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Utilization of forage legumes in pastoral systems: state of art in Uruguay *

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Introduction

Improved pastures, integrated by forage legumes, are the primary base of agriculture and cattle rearing in Uruguay. The growing demand for cattle products requires higher cattle productivity, which is at the present time limited by the yield and quality of the natural pastures, mainly based in summer grasses. Perennial sown pastures in Uruguay have had a slow but sustained increment in area in the last five decades, from 17.000 has in 1950 to 1.287.000 has in 2003, representing 7% of total pastoral area (DIEA, 2004). In spite of agricultural policies that promoted the sowing of introduced legumes in the sixties, natural grasslands over sown with legumes represents 5% of the total area at the present time (0,7 million has; DIEA, 2004). Diverse factors have influence on the slow adoption of sown pastures, among others the cost of establishment, the uncertainty of the physical result due to poor persistence of the introduced legumes, establishment difficulties, the need of careful defoliation management that require some legumes that produce bloat.

Extensive cattle production

Extensive cattle rearing in the North and Center of Uruguay is based on the production of beef, lamb and wool. The use of natural communities of grasses is the fundamental feeding of the cattle in the different eco-regions. The native communities of grasses have been grouped in five important regions by type of soil-geology-use of land: 1) Basaltic soils (superficial, medium and deep), 2) Sandy soils (Formation Tacuarembó and San Gregorio Tres Islas), 3) Brunosols of the Northeast, 4) Granitic soils of the Center-south, and 5) Rolling hills ("Lomadas del Este") and Granitic Hills of the East. Independently of the characteristics of each region, the types of exploitations and management of the ratio cattle/sheep, the average annual production of meat does not surpass 80 kg/ha on natural

grasslands, due to its variability and its low winter and/or summer growth, as well as for the medium to poor quality of its forage.

The description of the native communities (grasses, legumes, others) and its seasonal production for eco-region has been presented in Pastures IV (CIAAB, 1979). This publication summarizes the regional research that began at the end of the 60s with the establishment of regional experimental fields (CIAAB, Agricultural Plan, Direction of Soils - MGAP and Faculty of Agronomy). For their predominance, the grasses constitute the fundamental base of the natural swards (Rosengurtt, 1943; 1979; Rosengurtt *et al.,* 1970; Millot *et al.,* 1987; Izaguirre, 1995) that represent more than 70% of the area (approximately 11 millions hectares; DIEA, 2001).

Legumes in natural grasslands

Native legumes have been described in the different communities; their contribution varies from 0.8 to 3.6% of the total cover, where summer and winter grasses dominate (Castro, 1980; Berretta, 1994, 1998; Saldaña *et al.,* 2004). The main native legumes are: *Trifolium polymorphum*, *Adesmia bicolor*, *Desmanthus depressus*, *Desmodium* sp., although a great diversity of species exists, among others *Rhynchosia diversifolia*, *R. senna* (basaltic vertisols), *Arachis burkati*, *Lupinus* sp.. *Mimosa pudica* (sandy soils). These legumes are very sensitive to grazing and sheep/cattle ratio (Rosengurtt, 1979).

Phosphorus is an essential and deficient macronutrient in all the soils of the eco-regions. The fertilization of natural grassland with P does not produce an increase in forage yield of the native legumes in the short term (CIAAB, 1979). The slow response discourages farmers in the adoption of this technology, since there is no information of medium or long term interaction with grazing management and sheep-cattle ratio in communities dominated by grasses. In swards on Basaltic soils where there is a minimum proportion of high quality winter perennial grasses, Nitrogen and Phosphorus fertilization determines spring increment of grasses like *Poa lanigera* and *Stipa setigera* (Bemhaja *et al.,* 1998) and native legumes (*Adesmia bicolor*), although they are with a relatively low frequency in general (Berretta *et al.,* 2001).

