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Establishment and management of leucaena in Latin America

Establecimiento y manejo de leucaena en América Latina

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Abstract

Leucaena leucocephala (leucaena) is native to Mexico and Central America and is currently naturalized in the majority of Latin American countries. Over the last 2 decades, considerable research and promotion of leucaena have been carried out in Colombia, Mexico, Cuba, Brazil, Paraguay and Argentina. Research focused on the agronomic and management options for feeding beef, dairy or dual-purpose animals, with some studies on germplasm, weediness issues, toxicity, organic fertilizer application and environmental services.

Over the past 10–15 years, establishment and management of leucaena feeding systems in Latin America have varied according to country. For instance, intensive Silvopastoral Systems (iSPS) models are widely promoted and successfully adopted in Colombia, Mexico, Cuba, Venezuela and Northeast Brazil. In iSPS, leucaena is planted at high density (>10,000 trees/ha), in combination with improved tropical grass and high-value timber species (200–400 trees/ha), and intensively managed employing rotational grazing.

In Paraguay and Argentina, leucaena is planted in single or double hedgerows with inter-row alleys of 6–8 m, following the configuration used in Australia and mainly focused on beef production. In Mexico, leucaena is also cultivated with *Tithonia diversifolia* or lemon trees. Meanwhile, in other countries such as Cuba, leucaena has been established as protein banks using single/twin rows with inter-row spacing of 2–4 m for feeding beef, dairy or dual-purpose animals. Overall, paddock sizes for protein banks and iSPS range between 0.3 and 50 ha, while single and twin hedgerow systems are generally established over larger areas (20–500 ha). Despite the significant benefits demonstrated by research on leucaena feeding systems over the past 2 decades, coupled with successful outcomes for farmers who have adopted these systems, total area sown remains low across Latin America. This review provides a comparison between Latin American and Australian leucaena pasture systems, and recommendations for future collaborative research between countries.

Keywords: Adoption, beef production, dairy production, high-quality forage, tree legumes.

Resumen

Leucaena leucocephala (leucaena) es una especie leguminosa nativa de México y América Central y actualmente se la puede encontrar naturalizada en la mayoría de los países de América Latina. En las últimas dos décadas, considerables avances en investigación y promoción de leucaena se llevaron a cabo en Colombia, México, Cuba, Brasil, Paraguay y Argentina. Estas investigaciones se enfocaron en el manejo agronómico de la especie y su uso para la alimentación del

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ganado de carne, leche o doble propósito, mejoramiento genético, toxicidad, fertilización orgánica y servicios ambientales.

Sin embargo, el establecimiento y manejo de leucaena en América Latina son diferentes según región. Por ejemplo, el modelo de sistemas silvopastoriles intensivos (iSPS) es ampliamente promovido y exitosamente adoptado en Colombia, México, Cuba, Venezuela y el noreste de Brasil. En estos sistemas, leucaena es plantada en altas densidades (>10,000 plantas/ha), en combinación con gramíneas mejoradas y especies maderables de alto valor (200−400 árboles/ha). En Paraguay y Argentina, leucaena es plantada en hileras simples o dobles dejando callejones entre 6 y 8 m, donde se siembran gramíneas. Este modelo es muy similar al utilizado en Australia y su uso principal es para la alimentación de ganado de carne. En México, esta especie se puede encontrar asociada con *Tithonia diversifolia* o con árboles frutales (p.ej. cítricos). En otros países, leucaena es usada como banco de proteína y plantada en hileras simples o dobles con callejones de 2−4 m para alimentar ganado de carne, leche o doble propósito.

Los bancos de proteína y los iSPS se encuentran establecidos en áreas entre 0.3 y 50 ha, mientras que los sistemas de hilera simple o dobles asociados con gramíneas se encuentran plantados en grandes extensiones (20−500 ha). A pesar del gran avance en investigación y promoción de esta especie en las últimas décadas, su adopción es aún baja en América Latina. Este trabajo presenta información sobre el manejo y establecimiento de leucaena en América Latina, una comparación con el sistema australiano y recomendaciones de trabajos colaborativos entre países.

