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REVISIÓN CIENTÍFICA

Nota de la Dirección

Los dos últimos artículos de la siguiente relación, que coinciden con las ponencias presentados por sus autores con el mismo título en la 21st General Meeting of the European Grassland Federation, celebrada en Badajoz del 3 al 6 de abril de 2006, se incluyen en este número de la Revista Pastos porque con ellos se cierra un ciclo de revisiones sobre especies leguminosas pratenses, iniciado en 1998. Para su inclusión se ha obtenido la correspondiente autorización, tanto de los autores como de los Comités Organizador y Científico.

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ROLE AND POTENTIAL OF ANNUAL PASTURE LEGUMES IN MEDITERRANEAN FARMING SYSTEMS

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SUMMARY

This paper reviews the current use of self-regenerating pasture legumes in the farming systems of southern Europe. Annual legumes are mainly the base for the improvement of low quality native pastures in extensive farming systems. Traditional pasture legumes such as subterranean clovers and annual medics are the base plants of Mediterranean pastures, and are essential for pasture improvement of semiarid zones. The role of a recent second generation of annual pasture legumes is discussed. Some key agronomic aspects and the level of forage production and forage quality are considered. The constraints related to the low persistence of introduced materials and sward management are examined. The potential of using pasture legumes in simple and complex legume-legume or grass-legume mixtures is analysed. The implication of legume-rhizobia symbiosis is also briefly touched upon. Finally the alternative uses of annual self-reseeding legumes are listed.

Keywords: Legume pastures, pasture legume biodiversity, grass-legume mixtures, pasture legume-based management, alternative uses.

INTRODUCTION

In the Mediterranean pastures of semiarid areas, annual self-regenerating legumes play a special role as pasture species for their forage quality and aptitude to fix atmospheric nitrogen in symbiosis with their root-nodule bacteria, increasing soil fertility and assisting the nutritional needs of other plants (Crespo, 1997). Spontaneous annual legumes are an important component of Mediterranean pastures and their survival is strictly linked to their self-reseeding ability. We will refer to annual pasture self-regenerating legumes that show the adaptive advantage of having an annual cycle combined with a “seed escape” habit. To cope with the high environmental variability, both climatic and pedologic, under the ancient tradition of grazing utilisation, Mediterranean self-reseeding legumes have developed specific strategies to ensure adaptation and reproduction. Complex biological

and ecological mechanisms involving seed yield and soil seed bank dynamics allow long-term regeneration of perennial-like stands. Such reasons make annual legumes from the Mediterranean basin a valuable source of germplasm. These species were introduced to other Mediterranean-type areas, and their naturalisation and diffusion had a remarkable positive impact on the new environments, particularly in Australia where annual legumes have effectively contributed to sustaining and increasing cereal and animal production (Cocks, 1999). Moreover, the Mediterranean seed market for annual pasture legumes has been heavily reliant in recent decades on the Australian selections from germplasm often originating from the Mediterranean basin.

ANNUAL SELF-RESEEDING LEGUMES AND FARMING SYSTEMS

Because of the large number of species and the relevant diversity of their adaptive characteristics, annual self-regenerating legumes have the important potential role to be utilised in the widest range of environmental conditions and relevant farming systems of the Mediterranean areas (Piano and Talamucci, 1996). In response to the high environmental variability and local rural traditions there is a wide range of farming systems typologies in the Mediterranean regions of Europe (Porqueddu and Sulas, 1998). Extensive livestock production systems with integral open-air grazing during much of the year are prevalent under rainfed conditions. Annual legumes are mainly the base for the improvement of low quality native pastures in agro-silvopastoral (e.g. Dehesa in Spain) and agropastoral systems. When a natural seed bank of pasture legumes is present, fertilisation without overseeding may be sufficient to obtain satisfactory agronomic results, particularly when repeated over several years (Bullitta *et al.*, 1989). It is likely that the seed bank of annual pasture legumes in a natural unfertilised pasture is not quantitatively sufficient to guarantee a prompt response to P soil enrichment, but “domestication” of structured wild populations under less oligotrophic conditions is often agronomically more reliable than the introduction of selected uniform varieties (Yañez *et al.*, 1991; Roggero and Porqueddu, 1999).