Later investigations carried out with *Trifolium polymorphum* accessions obtained data about distribution, aerial and underground flowers, seed, tuberous roots, productivity, nutritive value and rhizobiology, whereas the distribution, fruit and seed, productivity, N fixation and nutritive value were established for *Adesmia bicolor* (Coll and Zarza, 1992; Izaguirre, 1995; Reyno *et al.,* 2004). Izaguirre and Beyhaut (2002¸ 2003) have published the botanical keys for indigenous and naturalized species of the genus *Trifolium* in Uruguay.

Introduction of legumes in natural grasslands

The introduction of legumes in natural swards provides Nitrogen to the system, increasing the quality and quantity of grasses. Therefore, this approach protects native genetic resources that contribute to the sustainable maintenance of biodiversity (FAO, 1996). The

introduction of cultivated and naturalized legumes and their associated symbionts on natural swards, as well as the establishment, persistence and phosphorus fertilization have been and continue being object of study in the eco-regions of extensive production of Uruguay. The best adapted legume to different native communities up to the mid eighties' have been *Lotus corniculatus* (cultivars San Gabriel, INIA Draco) and *Trifolium repens* (cultivars Estanzuela Zapicán and Bayucuá); they still maintain great importance today, so much in pure stands or in mixtures, under conditions of over sowing after defoliation by grazing, as well as in direct drilling without herbicide application (Ayala and Carámbula, 1996; Bemhaja, 1998; Risso et al., 2001; Olmos, 2001). The productivity of these pastures means significant changes in the seasonal production of the native grasslands (7 to 18 kg DM/ha/day in winter and 15 to 31 kg of DM/ha/día in spring) as well as in crude protein content (9 to 18%). *Lotus uliginosus* (=*L. pedunculatus*) has shown adaptation and persistence into specific ecological niches, such as Granitic hillsides and lowlandss, sandy soils and Eastern hills (Risso *et al.*, 1990; Bemhaja and Risso, 1998; Ayala *et al.*, 2001). *L. subbiflorus*, an annual species with marked seasonal production (from August to December), has been quickly adopted at commercial level, becoming the main legume for the improvement of natural grasslands in Uruguay, especially in the South and Eastern Granitic soils (Risso and Carámbula, 1998). In spite of its seasonality, the strategic use of this legume for the improvement of natural pastures due to the great reseeding capacity and persistence, stabilizes the carrying capacity by diminishing seasonal fluctuations (Risso *et al.*, 1997; Montossi *et al.*, 2000).

There are records of grassland improvements since the beginning of the 70s' in different extensive areas of Uruguay (deep basalt, Eastern and Southern Granitic, Northeastern Brunosols). The collections of naturalized and native populations of *T. repens* and *T. polymorphum*, respectively, have shown great variability as well as good adaptation to water stress conditions and grazing management when they have been evaluated under uniform conditions (Olmos, 2000). There is a similar potential to explore naturalized populations of *Lotus corniculatus* under extensive conditions at commercial level in the different echo-regions.

The introduction of adapted, persistent legumes into natural swards will directly benefit the cattle farmers' income. The highest seasonal stability in the improved natural grasslands allows an increment of the economic result of the extensive farms. This direct benefit to the farmer is based on the high impact that a low proportion of improved area promotes in the Integrated System of Production (ISP). There is evidence of a global improvement of the production systems that not only points to increase the productivity, but also to increase the quality of products, synchronization and reduction of the reproductive cycles, of both beef rearing and fattening systems that translates into an improvement in the net income of the farm for all the studied models. In summary, the integration of the improved natural sward to the ISP allows a better grazing management of natural swards and their communities that demands higher level of permanent and qualified labor. For example, the inclusion of legumes in only 10% of the land in the Granitic area increases the productivity in 20% (from 69 to 99 kg/ha of meat equivalent), whereas the net income increases more than twice. The increment of the area with legumes to 30%, a reachable objective in the medium term, would allow to increase the product to 161 kg/ha of meat equivalent and to increase the net income to 40 US$/ha, depending on meat prices (Ferreira and Pittaluga, 2001). Bearing in mind that

the potential area of the five eco-regions is superior to 11 millions hectares, it could have a strong social-economic impact for the extensive region and for the whole country, allowing a sustainable use of the natural resources that goes together with a specialization of labor and knowledge in the management of the species of the natural communities.

