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Review paper

Cratylia argentea – review of a tropical shrub legume: Quality and utilization[1]

Cratylia argentea- *revision de una leguminosa tropical arbustiva: Calidad y utilización*

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Abstract

A review synthesizing the research on the quality and use of *Cratylia argentea* forage to create incentives for its use in animal production systems in the tropics is presented. The species has been extensively evaluated, mainly in tropical America, to develop it as a shrub legume for infertile, acid soils as an alternative to *Leucaena leucocephala* and *Gliricidia sepium* that are not adapted to these soils. This review includes a synthesis and discussion of research findings with *C. argentea* forage on (1) nutritive value, including secondary compounds, (2) alternative uses in animal production systems, and (3) live weight gain and milk production. The strength of the species is its drought tolerance and high protein content that results in increased milk yield and liveweight gain when grazed in association with grasses, particularly in the dry season. Supplementation of fresh or ensiled cratylia to grazing animals usually results in increased carrying capacity of the pasture and milk yield for cows of medium to high genetic potential. Its deficiency is the low acceptability of fresh forage by animals with no previous experience and high demand for labor when used in cut and carry systems. The issue of low adoption is addressed and suggestions for future research are presented.

Keywords: Adoption, grazing, intake, milk yield and liveweight gain, protein and digestibility, secondary compounds, silage.

Resumen

Se presenta una revisión que resume las investigaciones sobre la calidad y utilización de *Cratylia argentea* con el objetivo de contribuir a crear incentivos para su uso en sistemas de producción animal del trópico. La especie ha sido ampliamente evaluada, principalmente en América tropical, con el objetivo de desarrollarla como una leguminosa arbustiva para suelos ácidos de baja fertilidad como alternativa a las especies *Leucaena leucocephala* y *Gliricidia sepium* que no están adaptadas a esos suelos. Esta revisión incluye una síntesis y discusión de resultados de las investigaciones con *C. argentea* sobre: (1) valor nutritivo, incluyendo compuestos secundarios, (2) usos alternativos en sistemas de producción animal, y (3) aumento de peso vivo y producción de leche. La fortaleza de la especie es su tolerancia a la sequía y su alto contenido de proteína que resulta en aumentos de la producción de leche y peso vivo cuando se pastorea en asociación con gramíneas, particularmente en la estación seca. La suplementación de *C. argentea* fresca o ensilada a animales de pastoreo resulta normalmente en aumentos de la capacidad de carga del potrero y producción de leche con vacas de potencial genético medio a alto. Sus limitaciones son la baja aceptabilidad del forraje fresco por parte de animales que no la han consumido previamente y la alta demanda de mano de obra cuando se utiliza en sistemas de corte y acarreo. Se discute el problema de la baja adopción de *C. argentea* y se presentan sugerencias para futuras investigaciones.

Palabras clave: Adopción, compuestos secundarios, consumo, ensilaje, pastoreo, proteína y digestilidad, producción de leche y ganancia de peso.

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[1]This review article is dedicated to the memory of Dr. Jorge Ramos de Otero, Brazilian pioneer in research on tropical forage plants in the 1940s and 1950s, and the first to recognize the potential of *Cratylia argentea*.

Introduction

One of the factors that limits milk and meat production in the tropics is availability and quality of forage grasses in the dry season, which varies in duration between 2 and 6 months, depending on the location. To solve this problem, producers have the alternative of using shrub legumes as a source of protein to supplement low-quality grasses. Some well-known shrub and woody legume species (*Leucaena leucocephala*, *Gliricidia sepium*), which have been extensively researched as sources of forage for ruminants, are marginally adapted to the acid infertile soils that prevail in some areas with prolonged dry seasons and where small and medium-sized producers rely on livestock for livelihoods. This has led to a marked interest in selection of shrub legumes adapted to these ecosystems. In Brazil, Otero (1952) first highlighted the potential of *Cratylia argentea* (Desv.) owing to its adaptation to acid soils, drought tolerance and high protein concentration. This potential was realized through extensive research on agronomy and management from 1978-1995 (Pizarro and Coradin 1996), although adoption has been limited. In this paper we summarize and analyze information on forage quality and utilization of *C. argentea* in production systems from research conducted throughout the tropics. We also briefly discuss the issue of low adoption of *C. argentea* and offer some suggestions on future research needs.