The annual self-reseeding pasture legumes are the key component of the ley farming and ‘phase farming’ system supporting wheat/wool industry on millions of hectares in southern Australia. The traditional ley farming is based on an annual cereal/pasture legume rotation while the second one relies on longer phases of cropping between pasture periods. Phase farming differs from ley farming in the requirement to re-sow the pasture after each cropping phase while pastures in ley farming are only rarely re-sown. In the last thirty years the annual self-reseeding legumes have also been increasingly utilised in Mediterranean Europe. However, commercial varieties of annual self-reseeding legumes imported from Australia sometimes proved unsuitable for pasture improvement in

southern Europe mainly due to the different climatic conditions and management systems (Olea and Viguera, 1999). In many cases the agronomic performance of the introduced legumes under both field trials and farm conditions were satisfactory the first few years after sowing, but subsequently, the contribution of sown varieties to the forage yield often decreased as native species became more competitive. Fara *et al.* (1997) found that native ecotypes were, on average, more persistent and better adapted than commercial varieties. These reasons have stimulated different European research institutes to carry out eco-geography studies and selection programmes aimed at the valorisation of local germplasm (Piano and Francis, 1993; Loi *et al.*, 1995). In Spain and Italy seven and five varieties of *Trifolium subterraneum* L. *sensu lato* (subterranean clover) respectively were selected in late '80 and '90 (González, 1994; Piano *et al.*, 1997). New varieties of *Medicago polymorpha* L. (burr medic) were also selected in Italy (Porqueddu *et al.*, 1999) and France (Prosperi *et al.*, 1999). Unfortunately, despite these new varieties proving to be superior than Australian ones, the lack of a European seed multiplication has not allowed their diffusion except for a few Italian varieties multiplied in Australia.

TRADITIONAL PASTURE LEGUMES

There is a marked association between distribution in nature and performance in agriculture of legume species and soil properties, related to the nature of parent rock, soil texture, soil chemical characteristics and associated differences in morpho-physiology of the species (Piano and Francis, 1993).

Subterranean clovers aka subclovers (*T. subterraneum* L., *T. brachycalycinum* Katzn. and Morley, *T. yanninicum* Katzn. and Morley) are the base plants of Mediterranean pastures, essential in any pasture improvement of semiarid zones with acid, neutral or lightly alkaline soils (Frame, 1997). Their importance relies on their good winter growth, high reseeding capacity, perfect adaptation to grazing due to their prostrate habit, ability to bury the seed heads in the soil, and excellent persistence. They grow well in moderate continental and semicontinental climates, either warm or temperate. The most favourable levels of rainfall are between 400 and 1000 mm. In terms of soil adaptation, *T. brachycalycinum* prefers clay, weakly acid or lightly alkaline soils whereas *T. subterraneum* prefers sandy acid soils. *T. yanninicum* is especially adapted to hydromorphic or flooded soils. There are around 40 varieties available in the seed market with a wide range of growing season length and hardseededness.

Annual medics (*Medicago spp.*) are the principal component of pastures in alkaline or lightly acid soils in areas of low and medium rainfall (250-600 mm). Medics show a high potential for seed and forage production, as well as producing a high percentage of hard seeds. These species are better adapted than subclovers to hard and clay soils, since they

do not have to bury their seed heads. The dominant species is *M. polymorpha*, due to its adaptation to a wide range of edaphic conditions, from acid to alkaline and from sandy-loam to clay soils (Loi *et al.*, 1995). *M. murex* Willd. (murex medic), is tolerant to acid soils (from pH 4.5 up to alkaline soils) while *M. truncatula* Gaertn. (barrel medic) and *M. scutellata* Mill. (snail medic) grow well in heavy soils, neutral to alkaline. Other less minor commercial species are: *M. rugosa* Desr. (gama medic), *M. littoralis* Rhode (strand medic), and *M. tornata* Mill. (disc medic). A total of about 30 annual medic varieties is commercialised.

Yellow serradella (*Ornithopus compressus* L.) is another species widely distributed in the Mediterranean regions and recognised to be successful on acid and sandy soils, especially in granitic soils where subclovers and medics are not productive. It grows best in well drained soils but does not tolerate waterlogged conditions.

