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Leucaena feeding systems in Argentina. II. Current uses and future research priorities

Sistemas de alimentación con leucaena en Argentina: II. Situación actual y prioridades de investigación futura

ALEJANDRO RADRIZZANI[1], NAHUEL A. PACHAS[2,3], LUIS GÁNDARA[1], FERNANDO NENNING[1] AND DANTE PUEYO[1]

[1]*Instituto de Investigación Animal del Chaco Semiárido, Instituto Nacional de Tecnología Agropecuaria (INTA), Leales, Tucumán, Argentina.* inta.gob.ar
[2]*Former staff member of INTA, Leales, Tucumán, Argentina.* inta.gob.ar
[3]*School of Agriculture and Food Sciences, The University of Queensland, Brisbane, QLD, Australia.* agriculture.uq.edu.au

Abstract

This paper presents the current status of *Leucaena leucocephala* (leucaena) feeding systems and proposes research priorities for leucaena development in Argentina. Although research on leucaena as forage for cattle production began in the late 1960s, it was not widely adopted until 2010 (5 decades later). The recent adoption is related to the incorporation of the 'Australian technology package', previously adapted for use by farmers in the neighboring region of the Paraguayan Chaco. In June 2018, we surveyed 8 properties with about 2,400 ha of leucaena in silvopastoral systems for beef cattle production in the Argentinean Chaco region, as well as 10 smallholder farms with about 10 ha of leucaena protein banks for dairy cattle in the northeast of Argentina. In the silvopastoral systems, leucaena condition was excellent on most properties in the 750–1,350 mm/year rainfall zone and low/poor on only 1 farm due to low rainfall (600 mm/year). In protein banks, leucaena condition was excellent or good on 6 of the properties and low/poor on the remaining 4, attributed to ingress of weeds and/or overgrazing. Grass condition was good in most of the systems but was low/poor in 2 silvopastoral systems due to very high stocking rates imposed to restrict leucaena height. Although there is high potential for leucaena development in Argentina, expansion should take place carefully with leucaena planted only on areas suitable for successful establishment, and using appropriate management practices to reduce establishment failures and costs, restrict leucaena height, enhance grass persistence, improve grazing strategies and manage mimosine toxicity problems.

Keywords: Beef cattle, Chaco region, forage tree legumes, protein banks, silvopastoral systems.

Resumen

Este trabajo presenta la situación actual de sistemas de producción ganadera que utilizan *Leucaena leucocephala* (leucaena) en Argentina. Aunque la investigación en leucaena como forrajera para la producción ganadera comenzó a fines de los 60s, la especie fue adoptada en mayor escala recién a partir del 2010 (5 décadas después). Esta reciente adopción se relaciona con la incorporación del 'paquete tecnológico australiano', también adoptado y adaptado por productores de la región vecina del Chaco paraguayo. En junio de 2018 identificamos y avaluamos unas 2,400 ha (8 propiedades) de leucaena en sistemas silvopastoriles de bovinos de carne en la región del Chaco argentino. Al mismo tiempo, evaluamos unas 10 ha (10 pequeños productores) con leucaena como bancos de proteína para vacas lecheras en el noreste argentino. En los sistemas silvopastoriles, la condición de leucaena fue calificada como excelente en la mayoría de los campos ubicados en áreas con precipitación anual de 750 a 1,350 mm/año, a excepción de una propiedad con mala condición de leucaena asociada a la baja precipitación (600 mm/año). En los bancos de proteína, la condición de leucaena fue valorada como excelente y buena en el 60% de los campos

Correspondence: Alejandro Radrizzani, Instituto de Investigación Animal del Chaco Semiárido, INTA, Chañar Pozo s/n, CP 4113, Leales, Tucumán, Argentina. Email: radrizzani.alejandro@inta.gob.ar

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y fue mala en el 40% restante, atribuida a la falta de control de malezas y/o sobrepastoreo. La condición de las gramíneas fue buena en la mayoría de los sistemas, pero fue mala en 2 de los sistemas silvopastoriles donde se aplicó alta presión de pastoreo para evitar el crecimiento excesivo de leucaena. Si bien existe un gran potencial para el desarrollo de leucaena en Argentina, la expansión debe hacerse cuidadosamente, seleccionando solo aquellos sitios apropiados para su crecimiento, y aplicando prácticas de manejo adecuadas para reducir riesgos y costos de implantación, restringir la altura excesiva, aumentar la persistencia de las gramíneas, mejorar las estrategias de pastoreo y manejar los problemas de toxicidad por mimosina.