Feed value

Of the many parameters measured in forages to assess their feed value, this review focuses on protein (CP), digestibility, minerals, and intake, which affect animal performance. Secondary compounds like condensed tannins (CT) and lectins in cratylia are also discussed. In most cases the plant part used in evaluation trials with animals is not specified and the material fed is referred to as cratylia forage, composed of leaf and fine edible stems.

Crude protein and digestibility

Crude protein and digestibility, as a proxy of energy, are quality parameters that are key in defining the feed value of a forage legume. Values reported for cratylia in comparison with other legume species are affected by accession, season, soil fertility, plant density and cutting management (Table 1). Where possible, we differentiate between species known to be adapted to acid soils (cratylia, *D. velutinum*, calliandra and flemingia) and those not adapted (*Cratylia mollis*, gliricidia, leucaena, and *Erythrina fusca*). The leaf protein concentration from different studies falls mostly in the range of 15–20%, values that are similar to those of other woody legumes, including leucaena, gliricidia, flemingia and calliandra (Perdomo 1991; Lascano 1996; Flores et al. 1998; Yi Kexian et al. 1998; Suárez Salazar et al. 2008; Peters et al. 2009; Zhou Hanlin et al. 2011). Soil fertility can affect protein concentration of cratylia, possibly related to a dilution effect due to differences in plant growth (Tiemann et al. 2009a).

Cratylia can be classified as having moderate digestibility (range 45–55%), associated with high fiber concentration (Lascano 1996; Andersson et al. 2006), but not with CT (Lascano 1996; Yi Kexian et al. 1998; Stürm et al. 2007). Fiber (NDF) values in cratylia range from 40 to 60% and as with digestibility are affected by accession, season and soil fertility (Fässler and Lascano 1995; Hess et al. 2004; Andersson et al. 2006; Tiemann et al. 2009a; Álvarez Carrillo et al. 2022).

Variability in crude protein and digestibility among accessions of cratylia was found in few studies (Lascano 1996; Andersson et al. 2006; Peters et al. 2009; Castillo-Gallegos et al. 2013). However, the extent to which variability affects intake and animal performance is not known and may not be significant. These results suggest that plant attributes, including leafiness, regrowth capacity, forage and seed yield, and environmental conditions, including soil fertility and length of dry season, may be more important than forage quality parameters in the selection of cratylia accessions for a given location.

Planting density does not affect quality of cratylia (Table 1) and forage maturity only has small effects on protein concentration and digestibility, similar to most tropical legumes in comparison with grasses (Franco et al. 1998; Santana and Medina 2005; Pasquier Flores and Rojas Vallecillo 2006; Reyes Sánchez et al. 2007; Lugo-Soto et al. 2009).

Table 1. Overview of crude protein (CP) and in vitro dry matter digestibility (IVDMD) values of *Cratylia argentea* in comparison with other shrub legumes as affected by season, soil fertility and management.

