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Leucaena intensive silvopastoral system: The CIPAV experience in Colombia

Sistema silvopastoril intensivo con leucaena: La experiencia de CIPAV en Colombia

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Abstract

The Center for Research in Sustainable Systems of Agricultural Production (CIPAV) has worked since 1991 on the establishment and management of intensive silvopastoral systems (ISPS) involving leucaena (*Leucaena leucocephala*). The initial work was carried out in the Valle del Cauca department, and afterwards in other regions of Colombia and abroad. This document presents the main characteristics of the work carried out on various farms in the tropical lowlands of Colombia, located between 0 and 1,300 masl, with 22–28 °C average annual temperature. The leucaena ISPS integrate this species with grasses, mainly *Cynodon plectostachyus*, *C. nlemfuensis* and *Megathyrus maximus*, although other species have been used, such as *Dichanthium annulatum*, *Urochloa humidicola* (including cv. Llanero, formerly classified as *Brachiaria dictyoneura*) and *Urochloa* hybrids. Leucaena is planted at densities in excess of 10,000 plants per ha, in rows 1 to 1.5 m apart with 0.3–0.6 m between plants within rows. These ISPS are grazed by *Bos indicus* and *B. taurus* cattle and their crosses, in beef, dairy (tropical lowlands) and dual-purpose systems. The proper management of an ISPS requires a rotational grazing strategy with each paddock grazed for 1–3 days (ideally 1 day) followed by a 42–46 day rest period. Stocking rates are 2.5–4.5 head/ha. Average daily gains by beef cattle are 650–800 g/head (2–3 kg/ha/d). Production in dairy systems (tropical lowlands) fluctuates between 5 and 14 L milk/cow/d, depending on genetic makeup, season (dry or rainy) and supplementation, with up to 17,000 L milk/ha/yr. Information from various farms that use ISPS is presented including main ecological characteristics and animal performance.

Keywords: Beef production, dairy production, dual-purpose production, establishment, management, stocking rate, tree legumes.

Resumen

El Centro para la Investigación en Sistemas Sostenibles de Producción Agropecuaria (CIPAV) ha trabajado desde 1991 en el establecimiento y manejo del sistema silvopastoril intensivo (SSPi) con leucaena (*Leucaena leucocephala*). El trabajo inicial se llevó a cabo en el Departamento del Valle del Cauca y posteriormente en otras regiones de Colombia y en el exterior. Este documento presenta las principales características del trabajo realizado en varias fincas del trópico bajo en Colombia, situadas entre 0 y 1,300 msnm, con temperatura promedio anual de 22–28 °C. El SSPi con leucaena integra esta especie con gramíneas, principalmente *Cynodon plectostachyus*, *C. nlemfuensis* y *Megathyrus maximus*, aunque otras especies han sido utilizadas, tales como *Dichanthium annulatum*, *Urochloa humidicola* (incluyendo el cv. Llanero, anteriormente clasificado como *Brachiaria dictyoneura*) e híbridos de *Urochloa*. La leucaena se establece en densidades superiores a 10.000 plantas por ha,

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en surcos separados entre 1 y 1.5 m, con distancias entre plantas de 0.3–0.6 m. Estos SSPi son pastoreados por ganado *Bos indicus* y *B. taurus* y sus cruces, en sistemas de producción de carne, leche (en trópico bajo) y doble propósito. El manejo adecuado de los SSPi requiere una estrategia de pastoreo rotacional con un período de pastoreo de cada potrero de 1–3 días (idealmente 1) seguido de un período de descanso de 42–46 días. Las cargas animal son 2.5–4.5 animales/ha. Aumentos de peso diario de ganado de carne son 650–800 g/animal (2–3 kg/ha/día). La producción en sistemas lecheras (trópico bajo) varía entre 5 y 14 L de leche/vaca/día, según raza y genética, época del año (seca o lluvias) y suplementación, obteniéndose hasta 17,000 L de leche/ha/año. Se presenta información de varias fincas que usan SSPi, incluyendo sus principales características ecológicas y datos de producción animal.

Palabras clave: Carga animal, establecimiento, ganado de doble propósito, manejo, producción de carne, producción de leche.