Palabras clave: Adopción, arboles leguminosos, forrajes de alta calidad, producción de carne, producción de leche.

Introduction

Leucaena leucocephala (leucaena) is a native multipurpose tree legume from Mexico and Central America and is currently naturalized in the majority of Latin American countries. Its use varies widely from human food, fuel, timber and shade (for perennial crops and livestock) to fodder for ruminant animals. According to Parrotta (1992), this species can be found in a range of environmental conditions across latitudes between 30° N and 30° S. It grows well in areas that receive annual rainfall of 500–2,000 mm, with dry seasons of 2–3 months, and with well-drained soils that are slightly acid (pH 6) to moderately alkaline (pH 7.5). Optimal temperatures range between 20 and 30 °C, but its growth is restricted at low temperatures (<15 °C), although it can survive mild frost events.

The aim of this review is to provide an update of research carried out with leucaena in the last 18 years (2000–2018) in Latin America and describe its establishment and management for ruminant feeding by region. Finally, it will provide a comparison between leucaena feeding systems in Latin America and Australia.

Research in Latin America

In the past 2 decades, Latin American researchers have actively participated in various leucaena studies involving germplasm, weediness issues, toxicity, animal production, organic fertilizer application and environmental services. To estimate the level of research activities on this species, Scopus, the worldwide largest abstracting service and database of peer-reviewed research literature (scientific journals and books plus congress and conference proceedings), was used to count the number of leucaena publications (where leucaena was included in the title or keywords) carried out by Latin American institutions. From 441 papers published between 2000 and 2018, 95% involved researchers affiliated with institutions from Brazil (117), Mexico (111), Cuba (89), Venezuela (44), Colombia (40) and Argentina (14) (Figure 1). Although it may not take into account all research published in congress and conference proceedings, it provides a snapshot of the status of leucaena research in Central and South American countries (Figure 1, Table 1).

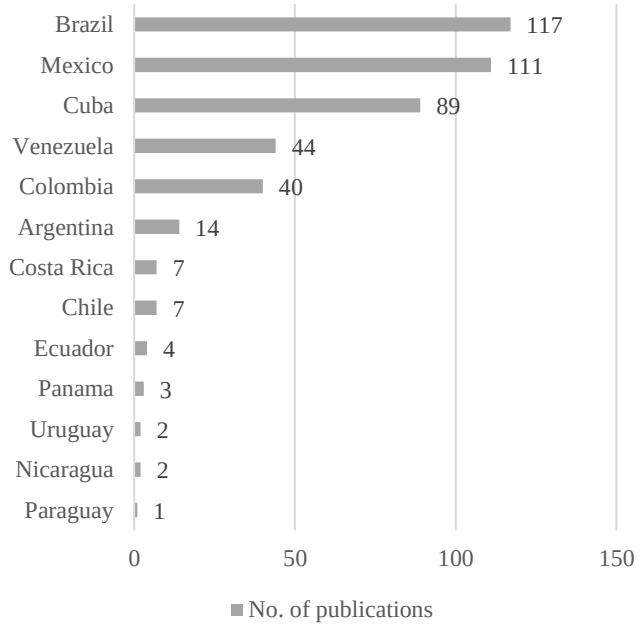

Figure 1. Total publications regarding leucaena by country.

Table 1. Top 3 Latin American institutions in each country during 2000–2018, listed by Scopus.