Country, region/site	Study	Values	Reference
Brazil, Mato Grosso do Sul (Campo Grande)	Quality of shrub legumes in wet and dry season (selection)	*C. argentea* Wet: CP 20.9%: IVDMD 48.0% Dry: CP 20.3%; IVDMD 47.9% *G. sepium* Wet: CP 20.3%; IVDMD 49.1% Dry: CP 20.9%; IVDMD 48.1% *L. leucocephala* Wet: CP 19.9%; IVDMD 44.2% Dry: CP 20.0%; IVDMD 44.7%	Gama et al. (2009)
China, Hainan (Danzhou)	Quality of shrub legumes adapted and not adapted to acid soils (selection)	*C. argentea* CP 18.4%; IVDMD 66.2% F. macrophylla CP 14.2%; IVDMD 43.0% *L. leucocephala* CP 18.2%; IVDMD 60.7%	Zhou Hanlin et al. (2011)
Colombia, Cauca (CIAT-Quilichao, Q) and Meta (Carimagua, C)	Quality comparison among 10 cratylia accessions at 2 acid-soil sites	Means: Q: CP 24.2%; IVDMD 58.4% C: CP 18.6%; IVDMD 52.7%	Lascano (1996)
Colombia, Cauca (CIAT-Quilichao)	Comparison of the quality of cratylia with 2 shrub legumes adapted to acid soils	*C. argentea* CP 21.1%; IVDMD 48.4% *D. velutinum* CP 20.8%; IVDMD 55.4% *F. macrophylla* CP 17.9%; IVDMD 22.9%	Yi Kexian et al. (1998)
Colombia, Antioquia (Bajo Cauca)	Effect of cutting frequency and height on quality of cratylia	Range of both effects: CP 19.1–21.0 Digestibility in situ: 58.9–68.6% Ranges: Wet: CP 18.4–22.2% Dry: CP 20.4–23.7% Wet: IVDMD 58.9–69.0% Dry: IVDMD 62.0–68.3%	Santana and Medina (2005)
Colombia, Cauca (CIAT-Quilichao)	Quality comparison among 38 cratylia accessions in wet and dry season	*C. argentea* F: CP 15.0%; IVDMD 26.7% R: CP 17.8%; IVDMD 35.3% *G. sepium* F: CP 18.2%; IVDMD 43.3% R: CP 22.4%; IVDMD 46.94% *Erythrina fusca* F: CP 15.8; IVDMD 21.6% R: CP 16.8; IVDMD 26.9%	Andersson et al. (2006)
Colombia, Caquetá (Amazon piedmont)	Quality of cratylia in comparison with other tree legumes in 2 topographies [flat (F) and rolling hills (R)]	*C. argentea* CP 17.7%; IVDMD 56.1% *Piptocoma discolor* CP 13.1%; IVDMD 55.6%	Suárez Salazar et al. (2008)

Continue

Country, region/site	Study	Values	Reference
Colombia, Caquetá (Amazon piedmont)	Quality of cratylia in comparison with a native non-timber species consumed by cattle in secondary forest	*C. argentea* (range) Wet: CP 22.5–28.6%; IVDMD 55–71% Dry: CP 24.7–30.8%; IVDMD 65–71% *C. mollis* (mean) Wet: CP 20.1%; IVDMD 63% Dry: CP 20.1%; IVDMD 59%	Álvarez Carrillo et al. (2022)
Colombia, Cauca (CIAT-Quilichao)	Quality of 8-wk old cratylia forage in wet and dry season; 11 'Yapacaní' and 6 shrub morphotype accessions, and 2 *C. mollis* accessions	*C. argentea* (range) Wet: CP 22.5–28.6%; IVDMD 55–71% Dry: CP 24.7–30.8%; IVDMD 65–71% *C. mollis* (mean) Wet: CP 20.1%; IVDMD 63% Dry: CP 20.1%; IVDMD 59%	Peters et al. (2009)
Colombia, Valle (CIAT-Palmira) and Meta ('Altillanura')	Protein of cratylia grown in fertile (Mollisol) and acid infertile (Oxisol) soil, in wet and dry season	Mollisol: Wet: CP 18.2% Dry: CP 16.9% Oxisol: Wet: CP 26.8% Dry: CP 26.9%	Tiemann et al. (2009a)
Costa Rica, Cartago, (Turrialba)	Quality of shrub legumes adapted and not adapted to acid soils (selection)	*C. argentea* CP 23.8%; IVDMD 51.5% *C. calothyrsus* CP 30.3%; IVDMD 34.0% *L. leucocephala* CP 24.5%; IVDMD 51.1%	Flores et al. (1998)
Costa Rica, Cartago (Turrialba)	Effect of regrowth age on quality of cratylia	Range of regrowth effect: CP 20.8–22.8%; IVDMD 51.9–53.4%	Franco et al. (1998)
Mexico, Veracruz (Atzalan)	Comparison among 4 cratylia accessions	Means: CP 19.1% (SE 0.7) In situ rate of degradation 0.0488/h (SE 0.019)	Castillo-Gallegos et al. (2013)
Nicaragua, Managua	Effect of plant density and cutting height on quality of cratylia CIAT 18668	Range of density effect: CP 20.1–21.1%; IVDMD 57.9–59.3% Range of height effect: CP 19.1–22.6%; IVDMD 56.6–60.8%	Pasquier Flores and Rojas Vallecillo (2006)
Nicaragua, Managua	Effect of plant density and cutting frequency on quality of cratylia cutlivar Veranera (means of 2 years)	Range of density effect: CP 18.6–20.8% IVDMD 54.8–59.6% Range of frequency effect: CP 18.5–21.9% IVDMD 54.7–60.5%	Reyes Sánchez et al. (2007)
Venezuela, Barinas (Pedraza)	Effect of regrowth age on protein of cratylia	Range of regrowth effect: CP 18.4–21.9%	Lugo-Soto et al. (2009)

