources (adding forest or deciduous shrubs), 11 months; and finally, adding a fifth component (for instance an evergreen shrub) we have covered the whole annual cycle. Of course, these are only examples; but it is always possible to find the optimal arrangement for each environment.

At the real farming scale, some examples of the features of different forage systems are presented in Table 4, that considers four cases studied in central Italy (Pardini and Rossini, 1997) and organized for cattle or for sheep: the animals are kept grazing for all the year in all the systems. Increasing the number of resources increases also the number of days of self-sufficiency at grazing, with the exception of system N° 2, including wood for a very large part.

At the territorial level, in the Mediterranean areas, sometimes forage production attains its stability only in multipurpose systems, such as agropastoral or silvopastoral systems. The agropastoral systems consist mainly in cereal-forage crops rotations. The silvopastoral systems and the combinations between herbaceous and ligneous resources show a wide variability. In any case they represent a very important ecological guarantee.

Pasture-woody resources relationships in view of a multi-use of the territory

Relationships between herbaceous and woody resources differ mainly because of the level of their interference: we pass from very low interference as in the cases of separation between the two kinds of vegetation (alternation of pastures and small woods as in the case of French "bocages" or windbreaks or firebreaks) to forms of agro-silvo-pastoralism (woody species planted in open pastures or in the cropping areas, or the sparse plants of the "Dehesas" or the "Montados" in the Iberian peninsula, or as in the cases of the chestnut or the cork oak woods). We can go up to grazing in productive, dense forests which can be managed or not by silvicultural techniques to favour access for animals. Examples of these systems are the oak forests or woods of pines (Papanastasis, 1996). The maximum impact of animals on woody plants is presented by the artificial plantations which are settled just for grazing as happens

with the alley cropping system in plantations of the genus *Prosopis* or *Leucaena* in the tropics (where these species have functions of windbreaks, shadowing, wood production, and nitrogen fixation at the same time), plantations of *C. palmensis* in certain sub-tropical areas or shrubs of *M. alba*, *M. arborea*, or the others already mentioned in the Mediterranean countries.

Table 2. Annual DM yield (t ha⁻¹) and availability periods of some pastoral resources categories studied in central Italy: maximum and minimum of a three years period (modified from Talamucci, 1996)

Resource	DM yield (t.ha ⁻¹) (min - max)	Availability period
Herbaceous		
<i>Lolium rigidum</i>	5.2-6.3	Nov-Apr
<i>Phalaris aquatica</i>	5.9-7.2	Nov-Apr
<i>Festuca arundinacea</i>	6.4-8.5	Oct-May
<i>Bromus willdenowii</i>	6.0-7.8	Oct-May
<i>Eragrostis curvula</i>	6.1-8.2	Jul-Sep
<i>Panicum virgatum</i>	4.9-6.8	Jul-Sep
<i>Bouteloua curtipendula</i>	3.1-4.9	Aug-Sep
<i>Lotus corniculatus</i>	4.2-5.8	Mar-Jun
<i>Trifolium subterraneum</i>	6.0-7.1	Nov-Apr
<i>Medicago polymorpha</i>	5.1-5.9	Nov-Apr
<i>F. arundinacea</i> / <i>E. curvula</i>	6.2-8.3	Feb-Dec
<i>T. subterraneum</i> / <i>E. curvula</i>	6.4-8.1	Feb-Dec
Woody, shrubs and associations herbaceous / shrubs		
<i>Morus alba</i>	4.2-5.3	Jul-Oct
<i>Acer negundo</i>	5.2-5.5	Jul-Sep
<i>Amorpha fruticosa</i>	4.0-4.8	Jul-Oct
<i>Robinia pseudacacia</i>	5.5-6.1	Jul-Sep
<i>Colutea arborescens</i>	3.7-4.2	Jul-Oct
<i>Medicago arborea</i>	3.9-5.0	Aug-Sep / Jan-Feb
<i>Acer negundo</i> / <i>T. subterraneum</i>	7.5-8.2	Mar-Dec
<i>Modus alba</i> / <i>T. subterraneum</i>	8.1-11.9	Mar-Dec
Mixed coppice		
<i>Carcase cerris</i> coppice in conversion to high tree stand	0.6-1.1	Jul-Sep
Mediterranean maquis	0.8-2.3	Jul-Sep
	0.2-2.5	Jan-Dec