A SECOND GENERATION OF PASTURE LEGUMES

Despite the unequivocal success of the southern Australian ley-farming systems, several contemporary factors have challenged their sustainability (Howieson *et al.*, 2000a). These are mainly associated with the excessive dependence on herbicides, incomplete use of water and nutrients by shallow-rooted annual species, and the emergence of new pests and diseases. In addition, the increased sensitivity to the costs, both economic and environmental, associated with suction harvesting of medics and subterranean clovers for seed production has had an impact on their popularity. These limitations led to a serious re-examination of the pasture legume components required for contemporary ley farming, and this resulted in the recognition that alternative legume species with different traits were probably required (Loi *et al.*, 2005a). Traits sought in the new species are deeper root systems, improved persistence from higher production of hard seed, acid tolerant rhizobial symbioses, tolerance to pests and diseases and ease of harvesting with conventional cereal harvesters. Several cultivars of a second generation of annual pasture legumes are now commercially available, e.g. biserrula (*Biserrula pelecinus* L.), French serradella (*Ornithopus sativus* L.), gland clover (*T. glanduliferum* Boiss) and improved varieties of arrowleaf clover (*T. vesiculosum* Savi.), balansa clover (*T. michelianum* Savi.), Persian clover (*T. resupinatum* L.) and yellow serradella, and have been rapidly adopted (Loi *et al.* 2000). Some other species are in an advanced phase of evaluation and are close to being released as commercial cultivars, e.g. *T. formosum* d'Urv. (eastern star clover), *T. spumosum* L. (bladder clover), *T. hirtum* All. (rose clover), *Melilotus albus* Medik (*white sweet-clover*), *Trigonella balansae* Boiss. and Reuter (trigonella) and *Lotus ornithopodioides* L. (annual birdsfoot trefoil). The availability of a wider range of species for Mediterranean agricultural systems in Australia are of benefit to farmers there,

who can thus choose from a wider range of species with different characteristics. The question posed by pasture specialists is whether or not these alternative pasture legumes are really of interest to European farmers. Some of the traits considered important for ley farming systems do not seem so relevant for establishment of permanent pasture in southern Europe, e.g. insect tolerance, high hardseededness. Preliminary results on the evaluation of these alternative pasture species in the Mediterranean basin are contrasting (Campiglia *et al.*, 2005; C. Porqueddu, unpublished data; A Franca, pers. comm.). Pure swards of several new Australian varieties have shown difficulties in establishment and re-establishment and lower forage production compared to subterranean clovers that produce higher levels of soft seed and consequently are able to compete against the native flora, usually richer than the Australian ones.

KEY AGRONOMIC ASPECTS AND PRODUCTIVITY

The adoption of legume-based grazing systems depends on farmers feeling confident about growing and utilising pasture legumes and this depends on overcoming the difficulties related to sward establishment, maintenance and management under grazing.

Establishment

The success of pasture establishment strictly depends on a good sowing method. Seed must be sown superficially, never deeper than 1 cm, and the soil consolidated by rolling, which is the key to provide a protection against ants and birds. Sowing should be carried out in late summer or at the beginning of autumn, and if possible also under dry soil conditions before the first rains or immediately after the season break, when warm temperatures allow good germination and fast establishment of legumes. It is very important to reach at least 200 plants m⁻² to assure a good establishment of the improved pasture.

Fertilisation

Mediterranean semiarid pastures are mainly located on soils which are deficient in phosphorus (P) and nitrogen (N), even with shortcomings of potassium (K) in some areas. The needs of N are covered by the legume-rhizobia symbiosis, although a low rate of N (less than 30 kg ha⁻¹) could be beneficial in the first stages of seedling development. Therefore, the needs for P are the most important, its addition to the soil being an essential requisite for the correct establishment of annual legume-based pastures. The first fertiliser should be applied during seed-bed preparation before sowing depending on soil P content

while, in successive years, P fertilisation should be applied on the soil surface, after the first autumn rains, at around 30–40 kg P₂O₅ ha⁻¹.

Forage production

The most productive and essential species in any pasture improvement scheme are subclovers. Yields depend upon the specific growing conditions, but especially rainfall during the growing season, Bolger *et al.* (1993) found a linear relationship between water use and dry matter (DM) yield up to 440 mm of growing-season rainfall with yields ranging from 3 to 12 t ha⁻¹. Most evaluations are made under a mowing regime that underestimates the potential yield of pasture legumes, particularly for species with a prostrate habit, such as subclovers. Pasture improvement does not only mean an absolute increase of DM, but also implies an increase of pasture production in critical periods (autumn, winter and late spring), which leads to a reduced need for complementary feedstuffs. Gloag *et al.*, (2004) found that *T. vesiculosum* extended the growing season by 3–4 weeks, had higher digestibility than *T. diffusum* Ehrh. (diffuse clover) and *T. subterraneum* in late spring, and could increase lamb live weights in late summer by more than 10%.