Minerals

Phosphorus (P) is the most limiting mineral in tropical grasses and the most expensive to supplement. In acid-soil savannas of eastern Venezuela, the level of P in cratylia averaged 0.34% and 0.19% in the wet and dry season, respectively (Rodríguez and Guevara 2002), while for the rainforest biome in Pucallpa, Peru, Medina Dávila (2021) reported no difference between seasons (average 0.34%). In a well-drained site of the eastern plains of Colombia, P concentration in cratylia was on average 0.19% across seasons and fertilizer treatments (Tiemann et al. 2009a). Results summarized by Corpoica (2017) showed that P levels in cratylia for 3 accessions evaluated also in the eastern plains of Colombia ranged from 0.17 to 0.28% (Taluma experimental station) and 0.12–0.19% (Carimagua experimental station). In the Amazon piedmont of Colombia (Caquetá department), a region that lacks a pronounced dry season, P averaged 0.33% (Suarez Salazar et al. 2008). For plants growing on an infertile Inceptisol at a hillside site in Cauca, Colombia, Cobo et al. (2002) reported 0.15% P concentration in cratylia. Considering the results of Little (1980) that 0.12% P in the forage of a tropical legume (*Stylosanthes humilis*) can sustain adequate growth of cattle, it is inferred that P concentrations in cratylia grown in different locations with contrasting soil fertility are adequate to sustain animal growth.

Other minerals measured in cratylia forage grown on both fertile and infertile soils are in the range of: Mg 0.1–0.7%; K 1.7–3.5%; S 0.16–0.41% and Ca 0.43–1.63% (Medina Dávila 2021; Cobo et al. 2002; Corpoica 2017). These values are in agreement with those of tropical legumes in general (Harricharan et al. 1988). Concentrations of micronutrients in cratylia are reported by Gomes et al. (2015) and Corpoica (2017). These results indicate that mineral concentrations in cratylia are similar to other tropical legumes and can sustain livestock requirements in different locations when grown on soils of contrasting fertility.

Acceptability and voluntary intake

Among the factors known to influence voluntary intake by ruminant animals are those dependent on plant attributes (plant part, chemical composition, secondary compounds), season, and those related to the animal (species, age, size, physiological state). In this section we review studies aimed at defining how acceptability/intake of cratylia compares with other shrub legumes when fed fresh, wilted or sun dried at different maturity stages (Table 2).

Acceptability/intake of shrub legumes seems to be less affected by animal species than by plant species, which in turn is related to quality factors such as digestibility and CT. This was shown by the study of Yi Kexian et al. (1998) where both sheep and goats consumed more cratylia and *D. velutinum* than flemingia, which has high levels of CT and low digestibility (Perdomo 1991; Pereira et al. 2018). In other studies, intake of cratylia in mixture with grasses was similar to intake recorded for leucaena but higher than intake of calliandra (Rodríguez et al. 2015) or *Codariocalyx* (Celis et al. 2004).

