Nitrogen fixation in pasture systems



Biological nitrogen fixation plays an essential role in the improvement of agricultural sustainability, particularly with regard to the contribution of pasture legumes. In fact, pasture legumes are among the most efficient leguminous plants in terms of nitrogen fixation and, depending on adequate management and on the establishment of effective symbioses with adequate rhizobia, they may contribute with high input rates of fixed-nitrogen into the soil (Materon 1988). A successful example of the BNF contribution in pastures is given by a particular agrosilvopastoral system in the Mediterranean area of Southern Iberian Peninsula. This system, which is designated "montado" in Portugal or "dehesa" in Spain, represents the most extended agroforestry system in Europe, covering more than 3.5 million hectares over the west, south-west and central parts of the Iberian Peninsula (Olea and San Miguel-Ayanz 2006; Trujillo and Mata 2001). The " montado" has been developed for a long time on poor or non-agricultural land, based on extensive livestock production associated with the exploitation of cork and holm oaks. Both natural and sown pastures are implemented among scattered oak trees and support the direct grazing by cattle and sheep. The Mediterranean climate of the "montado" is characterized by hot dry summers, usually lasting for several months, and cool winters with irregular, often scarce rainfall; the same type of climate is found at middle latitudes in all continents, including large areas of West Asia, Australia and North Africa (Saxena 1988). Desertification is a common situation, particularly in regions where the precipitation regime is more inconsistent, resulting in progressive degradation of the vegetation cover and erosion of surface soil. As a consequence, soils in "montado" are generally poor, deficient in phosphorus and calcium, and contain low levels

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using a strategy founded on the efficiency and diversification of structures, the "montado" represents an extremely rational form of land use in these environments, taking advantage of every natural resource with minimum inputs of energy and materials (Joffre et al. 1988; Olea and San Miguel-Ayanz 2006). When properly implemented, this multifunctional and versatile system ensures the optimization of available energetic resources through biomass production, circulation of nutrients, conservation of soil and water, and preservation of biodiversity, also contributing to climate bio-regulation or microclimate stability (Trujillo and Mata 2001). Pastures are an essential component of the "montado", as main source of fodder for livestock. However, due to low soil fertility associated with a diverse but little productive native flora, natural pastures in the Portuguese "montado" are mostly poor and managed with low animal stocking rates. A recent study investigated the role of biological nitrogen fixation on a range of long term natural pastures in the "montado" ecosystem of Southern Portugal, covering different edaphoclimatic environments (Ferreira and Castro 2011). Legume yields and biological nitrogen fixation in field conditions were evaluated in 36 sites, using the isotopic ¹⁵ N-dilution technique to access the amount and percentage of nitrogen derived from biological fixation. Although the amounts of fixed nitrogen were highly variable among sites, the results showed that nitrogen fixation was closely linked to the legume biomass production (Table 2). On average, nitrogen fixation contributed with 25 kg of nitrogen per 1000 kg of shoot dry biomass, a value that is similar to other field measurements undertaken at Mediterranean-type environments in Australia (Baldock and Ballard 2004; Peoples et al. 2001). The percentages of https://assignbuster.com/nitrogen-fixation-in-pasture-systems/

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nitrogen derived from BFN were generally high (87-89%) and similar among sites, despite the large diversity of native legumes and the differences in edaphoclimatic conditions. It was concluded that biological nitrogen fixation in these natural ecosystems provides almost all the nitrogen present in legumes, indicating that the natural symbioses are well adapted to these environments. Nevertheless, the study also confirmed that the legume productivity in these natural pastures is very low, as the result of poor natural flora. In this context, the introduction of improved legumes with higher yield potential and previously inoculated with specific and highly effective rhizobia strains represents an efficient way of increasing productivity.

A model for improving pastures in the "montado" started to be developed in Portugal in the late 1960s and has been largely diffused since then, spreading throughout similar Mediterranean environments in southern Europe. The strategy is based on the establishment of biodiverse permanent pastures rich in legumes, by sowing a diversity of selected and improved species, in which inoculated legumes are preponderant. These biodiverse legume-rich mixtures provide better productivity than the natural flora and are able to renew themselves on a permanent basis (Crespo 2006). At least 30% of the sown mixtures are made up of hard seed legumes, including a range of annual clovers and annual medics, yellow serradella and biserrula. Inoculation of the legume seeds with specific and effective rhizobia ensures enhanced symbiotic nitrogen fixation in the pasture. This approach has demonstrated marked improvements on soil fertility and rapid build-up soil organic matter through carbon sequestration, offering superior pasture productivity and animal carrying capacity. Nowadays, it is considered as a powerful management tool for improving pastures yield in the "montado" ecosystem, in which legumes are important components of the strategy for increasing productivity and sustainability, using symbiotic nitrogen fixation as a major process of providing nitrogen to the soils.