The complex system derived by woody and herbaceous plants combination involve different products, by-products and services: non fodder products (food, energy, raw material for different industries), water and soil conservation, shelters for animals, cinegetic reserves, environmental protection, aesthetical and recreational functions. According to the different environmental and socio-economic conditions, the multipurpose systems can give different importance to herbage productive aspects and to other activities (Hubert, 1988; Bellon, 1995)

Among the multipurpose systems an increasing interest is in the use of annual self-regenerating legumes as cover crops in vineyards and orchards (Masson and Ginzburger, 1986; Caporali *et al.*, 1993; Piemontese *et al.*, 1995, 1997; Pardini *et al.*, 1995). Because of their cool season cycle, they do not compete for water and nutrients with the trees, while they provide green forage for sheep in winter,

efficient control of soil erosion during the rainy period and a surface mulch during summer and early autumn (Piano and Talamucci, 1996).

Table 3. Lengthening of the grazing period through the combination of different resources (Talamucci, 1996, modified)

N. of resources	Natural pastures	Warm season grasses	Subterranean clover	Wood and deciduous shrubs	Evergreen shrubs	Grazing period (months)
1	x					4.5
2	x	x				7
3	x	x	x			9
4	x	x	x	x		11
5	x	x	x	x	x	12

Table 4. Some of the parameters used to compare four forage systems in central Italy (Pardini and Rossini, 1997, modified) and referred to the year-round average: kind of resources, surface of the experimental area (ha), animal stocking rate (LU ha⁻¹), number of days in which forage availability in the pasture exceeds the animal requirements (days a>r)

System	Resources of the system	ha	LU ha ⁻¹	Days a>r
1) Roman hills, beef husbandry	Natural meadow-pasture	40	1.3	136
2) Alto Lazio hills, beef husbandry	Natural meadow-pasture, annual self-reseeding legumes, Oak wood (63% of the surface)	100	0.5	134
3) Grosseto hills, milking sheep	Perennial meadow, Subterranean clover, Forage shrub plantation, Oak wood (40%)	100	0.9	187
4) Grosseto hills, with firebreak, milking sheep	<i>Medicago sativa</i> meadow, Subterranean clover, <i>Eragrostis curvula</i> meadow, firebreak, oak wood (40%)	100	0.9	208

Another interesting aspect is represented by the oversowing of forage species under forest cover (Koukoura and Papanastasis, 1996; Armand and Etienne, 1996; Ovalle and Del Pozo, 1995; Qarro, 1995) which is done with a double aim: to improve feeding availability and to keep clear the understore by means of animals grazing, thus reducing wildfire risk. A critical factor, especially when annual self-regenerating legumes are used, is represented by the tree density. Nonetheless *T. brachycalicinum* seems more tolerant than other clovers to shading and its regeneration can be even facilitated by the accumulated litter of tree leaves in the soil, that provides a favourable seed bed (Pardini, 1992).

Research problems

The right implementation and the efficient management of the pastoral systems dominated by fodder crops harvesting and grazing request a proper and specific technology and, consequently require particular investigations. According with the considerations made by Piano and Talamucci (1996) about annual legumes, for the Mediterranean pastoral systems research needs are also related to three different levels: plant, crop and systems level.

At plant level, research requirements involve ecophysiological and breeding studies. Investigation is required on climatic and management stress, on competition mechanisms and feeding value and, for annual self-regenerating species also on seed bank evolution. The selection of varieties targeted to specific environments and farming systems of the Mediterranean regions (including new non conventional systems) must be extended.

At crop level, key points for a correct control of crop establishment and persistence are: development of simplified techniques of sowing and oversowing (sod seeding, minimum tillage, soil pitting, use of relevant machinery, use of grazing animals before and soon after seed distribution in order to exploit trampling effects on seed burial); definition of intra and interspecific mixtures able to improve herbage yield and its seasonal distribution; use of appropriate fertilization to govern long term balance between legumes and grasses; development of right livestock management (continuous, rotational and intensive grazing) with adjustment of seasonal stocking rate, use of deferred grazing in summer and autumn in order to maintain a good stability and a satisfactory weed control.

At system level, it is important to improve knowledge on the combination of different resources, in space and in time, in order to increase efficiency of existing systems and to develop new systems, especially multipurpose systems.

From a general point of view, we can assert that the agronomic and ecological potential of the Mediterranean pastoral systems dominated by fodder crops harvesting and grazing is far from being completely exploited, and that the possibilities of improvement are wider than those previously considered.

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