Country	Top 3 institutions
Brazil	• Empresa Brasileira de Pesquisa Agropecuária (Embrapa) • Universidade Estadual Paulista (UNESP) • Universidade de São Paulo (USP)
Mexico	• Universidad Autónoma de Yucatán • Universidad Nacional Autónoma de México • Instituto Nacional de Investigaciones Forestales Agrícolas y Pecuarias (INIFAP)
Cuba	• Instituto de Ciencia Animal (ICA) • Estación Experimental de Pastos y Forrajes Indio Hatuey • Centro Nacional de Sanidad Agropecuaria
Venezuela	• Instituto Nacional de Investigaciones Agrícolas (INIA) • Universidad de los Andes (ULA) • Universidad del Zulia (LUZ)
Colombia	• Centro para la Investigación en Sistemas Sostenibles de Producción Agropecuaria (CIPAV) • Universidad Nacional de Colombia • International Center for Tropical Agriculture (CIAT)
Argentina	• Instituto Nacional de Tecnología Agropecuaria (INTA) • Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET) • Universidad de la Plata

Establishment and management of leucaena by region

Leucaena grows well and is adapted to a wide variety of environments in Central and South America (Lascano et al. 1995). However, its establishment and management vary by region. In this review, we have identified and characterized 3 different systems for growing and utilizing leucaena:

- Protein bank systems: mainly found in Cuba and Venezuela;
- Intensive Silvopastoral Systems (iSPS): found in Colombia (Caribbean region, Inter-Andean valleys); Mexico (Michoacán, San Luis de Potosí – Huasteca region, Veracruz, Tamaulipas, Yucatán, Campeche, Jalisco, Guerrero and Colima states); Panama (Azuero province); Cuba; Venezuela (Llanos); Brazil (state of Maranhão); and Argentina (Misiones province); and
- Australian-style systems: found in Paraguay (Chaco) and Argentina (Chaco, Formosa and Corrientes provinces).

A brief description of each production system is as follows:

Protein bank systems

In this system, leucaena is established strategically in small areas of the farm with the aim of providing a high-level protein source for cattle. Typically, site preparation is carried out by strip or total cultivation of the paddock using animal draft power and to a lesser extent, if farmers have access to tractors, mechanical cultivation. Inoculation of seeds with specific *Rhizobium* strains, such as ICA 4006 and ICA 4010 developed by the Institute of Animal Science (ICA, Cuba), is recommended. Fertilizer application is not a common practice owing to its high cost and labor requirement; however, the use of animal manure is highly recommended in soils that have been previously used for cropping. According to Ruiz et al. (1989), the optimal time for establishing leucaena is during the rainy season (April–June), particularly for cvv. Peru and Cunningham. Planting configuration of leucaena is usually in single or twin rows (2–5 plants/m), with 3–4 m inter-row spacing, providing densities between 5,000 and 8,000 shrubs/ha. Chemical or mechanical weed control is critical during the first 2–3 months after planting. Leucaena is intercropped with grasses such as *Cynodon nlemfuensis* and *Megathyrsus maximus* once the leucaena seedlings reach 0.1 m height. However, first grazing or cutting is not recommended until leucaena plants reach 1.2–1.5 m height. The main use of the protein bank is for feeding dairy and beef cattle in cut-and-carry systems or for grazing with limited temporal access.

Intensive Silvopastoral Systems (iSPS)

ISPS were developed in Colombia by CIPAV (Centro para la Investigación en Sistemas Sostenibles de Producción Agropecuaria). In these systems, leucaena is planted at high density (>10,000 shrubs/ha) in combination with improved grasses, including native or exotic trees and palms (200–400 trees/ha). The establishment, management and benefits of iSPS have been described and reported (Murgueitio and Ibrahim 2008; Uribe et al. 2011; Murgueitio et al. 2011, 2016; Zapata Cadavid and Tapasco 2016). Briefly, land preparation is carried out by mechanical cultivation and the needs for fertilizer application or soil amendment are assessed according to soil analysis. Common leucaena cultivar used is Cunningham. Before planting, seeds are scarified and inoculated with specific *Rhizobium* at 0.5 kg bacterial culture/10 kg seeds. Recommended planting configuration is single rows with 1.5–1.6 m between rows and 0.3–0.4 m between plants within rows, which provides leucaena densities of 10,000–22,000 shrubs/ha. Improved grasses such as *Megathyrsus maximus* and *Cynodon plectostachyus* are sown at the same time as leucaena or about 45 days after planting, when the legume has established. Overall, the first