Table 2. Legume yields and amounts of fixed nitrogen in long term natural pastures in the "montado" ecosystem of Southern Portugal.

Location	Soil origin/	Legume	Amount of		Soil origin/	Legume	Am
	site number	shoot yield	fixed-N 2	Location	site number	shoot yield	fixe
		(kg/ha)	(kg/ha)			(kg/ha)	(kg
Castro Verde	Schist 1	42	1.0	Portaleg re	Granite 16	732	21.
Castro Verde	Schist 2	724	16. 6	Portaleg re	Granite 17	100	2. 7
Castro Verde	Schist 3	720	24. 1	Portaleg re	Granite 18	772	17.
Castro Verde	Schist 4	107	3. 1	Portaleg re	Granite 19	71	1.6
Castro Verde	Schist 5	211	6. 4	Portaleg re	Granite 20	296	6. 9

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Castro Verde	Schist 6	14	0.4	Portaleg re	Granite 21	919	20.
Ourique	Schist 7	0	0. 0	Monfort e	Granite 22	178	5.3
Ourique	Schist 8	7	0.1	Monfort e	Granite 23	712	22.
Ourique	Schist 9	139	2. 6	Monfort e	Granite 24	302	6. 4
Serpa	Schist 10	1346	28. 6	Crato	Granite 30	42	1.2
Serpa	Schist 11	319	6. 8	Crato	Granite 30A	125	2.7
Serpa	Schist 12	548	16. 4	Alter	Granite 31	90	2. 5
Sousel	Schist 25	6	0.1	Alter	Granite 32	30	0. 8
Sousel	Schist 27	88	2. 5	Alter	Granite 33	68	1.8
Crato	Schist 28	42	1. 2	Crato	Granite 34	561	12.
Crato	Schist 29	125	2. 7	Crato	Granite 35	1003	26.
Nisa	Schist 37	281	7.7	Crato	Granite 36	1632	33.
Nisa	Schist 38	252	6. 7				

Nitrogen fixation i	Page 7		
Nisa Schist 3	9 242	6. 6	
Mean	274	7	449 11
Location	Soil of origin	Legume shoot yield	Amount of fixed-N
		(kg/ha)	(kg/ha)
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Castro Verde	Schist 2	724	16. 6
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Alter		Granite 32		30			0. 8	
Alter		Granite 33		68			1.8	
Crato		Granite 34		561			12. 8	
Crato		Granite 35		1003			26. 4	
Crato		Granite 36		1632			33. 5	
Nisa		Schist 37		281			7. 7	
Nisa		Schist 38		252			6. 7	
Nisa		Schist 39		242			6. 6	
Average				353			8. 9	
Location	Soil of origin	Legume shoot yield (kg/ha)	Amou fixed (kg/h	unt of -N a)	Locatio n	Soil origin/ site number	Legume shoot yield (kg/ha)	Amo fixe (kg/
Castro Verde	Schist 1	42	1.0		Monfort e	Granite 22	178	5.3
Castro Verde	Schist 2	724	16. 6		Monfort e	Granite 23	712	22.

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6. CONCLUDING REMARKS

The dependency of agriculture on nitrogen fertilizer inputs and the associated environmental costs, underscore the importance of biological nitrogen fixation by rhizobia in symbiotic association with legumes, mainly due to the advantage of being environmental friendly and ideal for sustainable agriculture. Several issues in this matter are important for understanding research on BNF in the present and in the future. However a concerted effort should be done to put knowledge into practical application.

Definitely, understanding the ecology of different rhizobial groups will further enhance the knowledge of rhizobia and will help to predict the environmental responses of rhizobial groups, bringing a more practical meaning to rhizobial classification and diversity. Also, soil populations of rhizobia are genetically diverse and could represent a pool of traits (such as plant growth-promoting activity, tolerance of soil acidity or salinity, or the ability to degrade pollutants) that can be readily exploited via selection or genetic manipulation for optimizing legume crop productivity.

Another important issue concerns the legume breeding programs, which must give greater emphasis to the symbiosis between host and rhizobia. Practical approaches to enhanced nitrogen fixation and improved tolerance to edaphic constraints would also permit lower costs and a more sustainable form of agriculture. Despite many decades of progress and the acquisition of a large amount of information, the physiological and molecular bases for the tolerance of legume rhizobia symbiotic systems to environmental stress remains largely unknown.

Finally, a better understanding of the diversity and dynamics of soil populations of rhizobia and how they affect the establishment of inoculant strains in nodules of the host plant is also required for the development of highly competitive commercial strains. The impact of agricultural practices, including the introduction of inoculants, on rhizobial diversity is little understood and there is a need for research in this area. In conclusion, the combination of a biotechnological approach (microbial inoculation) with a low-input technology could be a sustainable practice to facilitate the nutrient supply to plants.