Legumes for rainfed Mediterranean farming systems

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Abstract: A wide range of legumes is traditionally used in Mediterranean regions, owing to the extreme variability of environmental conditions and farming systems. Annual forage legumes are cultivated as short-term forage crops, usually in mixture with cereals or grasses. Self-reseeding annual legumes are sown to improve permanent pastures in extensive agro-pastoral systems. Breeding programs are carried out on alfalfa to select varieties with high tolerance to summer drought, grazing, and attitude, to grow in mixtures with summer dormant perennial grasses. Other perennial legumes are also under study for their flexible utilization. Nonetheless, some critical aspects concern the legume seed production in Mediterranean Europe and the rhizobia-legume symbiosis.

Key words: mixtures, pasture and forage legumes, rainfed systems, sustainability

Introduction

The rising cost of inputs and the foreseen water scarcity due to climate change can impact negatively on forage production. Nitrogen-fixing legumes tolerant to drought may play a crucial role in strategies of adaptation to climate changes and mitigation of their effects, while enhancing the sustainability of Mediterranean farming systems, by: i) reducing GHG emissions and energy consumption associated with the industrial synthesis of nitrogen fertilizer, ii) increasing the resilience and water use efficiency of grasslands, iii) reducing the amount of methane emitted per unit of animal product, by means of better feed quality, more balanced diets and more productive animals (5), iv) contributing to the diversification and flexibility of farming systems, and v) reducing the marked deficit of high-protein feedstuff and the related feed insecurity and exposure to feed price volatility. This last aspect is particularly important for organic and typical animal products.

A wide range of annual and, to a lesser extent, perennial legumes can be adopted in Mediterranean environments, owing to their wide variation of soil, climatic and crop management characteristics.

Annual forage legumes

Annual forage legumes are re-seeded every year (Table 1). They can be grazed in winter, harvested in the following spring for hay, or harvested for grain and straw at maturity (2). Largely-grown species are *Trifolium incarnatum*, *T. alexandrinum* L., *T. resupinatum* L., *Vicia sativa* L. and *V. villosa* Roth. Less common species such as *Pisum sativum* L. and *V. narbonensis* L. are under study in drought-prone areas, also because of their flexibility of utilization (Fig. 1). Most species are usually grown in mixture with winter cereals (oat, *Avena sativa* L., or barley, *Hordeum vulgare* L.) or grasses (Italian ryegrass, *Lolium perenne* L.), to achieve better weed and disease control and/or higher yields.

Table 1. Environmental requirements of annual and perennial legumes suitable or used in Mediterranean areas

Species	Mean annual rainfall (mm)	pH	Soil requirements
Annual forage legumes			
Trifolium resupinatum	> 400	5.0 - 8.0	Tolerant to alkaline soils and salinity
T. incarnatum	> 450	5.0 - 7.5	Not tolerant to alkaline soils
T. alexandrinum	> 400	6.5 - 8.0	Adapted to saline and alkaline soils
T. squarrosum	> 450	6.0 - 8.0	It prefers alkaline soils
Vicia sativa	> 350	6.0 - 8.0	It prefers moderately fertile soils
V. villosa	> 350	6.0 - 8.0	Sensible to alluminum
V. narbonensis	> 300	6.5 - 8.5	Adapted to alkaline soils
Pisum sativum	> 400	5.5 -7.5	Sensible to salinity
Annual pasture legumes			
Trifolium brachycalycinum	> 450	6.0 - 8.0	Adapted to clay-rich soils
T. subterraneum	> 450	5.0 - 7.5	Adapted to sandy soils
T. yanninicum	> 400	5.5 - 7.5	Tolerant to water logging
T. michaelianum	> 350	5.0 - 7.5	Tolerant to water logging
T. hirtum	> 250	5.5 - 7.5	Adapted to well-drained soils
T. glanduliferum	> 350	4.5 - 7.5	Tolerant to water logging
T. vesiculosum	> 400	5.0 - 7.5	Adapted to sandy soils
Biserrula pelecinus	> 400	5.0 - 7.5	Adapted to sandy soils
Ornithopus compressus	> 350	4.5 - 7.0	It prefers sandy soils
O. sativus	> 350	4.5 - 7.0	It prefers sandy soils
Medicago polymorpha	> 300	5.5 - 8.5	Suitable for all types of soils
M. truncatula	> 250	6.5 - 8.0	It prefers clay soils
M. scutellata	> 400	6.5 - 8.5	It prefers not too fertile soils
M. rugosa	> 350	6.5 - 8.0	It prefers clay soils
Perennial legumes			
Medicago sativa	> 450	6.5 - 8.0	Sensible to water logging
Trifolium pratense	> 400	5.5 - 7.5	Tolerant to aluminum-rich soils
Sulla coronaria	> 350	6.5 - 8.5	Not suitable to coarse-textured soils
Onobrychis viciifolia	> 400	6.5 - 8.5	Not adapted to fine-textured soils
Bituminaria bituminosa	> 300	5.0 - 8.5	Broad adaptation to soils

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Figure 1. Experimental field of annual forage legumes (peas and vetches) in pure stand and in mixture with winter cereals under evaluation within the REFORMA Project

Figure 2. Flowering stage of *Bituminaria bituminosa*, a perennial legume with high drought tolerance able to grow and remain green all-year-round even during summer