Persistence

In the presence of low persistence all other characteristics of success, including productivity, are meaningless. In order to obtain sward persistence it is fundamental to take into account certain considerations, because annual legumes will not remain in the pasture if the following situations occur: i) incorrect election of species and varieties ii) nutritional problems (mainly P deficiency) iii) incorrect sward utilisation (e.g. overgrazing). Apart from these main causes, there can be other factors which account for the lack of persistence, such as mature seeds being damaged by a plague of insects (Fara *et al.*, 1997). An important buffer mechanism against adverse abiotic factors or a flexible sward spring management is a long duration of the flowering phase and the ability to keep flowers and ripe pods at the same time. Many factors are responsible for the persistence but a high seed bank is fundamental for a successful use and long term persistence of annual dominant Mediterranean grassland types. Although winter grazing is advantageous to seed production, avoiding excessive predation of seed by livestock grazing stubble is also a critical aspect in legume persistence. The persistence is not only related to the seed yield but also to the pod and seed characteristics of each pasture legume e.g. seed size, hardseededness, softening pattern, seed dispersal capacity and seed burial ability. Seed size influences the persistence of pasture legumes in several ways. Larger seeds emerge from greater depths than smaller ones but are less likely to survive ingestion by sheep. Moreover small-seeded species guarantee a dense population of prostrate, small

seedlings having higher survival rates and maintaining an adequate photosynthetic area than a sparser stand of large seedlings. The softening of hard seeds differs between and within species, and in many situations the level of hardseededness may be less important than the softening pattern (Porqueddu *et al.*, 1996).

QUALITATIVE ASPECTS

Annual pasture legumes have a high feeding quality, determined by high crude protein (CP), mineral and vitamin contents, low proportion of cell walls and high animal intake levels. Forage quality in general was not included in most of the Australian legume breeding targets. However an emphasis was put in to selecting varieties with low oestrogen levels. The nutritive value of annual pasture legumes can vary between species, cultivars and plant organs according to the stage of development. Late maturing cultivars maintain higher DM digestibility and contain more essential nutrients than early maturing cultivars during late spring. Moreover, the differences in nutrient concentrations among cultivars within the same species are sometimes of the same magnitude of the differences among species. The main criteria of selection to improve feeding value in annual medics were suggested by Porqueddu (2001).

Relevant differences among annual legumes in terms of palatability have been identified. Specific indexes (SI, score from 1 to 5) have been attributed to define the “palatability” of a single pasture species in different environments and an inventory of SI has been made available by Roggero *et al.* (2002). Nevertheless high relative palatability may lead to an excessive selective grazing pressure for the species and its subsequent demise. The selection and use of varieties of low relative palatability suggested by some authors (Kellaway *et al.*, 1993) is a useful strategy for the varieties’ survival in a mixed sward or it may be used as a tool for controlling undesirable weeds under heavy grazing with high stocking rates, e.g. use of *T. formosum* (Loi *et al.*, 2005b).

The nutritive value of the whole plant is related to the quality of the individual plant parts and their proportions in the sward. Little attention has been given to stem thickness, which is also associated to variable plant habit. Prostrate and erect plants differ in the physical distribution of structural components (e.g. lignin) so that prostrate stems are less rigid and have higher digestibility. Differences in stem digestibility are usually associated with variations in numbers of vascular bundles. The stem anatomy of six annual legumes (*M. murex* cv Zodiac, *T. subterraneum* L. cv Junece, *T. michelianum* Savi cv Paradana and *T. resupinatum* L. cv Kyambro, Maral and SA12240) was examined. It was found that *M. murex* had a very high vascular bundles density mm^{-2} of stem tissue, which also resulted in a poor performance under grazing (Kellaway *et al.*, 1993). Therefore, species with

stems of higher nutritive value are of major interest as this is the part of the plant most available to livestock in late spring and summer.