Crop-pasture intensive systems

Milk and meat products represent an economically important part of the agriculture-alimentary industry of Uruguay. The dairy cattle feeding and winter beef fattening are based on the establishment of productive cultivated pastures, formed mainly by perennial legumes. The most remarkable feature in the utilization of perennial legumes in intensive areas of Uruguay is their incorporation in the rotations with crops such as wheat, barley, oats, rice, corn, sunflower. The adoption of this technology has had an important impact in the rural economy, since it has been able to keep crop farmers in marginal areas of the region. In addition to the high nutritious value, forage legumes contribute to the rotation sustainability, as long as they reduce erosion and fertilization requirements (García Préchac, 2003). The legumes also improve soil structure and increase organic matter, inproving agricultural profitability (Montossi *et al.*, 2000; Moron, 2003; Fernández and La Manna, 2003). Soil organic matter decreased 8 times in continuous agricultural systems, compared with the rotational systems with pastures based on legumes (96 vs 744 kg OM/ha/year, Díaz-Rossello, 1994; Baethgen *et al.*, 1994).

Intensive systems have utilized rotations of perennial pastures with annual crops for decades, although their adoption has been slow. In 1950 the main cultivated legume was alfalfa, with 17.000 hectares in total, of which 3.000 were cultivated in the agricultural area of Colonia and Soriano. The area sown with pastures, mainly *L. corniculatus*, increased sharply as a consequence of agricultural policies of that time, reaching 302.000 hectares in 1966. 30% of these pastures were sown in the agricultural areas of Colonia and Soriano, process that gave origin to the crop-pasture rotational system.
The increment of the area with pastures has been progressive, although in the 90's took place an increment of magnitude again, duplicating the sown area. Maintaining the tendency, 25% of the area of artificial pastures concentrates in Colonia and Soriano, areas where farmers have massively adopted rotational systems. In the last decade the improvements of pastures (perennial and annual) reached 50% of the pastoral area in the intensive agricultural areas (DIEA, 2001).

Legumes utilized in intensive systems

The cultivation of the main legumes (*Lotus corniculatus, Trifolium pratense, T. repens, Medicago sativa*) began with complex mixtures of introduced seeds of diverse origins (Mediterranean, Oceania). Although 84% of the permanent pastures are composed by mixtures of species at the present time, the most relevant species has been and still is *L. corniculatus* (DIEA, 2001). Since the cultivated species of *Lotus* are the most successful exotic legumes under grazing conditions, local research has focused in the evaluation and introduction of species and varieties of *Lotus* with economic potential. The utilization of *L.*

subbiflorus sharply increased in the eighties, while more recently the interest in *L. uliginosus* has increased due to the good performance of cultivar Grasslands Maku. Characteristic such as high nutritive value, tolerance to acid soils, growth with low Phosphorus availability, high seed production for their easy multiplication, rusticity and simplicity of defoliation management without detriment of their productivity, determined the good adaptation of these species to the ecological conditions of the region (Risso, 1991; Risso and Carámbula, 1998).

L. corniculatus has been the predominant legume throughout four decades, not having been extensively cultivated in Uruguay before 1950 (Henry, 1952; DIEA, 2001). Its historical importance could be appreciated in the proportion of accessions of this perennial legume stored in USDA-GRIN, where 60% of the samples correspond to this species. The current importance of the species can be appreciate clearly in the area of pure legumes, crops that are usually dedicated to seed harvesting. For example, the total area of pure *Lotus* crops in 2000 was 117.543 hectares (61% of the total area of pure legumes), whereas red and white clover represent only 12 and 7%, respectively (DIEA, 2001). In spite of its adaptation, *L. corniculatus* production is limited by several environmental restrictions, such as drought and flooding, diseases and pests that affect the establishment, growth and persistence (Borsani *et al.*, 2001; Altier, 1997). The comparison of a high number of experiments has demonstrated that *L. corniculatus* has a higher variability compared with alfalfa, particularly in the second year (Díaz Lago *et al.*, 1996). Rain distribution throughout the year together with heavy silt soils determine successive changes from water excess to deficit, with periods of important shortage of water during summer that reduce productivity and persistence.