Introduction

Since 1991 the CIPAV Foundation has worked on the establishment of Intensive Silvopastoral Systems (ISPS) incorporating leucaena (*Leucaena leucocephala*) and grasses, following preliminary research carried out by CIAT and CENICAFE (Echeverri et al. 1987; Suárez et al. 1987). The initial work by CIPAV was carried out in the Valle del Cauca department. Subsequently, work was performed on the Hacienda El Chaco (Tolima department), then beginning of 2002 in the Quindío department and since 2005 in other regions of Colombia (Ramírez 1997; Molina et al. 2001; Espinel et al. 2004; Zapata Cadavid and Silva 2010, 2016; Murgueitio et al. 2016) and abroad (Zapata Cadavid et al. 2010; Solorio-Sánchez and Flores-Estrada 2011; Alves-Cangussu et al. 2012; Mahecha et al. 2012a). The system and the particular characteristics of the work carried out on various farms in different regions are described below.

The CIPAV work with leucaena in Colombia and other countries has focused mainly on very high leucaena densities (above 10,000 shrubs per ha) in association with various tropical grasses under cattle grazing with rotational grazing systems. These systems are called Intensive Silvopastoral Systems, different from other silvopastoral arrays in which grasses are associated with lower tree densities or leucaena is used as a fodder bank.

ISPS in Colombia where leucaena has been planted

In Colombia leucaena ISPS have been planted in several geographical regions, between 3°30' N and 10°58' N, at elevations up to 1,300 masl, with average temperatures ranging from 22 to 26 °C, and an average annual rainfall range between 700 and 2,500 mm, in areas which originally were tropical forest (ranging from dry to humid tropical forest).

The farms, where leucaena has been planted in Colombia, are located in the Caribe region (0–200 masl), including areas of low (Dry Caribe) and higher (Wet Caribe) precipitation, and in the Andean region in the

main 2 valleys (Cauca and Magdalena Rivers) located amid the 3 Andean mountain ranges at elevations of 200–1,300 masl, in ecosystems originally supporting dry or wet tropical forest.

Systems of plantation

Colombian leucaena ISPS have been planted in different ways, briefly explained below according to availability of labor and machinery, cost and topographical conditions. The main features of the systems in Colombia are:

- Leucaena is planted at high density (>10,000 shrubs/ha) in a single-row configuration with 1–1.7 m between rows, and 0.3–1.0 m between plants within rows, to give leucaena densities of 10,000–20,000 shrubs/ha.
- Leucaena is planted in combination with improved grasses, mainly *Cynodon plectostachyus*, *C. nlemfuensis* and *Megathyrus maximus* (cvv. Tanzania, Mombasa, Colonial and Massai), although other species have been used, e.g. *Dichanthium annulatum*, *Urochloa humidicola* (including cv. Llanero, formerly classified as *Brachiaria dictyoneura*) and *Urochloa* (formerly *Brachiaria*) hybrids.
- Before planting, leucaena seeds are scarified and inoculated with specific rhizobium at 50 g peat powder/kg seed.
- Improved grasses are established just after leucaena planting or up to 45 days later.
- After planting, weed control is carried out using chemicals, mechanical control, manual weeding or a combination of these operations (Uribe et al. 2011).
- Leucaena toxicity has not been a limitation and animal inoculation with rumen bacteria (*Synergistes jonesii*) is not practiced.

Manual planting of nursery seedlings

This system has been used mainly in the central coffee production area of the country, in the Andean foothills (Espinel et al. 2004; Zapata Cadavid and Silva 2010, 2016).

In this case, seedlings are produced in a nursery for subsequent transplanting into the field. Plastic bags, such as those normally used for coffee seedlings (13 cm × 23 cm), are utilized. Good soil, preferably mixed with some chicken or cattle manure, is used and 3 or 4 seeds are deposited in each bag. The nursery phase lasts 6–8 weeks, during which the plants reach a height of 25–40 cm.

An advantage of this system is that it reduces establishment risks because seedlings have reached an acceptable height and stage of development before transplanting. This ensures seedlings have a greater capacity to withstand unfavorable weather conditions and it facilitates the control of weeds, while the establishment time for a field can be reduced by as much as 2 months compared with direct seeding. Disadvantages are the nursery cost, which can be very high (10,000 or more seedlings are required per hectare) for farmers with little experience in this type of activity, plus high labor costs for transplanting the seedlings to the field.

Direct planting with mechanical soil preparation

Planting following mechanical land preparation is carried out in situations where the topography (flat or of moderate slope) allows this method to be implemented and where machinery is available (areas with a tradition of mechanized agriculture like the Caribe region).