Regarding anti nutritional factors, coumestans, which induce temporary infertility in ewes, are especially present in annual medics. In contrast to oestrogenic activity of formononetin in subterranean clover, which ceases as the plant matures and dries, cumestrol in medics increases with maturity and reaches a high level in dry pastures. Intraspecific genetic variations in the content of oestrogenic substances enabled cultivars to be selected for reduced estrogenic activity or for its absence. It has also been observed that plants under stress, induced by deficiencies in nutrients or biotic diseases, increase estrogenic activity. If grazing sheep have a varied feeding regime, the infertility problems may be avoided.

Annual pasture legumes are an important feed resource not only as green forage during the growing season but also as standing hay and pods in summer and early autumn (Fois *et al.*, 2000). Pods of annual medics are an important component of the diet of sheep during the summer dry period. Medics with an appropriate spring management can produce over 1 t ha⁻¹ of seed (Lelievre and Porqueddu, 1994) or 3 t ha⁻¹ of pods with high CP content (Sitzia and Fois, 1999). However because of easy consumption of medic pods by sheep, grazing management control is needed during summer to avoid impoverishment of the seed bank.

SWARD MANAGEMENT

Grazing is a fundamental tool for enhancing sward persistence and productivity, but, as pointed out in a recent review by Rochon *et al.* (2004), there is still limited scientific information regarding grazing management of legumes in Mediterranean basin areas. In general, intensive grazing seems to favour Mediterranean annual legumes, especially subclover-based pastures. In autumn it would be advisable to initiate grazing at least one month after the first rains, so that seedlings can well establish or re-establish and grow before low temperatures occur. During winter, until the beginning of the flowering period, intensive grazing is useful to favour legume growth. Contrastingly, in spring, during flowering and seed development, grazing should be limited to stocking rates below sward potential, thus allowing a suitable production of new seeds to rebuild the seed bank. During summer, grazing allows animals to eat the excess of pasture and also favours pod burying, increased seed softening, and autumn seedling emergence. Regarding grazing methods, Sitzia *et al.* (1997) found higher forage availability under rotational grazing than continuous stocking in a mixed sown pasture of *Lolium rigidum*, *T. subterraneum* and *M. polymorpha*, but ewes' body weight and condition scores, as well as total milk yields, were similar between the two grazing techniques. Rochon (1994) found that high grazing

intensity under rotational grazing of burr medic pasture showed a higher productivity than under low grazing intensity.

USE OF LEGUMES IN MIXTURES

A productive and balanced pasture sward, able to persist under marginal conditions, can be obtained using subclover mixed with other species and cultivars well adapted to the local conditions. But the difficulties found in the establishment and persistence of these pastures during adverse climatic years have led to the conclusion that the more diversified the seed mixture, the greater likelihood of getting a productive, balanced and persistent pasture (Crespo, 1997). Likewise, Tilman and Downing (1994) already affirmed that the more diverse the botanical composition, the stabler the pasture during drought conditions. This is the main reason why other annual legumes (e.g. *O. compressus*, *B. pelecinus*) present in natural pastures (Moreno and Gallardo, 1983), are utilised for sward improvements in the SW of the Iberian Peninsula, together with other less abundant species (e.g. *T. michelianum*, *T. resupinatum*). Traditionally, pasture seed mixtures available in southern Europe consisted of a small number of legume species or 4-5 subclover varieties mainly differing in earliness, and sometimes including low rates of annual grasses such as *L. rigidum* Gaudin (annual ryegrass), *L. multiflorum* Lam. (Italian ryegrass), *Avena sativa* L. (common oat). Nowadays, it is common to find complex mixtures including up to 20 annual self-regenerating legumes. In some cases e.g. pasture improvement in areas with higher rainfall, perennial grasses, such as *Dactylis glomerata* L. (cocksfoot), *Phalaris aquatica* L. (bulbous canarygrass), *Festuca arundinacea* Schreber (tall fescue) are utilised in grass-legume mixtures. The compatibility of perennial grasses and annual legumes when grown in mixtures has been reviewed by Dear and Roggero (2003), who discussed particularly the effects of perennial grasses on emergence, survival and seed set by annual legumes. Encouraging results have been obtained by Porqueddu and Maltoni *et al.* (2005) evaluating 4-species mixtures belonging to different functional types as grass/legume and fast-annual/slow-perennial establishing species (*L. rigidum*, *D. glomerata*, *M. polymorpha* and *M. sativa*) in different proportions, within the common activity of the COST Action 852 (2002). Compared with pure stands, grass-legume mixtures provided higher yields with better seasonal distribution and decreased unsown species presence. Moreover, the constraints related to management of perennial grass-annual legume mixtures under grazing at a farm scale are being studied in the PERMED (2005) project.