Palabras clave: Bancos de proteína, ganado de carne, leguminosas forrajeras arbóreas, región del Chaco, sistemas silvopastoriles.

Introduction

Leucaena (*Leucaena leucocephala)* is grown as forage for grazing cattle in the subtropical region of the north of Argentina, where livestock graze mainly on pastures and grasslands that are deficient in protein for much of the year. Both research and extension staff recognize that the introduction of leucaena into grass pastures as hedgerows (silvopastoral systems) and as blocks of high leucaena density (protein banks) has excellent potential to increase both forage quality and animal production in areas suitable for its growth. This paper presents the current status of use of leucaena in livestock feeding systems in Argentina and proposes research priorities for future development.

Usage of leucaena feeding systems

In May-June 2018, we surveyed leucaena growers in Argentina to gather information regarding property location, area of established leucaena, its intended use, planting methods employed, grazing management, condition of grass and leucaena and any concerns about leucaena introduction into their feeding systems. We might not have included all growers, as adoption of leucaena feeding systems in the region has not previously been documented.

Hedgerow silvopastoral systems

Eight properties with leucaena established in hedgerow silvopastoral systems were surveyed and were located in the 600–1,350 mm average annual rainfall (AAR) zone of the Chaco region (Salta, Chaco and Formosa provinces) (Figure 1; Table 1). These silvopastoral systems were established between December 2011 and January 2018 and covered a total area of 2,379 ha (average 297 ha/property, range 4–950 ha). Physical and chemical properties of prevailing soils on the farms did not present any major obstacles to the growth of leucaena. The main purpose for introducing leucaena into the grazing systems was to improve forage and beef production and to enhance soil nitrogen (N) concentration and hence sustainability of the system. On all properties, leucaena was planted in twin rows with 5–10 m inter-row spacing using scarified seed of cv. Tarramba (improved K636) imported from Paraguay (previously imported to Paraguay from Australia). On one property (ID 4 in Table 1) leucaena cv. Cunningham was sown on part of the farm and cv. Tarramba on the other part. On 5 properties (63%) seed was inoculated with specific rhizobium provided by INTA's Institute of Microbiology and Agricultural Zoology (IMYZA-INTA), while seed was sown without rhizobia on the other 3 properties. The most common grass species sown in the inter-row spaces were *Megathyrsus maximus* (4 pastures with cv. Gatton panic and 1 with cv. Tanzania) and *Urochloa brizantha* (syn. *Brachiaria brizantha*) cv. Marandu, while other species were *Dichanthium aristatum* and native grasses. All leucaena silvopastoral systems were rotationally grazed, 6 at high grazing pressure and the remaining 2 at very high grazing pressure based on 4 possible ratings (low, moderate, high and very high). Cattle were inoculated with the mimosine-degrading rumen bacterium *Synergistes jonesii* imported from Paraguay (previously imported from Australia to Paraguay) on 5 properties, while no inoculum was applied on the other 3 properties.

Current leucaena condition, based on 4 possible levels (low/poor, moderate, good and excellent), was excellent on 7 farms, while the other property, where growth was rated as low/poor, was located in a dry zone (600 mm AAR) and 2 years after planting (February 2013) only 50% of the plants had survived. The farmer attributed leucaena mortality to low rainfall on this property (ID 2 in Table 1), since the surviving plants have persisted in depressions where soil water content was highest. The same farmer is successfully grazing 588 ha of leucaena in the northeast of Salta province (ID 1 in Table 1), where AAR is 750 mm. Current grass condition (same condition scale) was good on 6 of the properties and low/poor on 2 farms, where very high stocking rates were employed. These 2 farmers reported that leucaena had been heavily grazed to restrict the height growth of leucaena plants, causing overgrazing of the inter-row grass. The main concerns about leucaena silvopastoral systems were poor grass persistence and excessive leucaena height.