Acceptability of cratylia measured as short-term intake was low with immature (3-mo regrowth) forage fed fresh to sheep, but increased by twofold when the forage was wilted (48 h) or sun dried, regardless of age or previous experience of animals (Raaflaub and Lascano 1995). Ibrahim et al. (2001) reported a 32% increase in intake of cratylia (4-mo regrowth) when the forage was wilted under shade for 16 h and fed to crossbred heifers. The higher intake of wilted or dried immature cratylia forage can be the result of increased DM concentration or partial or complete loss of volatile compounds during wilting or drying. However, greater acceptability of dried forage could also be associated with previous experience of animals. Raaflaub and Lascano (1995) found that differences in intake rate between fresh and dried cratylia forage were greater when animals had been previously exposed to the legume. A similar observation was made in the Zona da Mata region of Minas Gerais, where grazing cows only consumed cratylia in the rainy season after being subjected to a period of adaptation (Xavier et al. 1995). Wilting fresh legume forage, however, does not always contribute to increased forage intake. For example, Palmer and Schlink (1992) found that intake of calliandra was 59% higher when fed fresh than wilted. The difference was attributed to the negative effect of CT on intake of wilted calliandra, which does not seem to be the case with cratylia with undetectable levels of CT, as will be discussed below. The role of other secondary compounds like lectins, possibly present in cratylia, on intake of fresh, wilted and dried forage is not known.

Table 2. Overview of intake of *Cratylia argentea* fed to small ruminants and cattle in different forms and levels.

Country, region/site	Study	Results[1,2]	Reference
Brazil, Minas Gerais (Zona da Mata)	Intake of cratylia fed to sheep housed in metabolism crates and offered leaf + stem of 2-mo regrowth	Intake (g DM/kg BW$^{0.75}$/day)[3] 46.0	Aroeira and Xavier (1991)
Brazil, Pará, (Belém)	Effect of incremental levels of inclusion of cratylia on DM intake by sheep fed *Urochloa humidicola* and housed in metabolism crates	Intake of DM/day (% of BW) 25% cratylia: 1.76b 50% cratylia: 1.96a 75% cratylia: 1.89ab 100% cratylia: 1.31c	Santos (2007)
Colombia, Cauca (CIAT-Quilichao)	Effect of plant maturity (immature vs. mature) and forage processing on short-term intake of cratylia forage offered to confined sheep	Intake (g DM/h/animal) Immature Fresh: 84b Wilted (24 h): 157a Wilted (48 h): 183a Sun-dried: 160a Mature Fresh: 291 Wilted: 376 Sun-dried: 359	Raaflaub and Lascano (1995)
Colombia, Cauca (CIAT-Quilichao)	Short-term (½ hour AM and ½ hour PM) intake by confined sheep and goats housed in metabolism crates, of fresh forage (6–8 mo regrowth) of cratylia in comparison with 2 other shrub legumes	Intake (g DM/kg BW$^{0.75}$/day)[3] *C. argentea* Goats: 4.12; sheep: 3.81; mean: 3.97a *D. velutinum* Goats: 4.21; sheep: 2.99; mean: 3.60a *F. macrophylla* Goats: 3.08; sheep: 2.09; mean: 3.06b	Yi Kexian et al. (1998)
Colombia, Valle (Corpoica-Palmira)	Intake of cratylia by sheep housed in metabolism crates, in comparison with 2 other woody species	Intake (g DM/kg BW/day) *C. argentea*: 16.3b *C. gyroides*: 16.8b *Malvaviscus arboreus*: 23.2a	Celis et al. (2004)
Colombia, Cauca (CIAT-Quilichao)	Effect of level and frequency of feeding cratylia (AM only vs. AM and PM) on intake by confined sheep	Intake (g DM/kg BW/day) Feeding AM: 0.5% BW: 2.0c 1.0% BW: 3.1b Feeding AM and PM: 0.5% BW: 2.0c 1.0% BW: 3.6a	Quiñonez et al. (2004)
Costa Rica, Puntarenas (San Miguel de Barranca)	Effect of wilting of cratylia and addition of molasses on intake by heifers after 4 hours of confinement	Intake (g DM/100 kg BW/day) Without molasses: Fresh: 280 Wilted: 370 With molasses: Fresh: 400 Wilted: 430	Ibrahim et al. (2001)
Puerto Rico, Mayagüez	Intake of sun-dried cratylia by confined sheep in comparison with 2 legumes offered in a 50:50 hay mixture with guinea grass	Intake (grass + legume) (g DM/animal/day) *C. argentea*: 1,210a *C. calothyrsus*: 802b *L. leucocephala*: 1,214a	Rodríguez et al. (2015)

[1]Results followed by different letters differ significantly ($P<0.05$).
[2]Units for intake vary by experiment.
[3]Metabolic weight.