grazing is carried out 3–6 months after planting leucaena using a low stocking rate, followed by a pruning of leucaena at 0.5–0.75 m for stimulating growth of branches. Leucaena-grass pasture is managed using intensive rotational grazing (12–48 hours) with electric fences and permanent supply of water, followed by 40–45 days for pasture recovery. The main use of iSPS is for feeding beef cattle, dual-purpose cattle and cows on tropical dairy farms (Figures 2 and 3). It is important to mention that leucaena toxicity is not considered as a limitation; therefore animal inoculation with the rumen bacterium *Synergistes jonesii* is not a common practice

Figure 2. Intensive silvopastoral system with leucaena - *Cynodon plectostachyus* pasture in the tropical dairy system at El Hatico, Valle del Cauca, Colombia.

Figure 3. Intensive silvopastoral system with *Leucaena leucocephala* and *Megathyrsus maximus* at Apatzingán, Michoacán, Mexico. Some leucaena is allowed to grow tall to provide shade.

Adopted Australian-style systems

In these systems, adopted and adapted by Paraguayan and Argentinian farmers, leucaena-grass pastures are established following procedures similar to those recommended in Australia (Dalzell et al. 2006; Radrizzani et al. 2019). Briefly, land is prepared by repeated mechanical cultivation and seed is scarified and inoculated with specific *Rhizobium* cultures. Common cultivars used are Cunningham, Tarramba and Peru. Recommended configuration is single or twin rows (1 m apart) with inter-row alleys between 5 and 6 m. After planting, weeds are controlled by chemical or mechanical means and, to a lesser extent, using manual weeding. In Argentina and Paraguay, intercropping with maize, soybean or sorghum is practiced after planting leucaena with the aim of controlling weeds and making use of the inter-row alleys. Grasses are introduced when leucaena reaches 1 m height (Figure 4). The common companion grasses are *Megathyrsus maximus*, *Chloris gayana* and *Urochloa brizantha* (cvv. Marandu, Xaraés and Mulato II). Leucaena is grazed initially when it reaches 2–2.5 m height. After that, the pasture is managed using rotational grazing mainly by beef cattle. Paraguayan producers inoculate their animals with rumen fluid, considered to contain the bacterium *Synergistes jonesii*, but this practice is not carried out in Argentina due to unavailability of inoculum. Still, the occurrence and effect of toxicity on animal productivity are unclear. Radrizzani and Nazca (2014) reported animal toxicity symptoms in an experiment with high proportion of leucaena in available feed (40%) in beef cattle in the Chaco region, Argentina. However, in several other experiments animals showed no symptoms (Gándara et al. 1986; Lacorte et al. 1987; Gándara and Casco 1993; Lacorte 2001; Pachas et al. 2012).

Figure 4. Leucaena intercropped with sorghum for silage in Pampa del Infierno, Chaco, Argentina.

Comparison between the Latin American and Australian leucaena feeding systems

Leucaena pasture systems used in Latin America and Australia have similarities and differences, which are summarized in Table 2. Regardless of differences, e.g. planting density and establishment, both systems are highly productive, profitable and sustainable (Klassen 2005; Dalzell et al. 2006; Murgueitio et al. 2011; Calle et al. 2013; Pachas et al. 2018).

Table 2. Summary of similarities and differences of leucaena feeding systems in Latin America and Australia.