Annual pasture legumes

Pasture legumes are widespread in Mediterranean natural and semi-natural grasslands. Species survival during summer droughts relies on seed dormancy (hard seeds) mediated by the presence of a water-impermeable coat. Proper management of the seed bank is fundamental for the preservation of annual species in permanent pastures. The most-grown species for pasture improvement are subterranean clover (*T. subterranuem* L.) and medics (*Medicago* spp.) (Table 1). When grown in suitable soils, they achieve long-lasting persistence through self-reseeding, while providing high levels of N fixation and excellent weed control. Their yield response is affected by the specific growing conditions, especially rainfall during the growing season (4). On average, their dry matter yields range from 3 t ha^{-1} $year^{-1}$ to 12 t ha^{-1} $year^{-1}$. The so-called second-generation alternative pasture legumes (e.g. *Biserrula pelecinus* L., *T. glanduliferum* Boiss.) are commercially available for pasture improvement. Most of them are imported from Australia, where they have been selected for the local management systems (ley farming, which requires high levels of hard seeds). When sown in Mediterranean permanent pastures, varieties of these species often show a difficult re-establishment in autumn, because of an unsuitable breakdown pattern of hardseededness that prevents a ready germination of seeds (8).

Perennial legumes

The most-known perennial legume is alfalfa (*Medicago sativa* L.). Its ability to respond to summer irrigation makes it suitable for forage production in Mediterranean environments with water availability. Under severe stress in rainfed conditions it frequently shows reduced persistence and yield. Breeding programs are exploiting landraces that evolved in rainfed Mediterranean environments to select new varieties with high tolerance to summer drought and grazing (2). The ERANet project REFORMA is investigating ecological and molecular strategies to improve alfalfa tolerance to drought, salinity and grazing, as well the potential to grow alfalfa in mixtures with summer-dormant perennial grasses (cocksfoot, *Dactylis glomerata* L., or tall fescue, *Festuca arundunacea* Schreb.).

Yet, other perennial legumes such as sulla (*Hedysarum coronarium* L.) and sainfoin (*Onobrychis viciifolia* Scop.) are able to survive summer drought and regrow after the first autumn rain, offering the opportunity to stabilize production and improve forage quality. An important trait of these two species is their flexibility of use, by direct grazing or hay production. In addition, they show moderate concentrations of condensed tannins that enhance their nutritive value by promoting amino-acid absorption in the intestine, decreasing nitrogen excretion and reduced loads of gastro-intestinal parasites (6). Studies on deep-rooted clover species (Caucasian clover, stoloniferous red clover, tallish clover) are being carried out in Tasmania and elsewhere. Another perennial legume with potential as a forage legume for Mediterranean areas is the native *Bituminaria bituminosa* (L.) C.H. Stirt (Fig. 2). This legume has deep roots and physiological traits conferring drought tolerance. It grows and remains green all-year-round, even during summer. It is assumed to be tolerant of heavy grazing and some accessions are being selected in Spain and Sardinia (9).

Higher yield gains, better seasonal distribution and better forage quality can be obtained through perennial and annual legume-grass mixtures of species belonging to different functional groups (i.e. fast and slow establishing grasses and legumes) (6). Moreover, the concurrent use of plants using different adaptation strategies might be one of the tools to overcome drought and improve the adaptation to climate change and the ecosystem stability.

Grain legumes

Pea (*Pisum sativum* L.) is the main feed grain legume along with faba bean (*Vicia faba* L.) in southern Europe. It has remarkable flexibility of utilization, as it may be harvested at crop maturity for grain and straw (whose nutritive value is slightly lower than an average lucerne hay), or harvested earlier for hay or silage production. In addition, it may be grazed at maturity when unfavorable climatic conditions lead to poor grain yield. The grain of modern pea varieties is valuable as a concentrate for livestock feeding, because of its high protein and energy value, lack of antinutritional factors, and ease of conservation. A traditional drawback of pea, namely its poor standing ability, has been improved remarkably by recent plant breeding. Novel varieties, however, have hardly ever targeted regions of the Mediterranean basin. Nevertheless, pea has showed higher grain yield than faba bean or lupins (*Lupinus* spp.) in southern Europe (1).

Legume-rhizobia symbiosis

Rhizobia are usually widespread in soils of the Mediterranean basin, leading to little artificial inoculation of legume seeds. Only sulla is frequently inoculated with a specific strain to guarantee plant establishment. In contrast, commercial seed of pasture legumes imported from Australia is often inoculated with specific strains selected in Australia from wild rhizobia populations collected in the Mediterranean basin. However, there is poor scientific knowledge on the interactions with natural populations of rhizobia and the fate of the introduced strains in Mediterranean soils (10).

Future challenges

The increasing interest in legume use for Mediterranean farming systems finds a bottleneck in the lack of a European seed industry that produces well-adapted Mediterranean forage and pasture legume species. This situation has prevented the full exploitation of the results of successful breeding programs for Mediterranean environmental condition carried out by public research institutions. Concurrently with breeding and marketing of improved and well-adapted varieties, it is essential to allocate more efforts to on-farm experimentation and knowledge transfer to farmers, with emphasis on the optimal management of legumes in different target environments and farming systems.

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