The effects of level and frequency of feeding cratylia to sheep in metabolism crates were evaluated by Quiñonez et al. (2004), who showed that frequency of feeding at a low level (0.5% of body weight, BW) had no effect on intake of cratylia. However, when a higher level (1% of BW) of cratylia was offered, more frequent feeding (AM + PM) resulted in greater intake than feeding only once a day. The level or frequency of feeding cratylia had no effect on digestibility, while N retention was greater when sheep were given forage-based supplements at the higher level and twice a day (Quiñonez et al. 2004).

Results from reviewed studies suggest that, in cut-and-carry systems, the need for wilting or drying immature forage of cratylia would not impose a major constraint to its utilization. However, under grazing use of cratylia as a protein bank or in association with a grass would require that animals, particularly in the wet season, be previously exposed to cratylia to ensure that it is well consumed. Results also showed that frequency and level of supplementation affect intake of cratylia when offered as a supplement in a cut-and-carry system.

Secondary compounds

A major secondary compound in some temperate and tropical legumes are CT, which in cratylia forage are absent or occur only at very low levels (Perdomo 1991; Celis et al. 2004; Stürm et al. 2007) when measured with the Butanol-HCl assay that separates extractable and bound CT (Terrill et al. 1992). Nevertheless, in some studies cratylia has been included as a tannin-rich legume, mainly to evaluate its effect on reducing enteric methane production or controlling gastrointestinal parasites.

Condensed tannins and rumen fermentation. In Brazil, in a study to evaluate the effect of 10 tannin-rich tropical legumes, including cratylia, on suppressing in vitro methane production, Fagundes et al. (2020) found that among the 5 shrub legumes tested only leucaena significantly suppressed rumen methanogenesis. Other studies confirm that shrub legumes high in CT like flemingia suppress methane production as compared to cratylia (Tiemann et al. 2009b; Aragadvay-Yungan et al. 2021). Hess et al. (2004) reported that cratylia can improve body protein retention but does not suppress absolute enteric methane release in vitro or in vivo.

When studying the effect of CT on in vitro ruminal fermentation of various low-tannin and high-tannin legumes, Stürm et al. (2007) found that CT concentrations measured with the Butanol-HCl assay in 4 different shrub legumes ranged from nil in cratylia to 260 g/kg DM in calliandra while fermentation parameters (in vitro DM digestibility, gas production, concentration of volatile fatty acids) were higher in cratylia than in the other legumes. The addition of CT-inactivating polyethylene glycol (PEG) (Decandia et al. 2000) had no effect in rumen fermentation parameters with cratylia in contrast to what was observed with the tanniniferous legumes, calliandra, flemingia and leucaena, evaluated in the study. Similarly, Fagundes et al. (2020) confirmed that cratylia did not suppress in vitro methane production as was the case with leucaena.

Condensed tannins and gastrointestinal parasites. As CT-containing legumes are known to have potential in controlling gastrointestinal (GI) nematodes in ruminants, von Son-de Fernex et al. (2012) carried out an in vitro study with 5 tropical legumes including 3 cratylia accessions (*C. argentea* cultivar 'Veranera' (Veranera), CIAT 22386 and the 'Yapacaní' morphotype CIAT 22397 (Yapacaní) to assess their effect on the GI nematode, *Haemonchus contortus*. Results showed differences among cratylia accessions regarding larval exsheathment and larval migration inhibition that were attributed to CT. The activity of cratylia extracts on parasites was blocked after addition of PEG, which is considered proof of prevention of tannins/phenolic compounds binding to proteins (Decandia et al. 2000).

In Brazil, Silva et al. (2018) carried out an in vivo trial with sheep to assess the effect of feeding cratylia on GI parasites. Crossbred lambs were fed cratylia, cratylia + grass (*Urochloa* species) or grass only. Animals fed cratylia had a lower average number of eggs per gram of feces, the average count being 10 times lower than that in the control. The authors concluded that both protein and tannin consumption from cratylia in a protein bank may have influenced the host's ability to control endoparasites.