Variable	Latin America	Australia
Planting density	Leucaena is planted at high density (>10,000 shrubs/ha) in iSPS, ~5,000–8,000 shrubs/ha in protein banks and lower density in the Argentinean and Paraguayan Chaco (3,000–8,000 shrubs/ha).	Leucaena is planted at lower density (3,000–8,000 shrubs/ha).
Planting configuration	Multi-strata systems (at least 3 strata): improved grasses, leucaena and timber trees, palms/fruit trees) in iSPS; otherwise only 2 strata using improved grasses.	Two strata: improved grass and leucaena.
Establishment	Grass is sown early (0–3 months) after planting leucaena. In the Argentinian and Paraguayan Chaco region it is common to intercrop the alleys with annual crops.	Grass is established once leucaena is fully established (8–12 months) to avoid competition. Meanwhile, weeds are chemically and mechanically controlled.
Uses	Dairy and beef production	Beef production
Area per farmer	Farmers plant leucaena on a small scale (1–50 ha).	Farmers plant leucaena on a large scale (50–6,000 ha).
Results	High animal productivity	High animal productivity

An important difference between the regions is that leucaena is an important component in the diet of dairy cattle in South and Central America but is used only to feed beef cattle in Australia. Another difference between regions is the area cultivated. The area of leucaena in Latin America is not well defined but it is most likely to be between 45,000 and 55,000 ha. The area established in Cuba is approximately 20,000 ha, ~7,000 ha as protein banks and the remaining 13,000 ha in association with grasses (T. Ruiz unpublished data). There are approx-imately 12,000 ha in 10 states of Mexico (Ramírez-Avilés et al. 2019), ~10,000 ha in Paraguay (Glatzle et al. 2019), with 3,000–5,000 ha in Venezuela (E. Escalante unpublished data), ~2,400 ha in Argentina (Radrizzani et al. 2019), 3,000 ha in Colombia (F. Uribe unpublished data) and perhaps 1,000–1,500 ha in the remainder of Latin American countries. This figure is significantly lower than ~200,000 ha cultivated in Australia. However, due to leucaena being planted in small areas (1–50 ha), the number of smallholders who have adopted this system is relatively higher (estimated at ~6,000–8,000 producers) compared with Australia (estimated at 500–1,000 producers).

Conclusions

Over the last 2 decades, significant research effort on leucaena feeding systems has occurred in Latin America with successful adoption in Colombia, Mexico, Cuba, Venezuela, Paraguay and Argentina. The research has shown that leucaena systems are highly productive and adapted to a wide range of environmental conditions. However, adoption of this technology remains low in cattle-producing countries. The similarities and differences between Latin American and Australian leucaena systems can be viewed as an opportunity for future collaboration between regions. For instance, Australia has developed a larger number of cultivars, which can be used in Latin America; meanwhile, although several germplasm collections were carried out in South and Central America, no successful cultivars have been released to the market. The multi-strata configuration systems used in South America´s iSPS have shown environmental benefits and we consider they should be tested in Australia, with the aim of improving carbon sequestration and biodiversity. The use of leucaena for feeding dairy cattle in subtropical environments in Australia could also be tested. Finally, collaboration between Central and South American researchers and producers should be promoted and fostered with the aim of enhancing adoption of this species and collaboration between countries.

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References

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Calle Z; Murgueitio E; Chará J; Molina CH; Zuluaga AF; Calle A. 2013. A strategy for scaling-up Intensive Silvopastoral Systems in Colombia. Journal of Sustainable Forestry 32: 677–693. doi: 10.1080/10549811.2013.817338

Dalzell SA; Shelton HM; Mullen BF; Larsen PH; McLaughin KG. 2006. Leucaena: A guide to establishment and management. Meat and Livestock Australia, Sydney, Australia. bit.ly/2YHs66P

Gándara FR; Goldfarb MC; Arias Mañotti AA; Ramírez WM. 1986. *Leucaena leucocephala* (Lam) de Wit como banco de proteína invernal en un campo natural de la provincia de Corrientes. Revista Argentina de Producción Animal 6:562−572.

Gándara FR; Goldfarb MC; Arias AA; Ramírez WM. 1993. Valor alimenticio de una asociación Pangola (*Digitaria decumbens*) y *Leucaena leucocephala*. Revista Argentina de Producción Animal 13(Supl. 1):41.