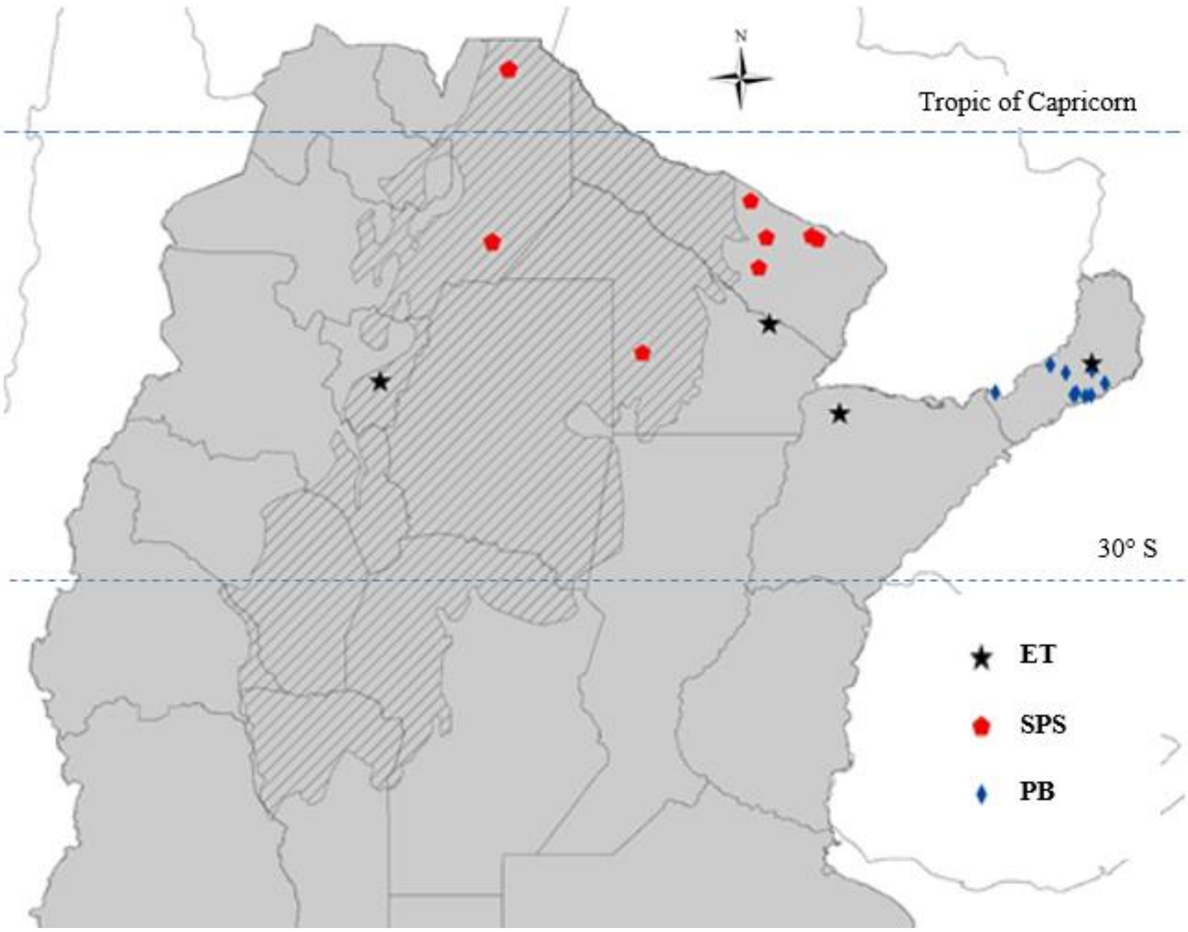

Figure 1. Leucaena feeding systems recognized and surveyed in Argentina in 2018: 8 hedgerow silvopastoral systems (SPS), 10 protein banks (PB) and 4 experimental trials (ET). The hatched area represents the Dry Chaco region.

Table 1. Characteristics of the leucaena hedgerow silvopastoral systems surveyed.