It is very important to determine the compatibility of the species to be utilised in the mixtures. According to several authors subclover used in mixture with annual medics and *T. michelianum* tends to dominate from the second year of establishment (Taylor and Rossiter, 1974; Dear *et al.*, 1999; Porqueddu *et al.*, 2004). Some studies are being

carried out at the SIDT station of Extremadura, Spain, using the same number of seeds for each species (i.e. *T. subterraneum*; *T. cherleri*; *T. glomeratum*; *T. striatum* L. (knotted clover); *M. polymorpha*; *O. compressus* and *B. pelecinus*, up to a whole of 20 kg ha⁻¹). The results show the dominance of *M. polymorpha* and *T. subterraneum*, suggesting that it is necessary to modify seed proportions taking into account seed vigour, and controlling the most vigorous species in the first stages by means of grazing (González, pers. comm.). Seed proportion in a species mixture is fundamental to get a balanced mixture. Advantages may be achieved combining seeds of different size (small and large seeds), hardseedness levels and softening patterns with the aim to guarantee long term pasture regeneration at satisfactory productive levels and to reduce inter- and intra-annual fluctuations. Moreover, every species colonises a different ecological niche so that the inclusion and ideal combination in mixture of new pasture legumes with traditional species, could be used to cope better with unpredictable climatic fluctuations and the extremely high heterogeneity of environmental and farming system situations (from large pasture areas to small single field scale).

LEGUME-RHIZOBIA SYMBIOSIS

N-fixation in nodulated pasture legumes is fundamental for the economic and environmental sustainability of Mediterranean farming systems. In the Mediterranean basin soils where rhizobia are usually widespread their importance has been overlooked, while contrastingly, in-depth studies and selection programmes have been carried out in new Mediterranean environments such as southern Australia, where the lack of adequate native rhizobia strains makes inoculation strictly necessary. Inoculation with suitable rhizobia is recommended, since there can be rhizobia shortcomings in soil, e.g. introduction or re-introduction of sown pastures into cereal crop fields, high acid soils. Nevertheless, in the Mediterranean basin there is a strong body of evidence that despite co-evolution of legume and rhizobia, the relationship is not always optimal (Howieson *et al.*, 2000b). Moreover, the commercial seed imported from Australian producers is often inoculated by the local seed companies or they suggest and provide inoculants also produced in Australia. However, there is no practical evidence on the effectiveness of such new inoculant strains and there is poor scientific knowledge on the interactions with natural populations of rhizobia and the fate of the introduced strains (Sulas, 2005).

The quantity of N fixed by Mediterranean legumes differ widely between species and environments (Unkovich and Pate, 2000). There is the need to determine the amount of N-fixation by pasture legumes at a local level for the development of appropriate agronomic techniques under both conventional and organic farm conditions. For example, in Sardinia, Sulas and Sitzia (2005), using the ¹⁵N dilution method, estimated fixed N

of 52 and 154 kg ha⁻¹ for grazed mixtures and a harvested pure stand of burr medic, respectively.

ALTERNATIVE USES OF ANNUAL SELF-RESEEDING LEGUMES

Annual self-regenerating legumes tend to be more and more used in non-conventional systems of southern Europe for sustainable environmental improvement. During the last decade they have been increasingly used as cover crops in vineyards, olive groves and orchards allowing low impact soil management alternatives to traditional tillage and herbicide application (Porqueddu *et al.*, 2000). Self-regenerating cover crops cope with many functions: reduce erosion risks and summer evaporation throughout the dead mulch, avoid the costs associated with tillage, improve soil fertility, increase soil carrying capacity for agricultural machinery and can be also used to reduce the vigour of vines. In many situations sward mowing can be substituted by sheep grazing making management easier and more economical. Subclovers and annual medics have been tested successfully in several Mediterranean regions (Masson and Gintzburger, 2000). Although they compete quite effectively with weeds it seems necessary to re-sow the cover crop in 3 to 4 years to ensure legume dominance or alternatively setting up more appropriate management techniques (e.g. minimum tillage in autumn) and using legume or grass-legume mixtures (Nieddu *et al.*, 2000). Subclover has been also proposed for use in cereal crops as living mulch, then subsequently used as cover crop and green manure (Campiglia *et al.*, 2000). Moreover, several varieties of subclovers proved suitable for understorey oversowing to improve forage quality and quantity in agroforestry and silvopastoral systems (Papanastasis, 1998). Pasture legumes have been also used to develop management systems of fire-break lines with grazing for fire prevention in some woody areas (Etienne, 1996; Caredda *et al.*, 2002).