Glatzle AF; Cabrera AN; Naegele A; Klassen N. 2019. Leucaena feeding systems in Paraguay. Tropical Grasslands-Forrajes Tropicales 7 (in press).

Klassen N. 2005. Producción animal con *Leucaena* en el Chaco. In: Glatzle A; Klassen P; Klassen N, eds. *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.

Lacorte SM. 2001. Engorde de vaquillonas a corral con leucaena como fuente proteica. Boletín técnico 1. Instituto de Tecnología Agropecuaria (INTA), Misiones, Argentina.

Lacorte SM; Martínez PE; Fernández FL. 1987. Uso de Leucaena como banco de proteínas en Misiones. Nota Técnica 38. Instituto de Tecnología Agropecuaria (INTA), Misiones, Argentina.

Lascano CE; Maass BL; Argel PJ; Víquez E. 1995. Leucaena in Central and South America. In: Shelton HM; Piggin CM; Brewbaker JL, eds. Leucaena - opportunities and limitations. Proceedings of a workshop held in Bogor, Indonesia, 24−29 January 1994. ACIAR Proceedings No. 57. ACIAR, Canberra, ACT, Australia. p. 152−158. bit.ly/2UphJVM

Murgueitio E; Ibrahim M. 2008. Ganadería y medio ambiente en América Latina. In: Murgueitio E; Cuartas CA; Naranjo JF, eds. Ganadería del futuro: Investigación para el desarrollo. Fundación CIPAV, Cali, Colombia. p. 19–39. bit.ly/2ZQqtnP

Murgueitio E; Calle Z; Uribe F; Calle A; Solorio B. 2011. Native trees and shrubs for the productive rehabilitation of tropical cattle ranching lands. Forest Ecology and Management 261:1654−1663. doi: 10.1016/j.foreco.2010.09.027

Murgueitio E; Galindo W; Chará JD; Uribe F. 2016. Establecimiento y manejo de sistemas silvopastoriles intensivos con Leucaena. Editorial CIPAV, Cali, Colombia. bit.ly/2Y1b2Yf

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.

Pachas ANA; Shelton HM; Lambrides CJ; Dalzell SA; Murtagh GJ. 2018. Effect of tree density on competition between *Leucaena leucocephala* and *Chloris gayana* using a Nelder Wheel trial. I. Aboveground interactions. Crop & Pasture Science 69:419−429. doi: 10.1071/CP17311

Parrotta JA. 1992. *Leucaena leucocephala* (Lam.) de Wit. Leucaena, tantan. Leguminosae (Mimosoideae) Legume family. USDA Forest Service, New Orleans, LA, USA. bit.ly/2WkiwVT

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; Nenning F; Pueyo D. 2019. Leucaena feeding systems in Argentina. II Current uses and future priorities. Tropical Grasslands-Forrajes Tropicales 7 (in press).

Ramírez-Avilés L; Solorio-Sánchez FJ; Aguilar-Pérez CF; Ayala-Burgos AJ; Ku-Vera JC. 2019. *Leucaena leucocephala* feeding systems for cattle production in Mexico. Tropical Grasslands-Forrajes Tropicales 7 (in press).

Ruiz TE; Febles G; Bernal G; Díaz LE. 1989. A study on sowing time of *Leucaena leucocephala* in Cuba. Cuban Journal of Agricultural Science 23:217.

Uribe F; Zuluaga AF; Valencia L; Murgueitio E; Valencia LM; Zapata A; […] Soto R. 2011. Establecimiento y manejo de sistemas silvopastoriles. Manual 1, Proyecto Ganadería Colombiana Sostenible. GEF, BANCO MUNDIAL, FEDEGAN, CIPAV, FONDO ACCION, TNC, Bogotá, Colombia. bit.ly/2VbBT71

Zapata Cadavid Z; Tapasco BES. 2016. Sistemas silvopastoriles: Aspectos teóricos y prácticos. CARDER, CIPAV, Editorial CIPAV, Cali, Colombia.

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