After land preparation, leucaena seed is planted either with machinery or manually, in single rows 1.5–1.7 m apart and with about 20 seeds/m of row. All seeds that germinate and establish are allowed to remain, so plant densities in excess of 20,000 shrubs per ha can be obtained ([Zapata Cadavid and Silva 2010](#), [2016](#); [Murgueitio et al. 2016](#)).

Direct planting with manual soil preparation

In some cases leucaena has been seeded into plots by hand without mechanical preparation but using herbicides to eliminate the plant cover. A common layout has been single rows at 1–1.5 m spacing with 50–70 cm between planting sites within rows and 4 or 5 leucaena seeds per site.

Grass establishment

Grasses have been planted either immediately after leucaena or about 45 days later (in order to allow leucaena to reach 30–45 cm height). In the former case, rapid growth of the grass can outstrip the growth of leucaena and compete for light, nutrients and water, thereby affecting development of leucaena. Planting grasses about 45 days after leucaena seeds are sown is the most commonly used system now.

Management and utilization

Leucaena is first grazed about 5–7 months after planting, when the plants are about 1.8 m tall.

Recommended management of the leucaena ISPS requires that the plots be divided into several paddocks, thus allowing a rotational grazing system to be implemented with:

- Grazing not exceeding 5 days — preferably 1 day only; and
- Rest periods of 45–50 days.

Applying these 2 strategies means that each cycle requires a minimum of 9 paddocks and preferably more than 15. To reduce establishment costs, plots are divided with electric fencing, although permanent fencing or a combination of permanent fencing and mobile electric wires is often used.

In Colombia leucaena trees are normally pruned every 6–12 months. The higher frequency is employed in the Caribe region where solar radiation is high and leucaena grows very quickly during the rainy season. Trees are pruned at 1–1.2 m from ground level with a machete.

Mimosine toxicity has not been observed to be a problem for cattle in Colombia so inoculation with rumen bacteria is not carried out.

Animal performance

In Colombia, leucaena is grazed by both dairy and beef cattle, although dual-purpose cattle are most common. Both *Bos taurus* and *B. indicus* cattle are used, as well as their crosses, but usually not 100% *B. taurus*, as in Colombia 100% *Bos taurus* dairy or beef cattle are raised at elevations above 2,000 masl, which are unsuitable for leucaena ISPS.

Stocking rates in Colombia range from 2.5 to 4.5 adult equivalents (AE; 450 kg dry animal)/ha. In the Caribe region, where the dry season lasts for 4–5 months, stocking rates must be adjusted seasonally, i.e. 4–6 AE/ha during the rainy season and 2–3 AE/ha during the dry season.

Animal performance and general characteristics of some farms, on which CIPAV has worked for several years, are presented in Table 1.

Beef production

Hacienda El Chaco is devoted to dairy production but in 2010 an experiment was carried out to investigate fattening of young steers in the leucaena systems ([Mahecha et al. 2011](#); [2012a](#), [2012b](#)). The results of this experiment are presented in Table 2.

Table 1. Location, system characteristics and animal performance of some farms on which CIPAV has worked over a number of years.

Farm, location	Geographical conditions, leucaena ISPS characteristics	Livestock breed composition and productive parameters
Hacienda Lucerna ¹ , Bugalagrande, Valle del Cauca	1,000 masl; 1,400 mm rainfall/year (AAR); 24 °C. Tropical dry forest; leucaena first established in 1991, currently 49 ha, with <i>C. plectostachyus</i> and <i>M. maximus</i> (cvv. Mombasa and Tanzania).	Dual-purpose Lucerna breed ² (national breed); 142 milking cows producing 10.7 L milk/cow/d and 17,000 L/ha/yr; stocking rate 4.3 cows/ha; calving interval 390 days.
El Hatico ¹ , El Cerrito, Valle del Cauca	1,000 masl; 750 mm AAR; 24 °C. Tropical dry forest; leucaena first established in 1992, currently 64 ha, with <i>C. plectostachyus</i> and <i>M. maximus</i> (cvv. Mombasa and Tanzania).	Dual-purpose Lucerna breed; 220 milking cows producing 10 L/cow/d and 15,000 L/ha/yr; stocking rate 4.3 cows/ha; milking cows fed 3.5 kg/d of an energy supplement (rice and wheat byproducts); calving interval 395 days.
Hacienda El Chaco, Piedras, Tolima	605 masl; 1,200 mm AAR. Tropical dry forest; leucaena first established in 1992, currently 42 ha, with <i>C. plectostachyus</i> .	Tropical lowland specialized dairy. Around 75% <i>Bos taurus</i> × 25% <i>B. indicus</i> cows; 70 milking cows producing 13 L/cow/d; lactation length 296 days; stocking rate 3.5 cows/ha; calving interval 380 days.
Hacienda Asturias, La Tebaida, Quindío	1,300 masl; 1,800 mm AAR. Leucaena first planted in 2002 using seedlings, 1 m between rows and 1 m between plants within rows with <i>C. plectostachyus</i> and <i>M. maximus</i> .	50–75% <i>B. taurus</i> × 25–50% <i>B. indicus</i> cows; 183 milking cows producing 13 L/cow/d; stocking rate 4 cows/ha; milking cows fed 2.7 kg concentrate/d.
Hacienda El Porvenir, San Diego, Cesar	724 mm AAR. Caribe region; dry tropical forest; leucaena first established in 2006, currently 110 ha (60 ha associated with rows of <i>Eucalyptus tereticornis</i> and 50 ha with native trees).	Steers 180–250 kg achieving liveweight gains of 524 g/d; stocking rate 2.33 AE/ha.