The positive response of cratylia in controlling GI parasites suggests that secondary compounds with CT-type properties are present in this legume but are not detected with the Butanol-HCl assay. CTs are heterogeneous phenolic compounds with different monomer composition and molecular weights. Most plant CTs (anthocyanins) are composed of cyanidin, delphinidin, and pelargonidin monomer units (Mueller-Harvey 2006). Studies to define the antioxidant and biological activity of monomer units in CT showed that delphinidin had the strongest activity followed by cyanidin and pelargonidin (Quijada et al. 2015; Koss-Mikołajczyk and Bartoszek 2023). In Brazil, Pereira et al. (2018) characterized CT in tropical forage legumes and found that only pelargonidin was present in cratylia. Thus, future studies should assess the role of pelargonidin in parasite control.

Lectins and gastrointestinal parasites. Early studies reported the presence of a lectin in seeds of cratylia (Moreira et al. 1984; Oliveira et al. 2004). An in vitro study showed that cratylia extracts obtained from pods/ground seeds had the potential to control young stages of GI nematodes (Silva et al. 2017). Lectins are plant secondary metabolites, which bind carbohydrates and have been reported to control GI parasites through disrupting the development of parasitic larvae. This property was shown in vitro with plant extracts of gliricidia and leucaena (Ríos-de Alvarez et al. 2012). Including PEG and fetuin, which are CT and lectin inhibitors, respectively, partially reversed the anthelmintic activity of extracts of the 2 legumes. In this study, however, fetuin was more potent than PEG in inhibiting the anti-larval effects of extracts of gliricidia than of leucaena, suggesting that in the former the anthelmintic activity could be mainly due to lectins and not CT. We postulate that this could also be the case with cratylia and suggest that plant extracts of cratylia accessions should be screened for type of lectins present, and in vitro anthelmintic properties need to be validated through in vivo studies.

Utilization in livestock production systems

Tropical pastures are characterized by marked seasonal fluctuations in quantity and quality of forage biomass. In grasses, a reduction in protein concentration and digestibility, and an increase in the cell wall component are common during the dry season, causing decreased intake and weight loss or reduced milk yield. Under these circumstances, supplementation with a drought-tolerant shrub legume like cratylia is an option.

Consequently, cratylia, as a high protein forage legume, is frequently used in protein banks (pure stands) for cut-and-carry or grazing with controlled access or in association with grasses for direct grazing. It is recommended for use as a fresh or ensiled forage/feed supplement for cattle and small ruminants, poultry and swine or for strategic feeding mainly during periods of forage scarcity, mostly in dry seasons, but in the humid tropics also during periods of excessive rains. A concrete example of strategic use of a cratylia protein bank in the subhumid tropics was the suggestion to cut forage for conservation as silage in the rainy season and feed as fresh forage in the dry season (Lobo and Acuña 2004) (Figure 1).