ID	AAR (mm/yr)	Leucaena area (ha)	Establishment (month and year)	Inter-row spacing (m)	Seed inoculation	Companion grass[1]	Cattle inoculation	Grazing pressure	Current leucaena condition	Current grass condition
1	750	588	Dec. 11–Mar. 14	5.5 (twin)	Yes	Mm	Yes	Very high	Excellent	Low/poor
2	600	104	Feb. 13	6 (twin)	Yes	Mm	Yes	High	Low/poor	Good
3	950	50	Oct. 17	6 (twin)	No	Ub	No	High	Excellent	Good
4	1,100	28	Mar. 14	5 (twin)	Yes	Nat - Mm	Yes	Very high	Excellent	Low/poor
5	1,350	650	Jan. 17–18	8–10 (twin)	Yes	Mm - Ub	Yes	High	Excellent	Good
6	1,150	950	Jan. 15–16	10 (twin)	Yes	Mm	Yes	High	Excellent	Good
7	1,000	4	Dec. 11	5 (twin)	No	Ub - Da	No	High	Excellent	Good
8	900	5	Dec. 17	6 (twin)	No	Ub	No	High	Excellent	Good

[1]Mm: *Megathyrsus maximus*; Ub: *Urochloa brizantha*; Nat: Native grass; Da: *Dichanthium aristatum*.

The survey indicated that recent adoption of leucaena in Argentina was based on technology developed over the last 2 decades in northern Australia, including mechanical seed scarification, improved agronomic practices, especially weed control during establishment, appropriate animal management and solving of the mimosine toxicity problem (Dalzell et al. 2006; Radrizzani et al. 2010). This 'Australian technology package' was adopted initially by cattle farmers in the neighboring central Chaco region of Paraguay, where the area sown increased from 20 ha in 2001 to about 10,000 ha in 2018 (Glatzle et al. 2019). A contributing factor in this expansion was the introduction of cv. Tarramba and the rumen bacterium from Australia, with the support of the Central Chaco Research Station (EECC) and the Initiative for Sustainable Agricultural Technology Research and Transfer (INTTAS) (Klassen 2005).

Protein banks

Ten properties with leucaena protein banks for dairy cattle production were surveyed in the 1,650 mm AAR zone of the Misiones province, in the humid Mesopotamia region of northeast Argentina (Figure 1; Table 2). These protein banks occupied a total area of 10 ha (average 1 ha/property, range 0.25–3 ha). Physical and chemical properties of prevailing soils on the farms did not present any major obstacles to the growth of leucaena. The main purpose of introducing leucaena to these grazing systems was to improve forage quantity and quality for increased milk production, and to enhance soil fertility from atmospheric nitrogen fixed by leucaena. Most of the farmers established leucaena between December 2010 and October 2011, while one planted it in October 2006. In contrast with hedgerow silvopastoral systems, all protein banks were planted in single rows 1.5–2.5 m apart using cvv. Cunningham and Peru. Seed was inoculated with rhizobia on 9 properties with specific rhizobium provided by IMYZA-INTA. The most common grass species sown between leucaena hedgerows was *Axonopus catarinensis* ('Jesuita gigante'), while other species were *U. brizantha* and *Cynodon nlemfluensis* ('pasto estrella'). All protein banks were rotationally grazed, 8 at high grazing pressure and the remaining 2 at very high grazing pressure. Cattle were not inoculated with the mimosine-degrading rumen bacterium on any property.

Current leucaena condition was excellent on 2 farms, good on 4 farms and poor on the remaining 4, owing to an ingress of weeds and/or overgrazing. Grass condition was good on 9 properties with only a single farm classed as moderate, associated with a very high stocking rate. The main concerns about leucaena protein banks were how to manage leucaena in relation to intensity and frequency of grazing and height control. Poor establishment and overgrazing were observed on farms that received less technical support. Farmers were not familiar with managing leguminous trees in their feeding systems and need ongoing technical support to optimize the establishment and persistence of their protein banks. While dairy farmers are still interested in growing leucaena in the Misiones and Corrientes provinces, based on the assessment of research and extension personnel, adoption remains low, probably due to a lack of promotion and information about how to utilize leucaena for feeding dairy and beef cattle.

Experimental trials

Four experiments were identified and surveyed. Their main purposes were: to evaluate leucaena persistence under different environmental conditions, agronomic practices and grazing systems; to determine the potential of leucaena introduction to improve forage and animal production; and to enrich soil fertility and C sequestration in the soil. The 4 experiments occupied a total area of 5.2 ha (average 1.3 ha/experiment, range 0.2–4 ha) and were located on Experimental Farms operated by INTA (Figure 1; Table 3).