¹Lucerna and El Hatico farms have international organic certification and include livestock and sugar cane production.

²The Lucerna breed is a Colombian 100% *B. taurus* breed developed in Hacienda Lucerna as a product of a crossbreeding program started in 1937 with Holstein, Red Milking Shorthorn and Hartón del Valle (a red Criollo breed in the region, descended from cattle brought by Spanish conquerors about 500 years ago).

Table 2. Fattening of steers in the leucaena ISPS of Hacienda El Chaco¹ (Mahecha et al. 2012a; 2012b).

	LWG (g/animal/d)	Stocking rate (AE/ha)	LWG (kg/ha/yr)
Leucaena Group 1	896	3.5	1,145
Leucaena Group 2	811	3.5	1,036

¹Performance of steers was evaluated over a period of 8.8 months. Final weight was 451 kg (average).

LWG = liveweight gain; AE = adult equivalent.

Leucaena and cow reproductive performance

Data from more than 20 years, hundreds of cows and different farms show calving intervals for cows grazing leucaena that are considerably lower than those recorded in Colombia for outstanding dual-purpose and specialized dairy farms (456 and 458 days, respectively, the national averages being 664–700 days; [Gómez 2013](#)). For example, calving rates recorded in the farms Lucerna, El Hatico and El Chaco are 390, 395 and 380 days, respectively (Table 1).

Problems and constraints

Cost of establishment

High cost of establishment has been a major constraint for scaling-up the area under the leucaena intensive silvopastoral system in Colombia and several factors contribute to these high costs. Difficult topography or lack of available machinery means some farmers use manual labor and this increases the costs of land preparation, planting and all subsequent activities required. Even where machinery is used, the machinery plus operating costs are usually high. Cost of establishment is about US \$1,000 per ha, and to this must be added the infrastructure for intensive rotational grazing (paddock divisions, electric fences and a system for permanent supply of water), if these have to be constructed.

Proper management of grazing and rest periods

In rotational grazing systems, ranchers traditionally allow a rest period of about 30 days for their grass-only pastures

and many find it difficult to understand or accept that a system which requires a 42–50 day rest period can be more productive than a set-stocked area, and must be managed accordingly. It has been observed that a rest period shorter than 42 days does not allow leucaena to recover properly and plants begin to progressively weaken, which can lead to the death of plants and the collapse of the whole system.

Overgrazing

Although stocking rates achieved on ISPS are significantly higher than those under traditional grass-only grazing (≥ 3 vs. ≤ 1 AE/ha), farmers often tend to increase the stocking rate beyond the capacity of the leucaena silvopastoral system they have established, and a progressive and steady process of leucaena weakening and death begins. Fine-tuning of the management has proved difficult to achieve on many farms, and long-term and good-quality technical assistance is required.

Leucaena is not invasive

CIPAV has worked with leucaena for more than 25 years, not only in Colombia but also in other countries like Brazil, Nicaragua ([Zapata Cadavid et al. 2010](#)) and Mexico ([Mahecha et al. 2012a](#)). No cases of leucaena weediness have been observed ([Calle et al. 2011](#)). While leucaena is invasive in disturbed areas like degraded lands or roadsides, it has not been observed to invade undisturbed ecosystems. This observation is in accordance with findings of Costa and Durigan ([2010](#)) in Brazil.

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(Note of the editors: All hyperlinks were verified 11 August 2019.)

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