Some annual legumes can be utilised as pioneer species for land rehabilitation and to restore biological activity in degraded sites (e.g. quarries, mine sites, roadsides). Preliminary results comparing native and commercial accessions are promising (Maltoni *et al.*, 2005) e.g. *O. sativus*, *T. campestre* Schreb. (hop clover) and *M. indica* (L.) All. (yellow sweet-clover) performed well on acid sandy soils.

PROSPECTS FOR ANNUAL PASTURE LEGUMES

The use of annual pasture legumes in the Mediterranean agro-pastoral and cereal-based farming systems increased in recent decades due to the rapid conversion of many farms to organic management, despite the general decrease of forage legumes across Europe. However, many farmers recently decided to go back to conventional farming

as a result of new European Union Directives, more restrictive in terms of subsidies for organic farming. At the same time seed demand for pasture legumes increased in Australia pushing up the seed price, and consequently seed demand for pasture legumes in some Mediterranean regions of Europe fell in the last two years. Moreover, the real prices for animal products are declining (e.g. milk ewe in Sardinia), reducing the product/inorganic-N fertiliser price ratio. Decoupling payments from production-related activities to agri-environment opportunities will reduce the attraction of growing arable crops such as cereals. This will encourage Mediterranean farmers to seek ways of reducing costs, associated with the use of inorganic-N fertilisers, soil tillages, purchased feed, and to increase their reliance on low-cost and low-input grassland systems with an associated important potential role of legume-based natural or sown permanent pastures. Because farmers in low-input systems cannot afford expensive seed, the easiness of seed harvesting is an essential trait for the development of new pasture legume species. Moreover, the ease of harvesting may play a major role in their adoption because, as in Australia, seed production can be achieved locally at the farm scale with conventional cereal harvesters. This may require the valorisation of new native pasture legumes with different traits to those possessed by the currently commercial materials, e.g. legumes with erect habit that set heads on the top of the plants such as *T. nigrescens* Viv. (ball clover). But at the same time a successful development of a European seed industry for Mediterranean pasture species is needed to make effective the selection activities carried out by several public research institutions. On the other hand, more efforts in on-farm experimentation and knowledge transfer to farmers about the correct incorporation and management of annual legumes is necessary for their full exploitation.

There is a great potential for the use of mixtures (i.e. only different annual legumes, annual grass-legumes, perennial grass-annual legumes) in forage and non-conventional systems. However, further studies should be aimed at investigating the adaptation mechanisms of annual legumes to associated companion grasses and the effects of management factors on the maintenance of a balanced sward botanical composition over time.

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PAPEL Y EL POTENCIAL DE LAS LEGUMINOSAS ANUALES EN LOS SISTEMAS PRATENSES DEL MEDITERRÁNEO

RESUMEN

En este artículo se revisa el uso actual de las leguminosas pratenses anuales de auto-resiembra en los sistemas pratenses del Sur de Europa. Las leguminosas anuales son la base principal para la mejora de los pastos naturales de sistemas extensivos. Especies tradicionales de leguminosas como el trébol subterráneo y las medicagos anuales son las plantas básicas de los pastos mediterráneos, que son esenciales para la mejora de los pastos de zonas semiáridas. Se analiza el papel de una reciente segunda generación de leguminosas pratenses anuales. Se tienen en cuenta algunos aspectos agronómicos clave y el nivel de producción y calidad del forraje. Se examinan las limitaciones relacionadas con la baja persistencia del material introducido y con el manejo de los pastos. Se analiza el potencial de utilización de las leguminosas en mezclas simples o complejas leguminosa-leguminosa o gramínea-leguminosa. Se toca también brevemente la asociación simbiótica leguminosa-rizobio. Finalmente, se relacionan los usos alternativos de las leguminosas anuales de auto-resiembra.

Palabras clave: Biodiversidad de pastos de leguminosas, mezclas gramínea-leguminosa, manejo de pastos con leguminosas, usos alternativos.