'Cerro Azul' Agricultural Research Station, 'Cuartel Río Victoria' farm. This farm (ID 1 in Table 3) is located in the center of Misiones province where AAR is 1,650 mm. The soils in the experimental area are Ultisols and Oxisols (Rhodic Kandiult and Rhodic Hapludox, respectively, in the US Soil Taxonomy System), deep, well-drained, strongly acidic and of low fertility (including high aluminum concentration). Leucaena cvv. Cunningham and Peru were planted in October 1985 as a protein bank for dairy cattle production, in single rows 2 m apart. *Cynodon nlemfuensis* was planted between the rows.

Table 2. Characteristics of the leucaena protein bank systems surveyed.

ID	AAR (mm/year)	Leucaena area (ha)	Establishment (month and year)	Inter-row spacing (m)	Seed inoculation	Companion grass[1]	Cattle inoculation	Grazing pressure	Current leucaena condition	Current grass condition
1	1,650	0.9	Dec. 10	1.5 (single)	Yes	Ac	No	High	Good	Good
2	1,650	0.8	Jun. 11	1.5 (single)	Yes	Ac	No	Very High	Good	Moderate
3	1,650	3.0	Sep. 11	1.5 (single)	Yes	Ub	No	Very High	Poor	Good
4	1,650	1.0	Oct. 11	1.5 (single)	Yes	Ac	No	High	Poor	Good
5	1,650	0.5	Sep. 11	1.5 (single)	Yes	Ac	No	High	Good	Good
6	1,650	0.5	Sep. 11	1.5 (single)	Yes	Ac	No	High	Poor	Good
7	1,650	1.0	Sep. 11	1.5 (single)	Yes	Ac	No	High	Good	Good
8	1,650	0.3	Oct. 11	1.5 (single)	Yes	Ac	No	High	Excellent	Good
9	1,650	0.8	Sep. 11	2.5 (single)	Yes	Ac	No	High	Poor	Good
10	1,650	1.0	Oct. 06	1.0 (single)	No	Cn	No	High	Excellent	Good

[1]Ac: *Axonopus catarinensis*; Ub: *Urochloa brizantha*; Cn: *Cynodon nlemfuensis*.

Table 3. Characteristics of the experimental trials surveyed (1. INTA Cerro Azul; 2. INTA El Colorado; 3. INTA Leales; and 4. INTA Corrientes).

ID	AAR (mm/year)	Leucaena area (ha)	Establishment (month and year)	Inter-row spacing (m)	Seed inoculation	Companion grass[1]	Cattle inoculation	Grazing pressure	Current leucaena condition	Current grass condition
1	1,650	2.0	Oct. 85	2 (single)	No	Cn	No	High	Good	Good
2	1,150	0.8	Oct. 01	8 (single)	No	Cp - Ub	No	Very high	Excellent	Low/poor
3	880	4.0	Dec. 09	5 (double)	Yes	Ub - Cg	No	Very high	Excellent	Low/poor
4	1,350	0.2	Oct. 16	2–8 (double)	No	Ub	No	High	Excellent	Good

[1]Cn: *Cynodon nlemfuensis*; Cp: *Cenchrus purpureus;* Ub: *Urochloa brizantha*; Cg: *Chloris gayana.*

'El Colorado' Agricultural Research Station. This site (ID 2 in Table 3) is located in the southeast of Formosa province with AAR of 1150 mm. The soil in the experimental area is a Mollisol (Oxic Haplustoll in the US Soil Taxonomy System), clayey but well-drained, acidic. Leucaena cv. Cunningham was sown in a hedgerow pastoral system (single rows 8 m apart) in October 2001 with *Urochloa brizantha* and *Cenchrus purpureus* (syn. *Pennisetum purpureum*, 'pasto elefante') in the inter-row spaces. The pasture was rotationally grazed at very high stocking rates.