The creation of superior genetic materials in yield and/or resistance to adverse factors (biological or chemical) is one of the fundamental components of the sustainability of any production system (Francis, 1990). The cultivated forms are extremely important sources of genetic variation for the improvement of pastures (Charmet *et al.*, 1997). The natural selection as well as the introgression of local populations conducted to the development of locally adapted ecotypes and farmers landvarieties with the consequent increases in the adaptation as well as the intra-specific variability (Rebuffo and Abadie, 2001; Olmos, 2001; Rebuffo *et al.*, 2005). Outstanding examples are the local cultivars San Gabriel and Estanzuela Ganador that produce twice as much forage as most of the American cultivars of *L. corniculatus* (García *et al.*, 1988; INASE, 2001). The use of landvarieties in the breeding program has led to the development of *L. corniculatus* cultivar INIA Draco that produces 10% more forage than San Gabriel, the traditional variety (Rebuffo and Altier, 1997; INASE, 2001). Furthermore, its potential of adaptation has been observed in severe droughts, as 1999-2000, when almost all legumes dried off.

International efforts represented in the region by PROCISUR, have among their priorities the recognition and use of genetic resources and biotechnology for agriculture development (http://www.procisur.org.uy/). Although the enormous value of the genetic resources is recognized, up to date a limited support has been given to the collection and characterization of naturalized forage legumes with good adaptation to soils and climatic conditions of the region that attend to create more persistent cultivars. The multiplication of their own seed by traditional farmers of crop-pasture systems has generated naturalized populations adapted to

grazing (Rebuffo *et al.*, 2005). Even when these populations constitute a privileged genetic resource to identify characters of high adaptative value, the risk of genetic erosion has increased recently in Uruguay. The progressive changes in the rural structure (decrease in the number of farms), productive specialization (decrease of multiplication of their own seed), extension of soybean monoculture and the leveling of the environment imposed by the modifications of the agricultural ecosystems have contributed to the substitution of naturalized populations by new national or introduced varieties (Rebuffo and Abadie, 2001; Rebuffo *et al.*, 2005).

Historically, breeding of *Lotus* in Uruguay has been focused on introduction and evaluation of accessions. The high adoption of local cultivars of *L. corniculatus* (San Gabriel, Estanzuela Ganador, INIA Draco) reflects the success of this strategy. Nevertheless, INIA's Genetic Resources Unit, in an effort to safeguard landvarieties from genetic erosion, carried out in 1999 the collection of accessions generated by the most traditional farms, with the collaboration of PROCISUR - Subprogram Genetic Resources. This approach valorizes the National Banks, since it allows to supplement strategies of *ex situ* conservation (collection and long term conservation of genetic diversity in banks) bound to the maintenance of naturalized populations where they have evolved (*in situ* conservation made by the farmer; Swanson and Goeschl, 1999). 132 farmers actively participated in this activity, donating more than 130 samples of forage legumes, 74 of those correspond *Lotus* (Rebuffo *et al.*, 2005). The potential use of landvarieties in breeding does not generate additional costs to farmers, since the final product (new cultivars) is a current input of pastures. The increment in persistence will improve the agricultural environment by reducing soil erosion, while the higher production of biological nitrogen will contribute to the sustainability of rotational systems. In addition, the benefits can extend to most of the current area of perennial pastures (more than a million hectares) and areas of natural grasslands (more than 11 millions hectares), as it has been demonstrated by the largest productivity and persistence of INIA Draco in grassland improvements (Castaño and Menéndez, 1998).

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