Animal Research Institute of the semi-arid Chaco region in Leales. Located in the southeast of Tucumán province, this site (ID 3 in Table 3) has AAR of 880 mm. The soils in the experimental area are Mollisols (Fluventic Haplustoll and Typic Haplustoll in the US Soil Taxonomy System), both well-drained with slow to good permeability, slightly basic reaction. Leucaena cv. K636 was sown as a hedgerow silvopastoral system in double rows 5 m apart after inoculation with specific rhizobium provided by IMYZA-INTA in December 2009. *Urochloa brizantha* was sown in the inter-row spaces in association with *Chloris gayana* ('grama Rhodes'). The pasture was rotationally grazed at very high stocking rates.

Corrientes Agricultural Research Station. The research station (ID 4 in Table 3) is located in the northwest of Corrientes province with AAR of 1,350 mm. The soil in the experimental area is a Mollisol (Aquic Argiudoll in the US Soil Taxonomy System), clayey, with low phosphorus, slightly acidic. Cultivar Cunningham was sown as a hedgerow silvopastoral system in October 2016 in double rows at different row spacings (2–8 m apart) with *U. brizantha* in the inter-rows.

Cattle were not inoculated with the mimosine-degrading rumen bacteria in any experimental trial. Leucaena condition was good to excellent at all sites, while grass condition was low/poor at El Colorado and Leales, associated with very high grazing pressure and overgrazing.

Apart from the 4 experiments, germplasm is preserved in 2 leucaena collections in Argentina. The first was established at INTA Corrientes in September 1994 and the second, a replica of the first, at the Animal Research Institute of the semi-arid Chaco region in Leales, Tucumán in September 2011. The 57 accessions of *Leucaena* spp. and hybrids in each collection were selected by Goldfarb and Casco (1998) for low-temperature tolerance and for forage yield and quality.

Future research and development priorities

The potential for further adoption of leucaena in subtropical Argentina, particularly in the Chaco region, is huge. Areas suitable for leucaena are mostly in the subhumid part of the Chaco region (AAR 700–1,200 mm), where large and medium size farms for breeding and finishing beef cattle predominate. Both domestic and export markets require tender beef that usually is produced in farming systems where cattle gain weight throughout the whole year, which is difficult for farmers to achieve on native pastures in the north of Argentina without significant protein and energy supplementation. Leucaena is an excellent protein source with potential to increase daily liveweight gains in the Chaco region (Radrizzani and Nasca 2014) and can contribute to reducing reliance on expensive protein supplements for growing and finishing cattle.

Other benefits from leucaena demonstrated in the Chaco region are its contribution to deep C storage/ sequestration in the subsoil and to increased availability of soil N in the topsoil (Banegas et al. 2019). Moreover, there is substantial potential for dairy cattle farmers in the humid Mesopotamia region of northeast Argentina to establish leucaena to supply protein-rich forage and improve digestibility of native grasslands and improved grass pastures (Pachas et al. 2011; 2012). Nitrogen is the key element for sustaining grazing systems and there is a great opportunity for increasing usage of tropical forage legumes as cattle farming systems are intensified.

However, many issues still need to be clarified if maximum benefit is to be obtained from this 'new' technology, namely:

- *High establishment risks and costs***.** Since leucaena seedlings are susceptible to ant attacks, weed and grass competition and predatory wildlife (rabbits), leucaena has to be planted as a crop using current cropping techniques (e.g. zero till for sowing leucaena into grass pastures, selective herbicides for weed control and appropriate insecticides for ant control). Furthermore, the erratic leucaena establishment associated with the unreliable summer rain of the semiarid Chaco region demands careful approach to establishment. The establishment cost of leucaena hedgerows, plus the establishment cost of the grass, plus seed scarification, plus ant, weeds and rabbit control, is higher (about double) than that of a pure-grass pasture. Consequently, a long productive life of leucaena is essential to achieve high returns and allow repayment of the initial investment in establishment.
- *Inoculation with an effective rhizobial strain.* This is required to promote vigorous leucaena growth. Native rhizobia in the soil in northeast Argentina are unlikely to form effective nodules with leucaena and will fix little, if any, N (Radrizzani et al. 2019). However, no commercial leucaena inoculant is readily available and only IMYZA-INTA supplies specific rhizobial strains to leucaena growers. To maintain the availability of inoculant, it is vital to preserve the IMYZA-INTA strain collection. This collection could also provide strains to assess rhizobial effectiveness and competitiveness in both the northeast and northwest regions. Moreover, since farmers expect to enhance soil N concentration using leucaena in their pastures, further research is needed to determine soil organic carbon and total N stocks, and to quantify actual biological N fixation by leucaena in association with different rhizobial strains under a range of environmental conditions, management practices and grazing systems.
- *Excessive leucaena height.* Large animals (big steers, bulls and cows) control leucaena height better than small animals, since they can break down tall stems (4–5 m) to reach leaf at the tips. However, most cattle in Argentinean herds are small animals, such as calves, heifers and even fattening steers (mean live weight at slaughter is 280–300 kg for the domestic market), and only a few animals in the herds are large (cows, bulls and steers finished for export). When leucaena plants grow to beyond browse height, material above the desirable height must be removed by trimming machines (e.g. slashers/mulchers, tree pruners and roller-choppers). This operation incurs unnecessary costs. Development of appropriate machinery and management practices to control leucaena height is necessary.
- *Low grass persistence***.** This problem is closely linked to excessive leucaena height since, when grazing pressure is increased to control the height of leucaena hedgerows, overgrazing of the inter-row grass can result. Grass persistence and productivity over time need to be evaluated under different management practices and grazing regimes. Grass management in relation to leucaena density (inter-row spacing, double or twin rows, plant numbers/ha) and plant height also must be evaluated to properly understand the interaction between leucaena and grass (competition and ecosystem benefits).
- *Interactions between leucaena and grasses.* A better understanding of above- and below-ground interactions between leucaena and grasses is required to optimize the design and management of leucaena silvopastoral systems given the highly variable rainfall and severe dry seasons in the Chaco region. Studies on root distribution of both leucaena and grass, together with better knowledge of soil water usage and the resulting water use efficiencies under diverse leucaena densities (e.g. combinations of single or twin rows with varying inter-row spacings) and different environmental conditions, management practices and grazing systems, would provide information to promote efficient use and long-term stability of leucaena feeding systems.
- *Improved winter growth of leucaena*. This is needed as in many areas of northern Argentina growth is constrained by cold temperatures and frost (Radrizzani unpublished data), which occur at a time when leucaena is most needed to supply protein to ruminant diets. There are promising cold-tolerant accessions in the INTA collection which could increase forage availability in winter (Radrizzani et al. 2019). Research to evaluate these accessions under different environmental conditions, agronomic management and grazing systems needs to be continued. Furthermore, development of new leucaena varieties, cultivars and even interspecific hybrids, e.g. combining the frost resistance of *L. retusa* and *L. greggii* with the vigor and cool-season growth of *L. pallida*, *L. diversifolia* and *L. trichandra* and the superior forage quality of *L. leucocephala,* could help fill the winter forage gap and extend the environmental adaptation of *Leucaena* spp. in Argentina.
- *Mimosine toxicity***.** Concern about mimosine toxicity and its management has contributed to restrict

adoption of leucaena as a forage for ruminants in Argentina (Radrizzani et al. 2019). Farmers are uncertain if their animals are suffering from toxicity since animals may still be performing better in systems with leucaena than in those without it. Research is needed to clarify the effects of feeding high leucaena diets on cattle performance (Shelton et al. 2019) and to improve management practices (Halliday et al. 2018), along with extension activities for future success of leucaena feeding systems.

- ***Scarce research and development programs*.** For successful leucaena adoption, farmers must increase their skills and become involved in the process of testing and validating the technology and even in establishing priorities for research. Research and extension specialists must develop and provide to farmers all necessary information for effective leucaena adoption, if the species suits their farming system. Participatory research and extension activities, including training courses, on-farm demonstrations and field days, are valuable techniques to ensure that accurate and practical information about the technology is readily available and is transmitted to farmers using appropriate tools. A flexible approach is necessary to allow farmer innovations to be included in the information base to improve recommendations and for these to be passed on to other farmers in their locality (neighbors) and in other regions.

Conclusion

Leucaena as forage for cattle production was not widely adopted in Argentina until 2010 and there is still a considerable potential for a broader adoption in the north of the country. However, expansion should take place wisely, selecting only suitable areas for its establishment, and using appropriate management practices to: reduce establishment costs and risk of failure; restrict leucaena height; enhance grass persistence; improve grazing strategies; and manage mimosine toxicity problems. Although some adoption can be achieved with relatively little intervention, for complex and new farming systems, such as leucaena silvopastoral systems, sustained support from the State and private sector is required in order to reach maximum adoption with real impact for the economic, environmental and social well-being of farmers and rural communities.

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References

(Note of the editors: All hyperlinks were verified 14 August 2019.)

Banegas NR; Corbella R; Virual E; Plasencia A; Roig B; Radrizzani A. 2019. *Leucaena leucocephala* introduction into a tropical pasture in the Chaco region of Argentina: Effects on soil carbon and total nitrogen. Tropical Grasslands-Forrajes Tropicales 7:295–302. doi: 10.17138/TGFT(7)295-302

Dalzell SA; Shelton HM; Mullen BF; Larsen PH; McLaughlin KG. 2006. Leucaena: A guide to establishment and management. Meat & Livestock Australia Ltd, Sydney, Australia.

Glatzle AF; Cabrera AN; Naegele The Late A; Klassen N. 2019. Leucaena feeding systems in Paraguay. Tropical Grasslands-Forrajes Tropicales 7:397–402. doi: 10.17138/TGFT(7)397-402

Goldfarb MC; Casco JF. 1998. Selection and agronomic characterisation of *Leucaena* spp. genotypes for cold tolerance. In: Shelton HM; Gutteridge RC; Mullen BF; Bray RA, eds. Leucaena – adaptation, quality and farming systems. Proceedings of a Workshop held in Hanoi, Vietnam, 9–14 February 1998. ACIAR Proceedings 86. ACIAR, Canberra, Australia. p. 172–173. purl.umn.edu/135197

Halliday MJ. 2018. Unravelling *Leucaena leucocephala* toxicity: Ruminant studies in eastern Indonesia and Australia. Ph.D. Thesis. The University of Queensland, Brisbane, Australia. doi: 10.14264/uql.2018.382

Klassen N. 2005. Producción animal con Leucaena en el Chaco. In: Glatzle A; Klassen P; Klassen N, eds. 2005. *Leucaena* y otras leguminosas con potencial para el Chaco. Congreso Internacional, Iniciativa para la Investigación y Transferencia de Tecnología Agraria Sostenible (INTTAS), Loma Plata, Paraguay, 9–11 March 2005. p. 4–16.

Pachas AN; Colcombet L; Fassola HE. 2011. Los sistemas silvopastoriles en Argentina. Oportunidades para pequeños productores de producción de leche en sistemas silvopastoriles en la provincia de Misiones, Argentina. In: Memorias, III Congreso sobre Sistemas Silvopastoriles Intensivos para la ganadería sostenible del siglo XXI, Morelia y Tepalcatepec, Michoacán, Mexico, 2–3 marzo 2011. bit.ly/2KHUOOx

Pachas ANA; Dehle R; Colcombet L; Esquivel JI; Fleitas F. 2012. Sistemas silvopastoriles intensivos en Misiones. In: Actas del 2º Congreso Nacional de Sistemas Silvopastoriles, Santiago del Estero, Argentina, 9–11 May 2012. p. 191.

Radrizzani A; Dalzell SA; Kravchuk O; Shelton HM. 2010. A grazier survey of the long-term productivity of leucaena (*Leucaena leucocephala*)-grass pastures in Queensland. Animal Production Science 50:105–113. doi: 10.1071/AN09040

Radrizzani A; Nasca JA. 2014. The effect of *Leucaena leucocephala* on beef production and its toxicity in the Chaco Region of Argentina. Tropical Grasslands-Forrajes Tropicales 2:127–129. doi: 10.17138/TGFT(2)127-129

Radrizzani A; Pachas ANA; Gándara L; Goldfarb C; Perticari A; Lacorte S; Pueyo D. 2019. Leucaena feeding systems in Argentina. I. Five decades of research and limitations for adoption. Tropical Grasslands-Forrajes Tropicales 7:381–388. doi: 10.17138/TGFT(7)381-388

Shelton HM; Graham LK; Dalzell SA. 2019. An update on leucaena toxicity: Is inoculation with *Synergistes jonesii* necessary? Tropical Grasslands-Forrajes Tropicales 7:146–153. doi: 10.17138/tgft(7)146-153

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