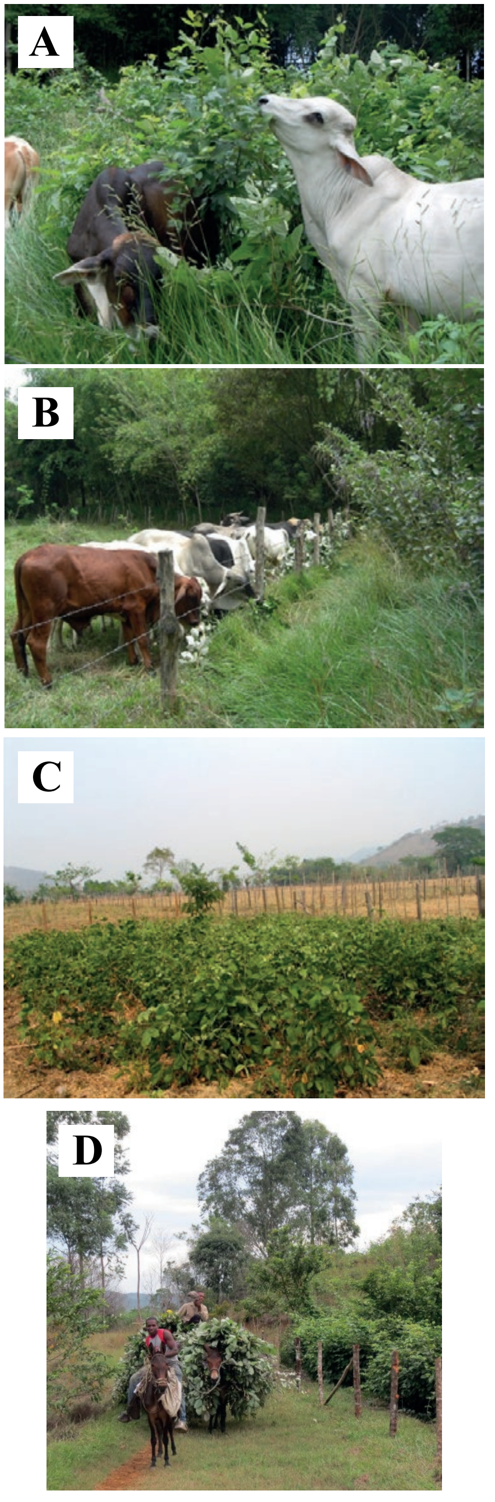

Figure 1. Utilization of *Cratylia argentea*. (A) Steers browsing cratylia in a *Urochloa humidicola* pasture, Valle del Cauca, Colombia (Photograph: R. Schultze-Kraft); (B) Steers in a *U. humidicola* pasture feeding on cut cratylia branches, Valle del Cauca, Colombia (Photograph. R. Schultze-Kraft); (C) Young protein bank in dry season, Danlí, El Paraíso, Honduras (Photograph: R. Schultze Kraft); (D) Cut-and-carry, Patía, Cauca, Colombia (Photograph: B. Hincapié, CIAT).

Silage production and utilization for milking cows

Results of research on silage production and on-station and on-farm trials conducted to evaluate cratylia as a protein supplement for cattle, small ruminants, and other animal species, for forage intake, milk yield and liveweight gain are presented. Use of silage for dry season feeding and as an alternative to replace concentrates or crop by-products is considered an alternative for dual-purpose cattle production systems. However, it is recognized that ensiling legumes presents difficulties due to their high buffering capacity and low concentration of water-soluble carbohydrates (WSC). In a study in Colombia, Correa Pinzón and Niño-Mariño Mariño (2010) found that the protein concentration in cratylia silage (15.8%) was lower than that of fresh forage (19.3%) or cratylia hay (19.2%), possibly related to proteolysis known to occur in silage stored at high temperatures (Aloba et al. 2022).

Lactic acid bacteria inoculation together with addition of a fermentable carbohydrate source has proven useful for promoting favorable fermentation in forage species including tropical legumes (Oliveira et al. 2017). This was confirmed for cratylia in a laboratory study with 10 legume species, where Heinritz et al. (2012) found a low concentration of WSC (34.8 g/kg DM), similar to that of other shrub legumes like flemingia and *L. diversifolia*. After addition of sucrose (20 g/kg of fresh forage) to the material being ensiled and inoculation with a *Lactobacillus* strain, cratylia and the other legumes could be ensiled satisfactorily. The inoculation with *Lactobacillus* in combination with WSC reduced protein losses by ammonia-N formation through rapid acidification. Similarly, Jiménez et al. (2004) obtained satisfactory lactic acid fermentation with the addition of 10% molasses to chopped cratylia, resulting in good quality silage. They also found that adding 25% chopped sugarcane as an alternative source of WSC was adequate to prevent alcoholic fermentation.

Another role of cratylia is to improve the quality of grass silage. By adding 30–45% of cratylia, López Monroy (2014) raised the protein concentration of Napier grass [*Cenchrus purpureus* (formerly *Pennisetum purpureum*)]/ sugarcane silage from 5.0 to 8.8–10.8%. Romero and González (2004) found that a 3-month regrowth of cratylia resulted in good quality silage when mixed in a proportion of 65% sugarcane and 35% cratylia.

Utilization of cratylia silage as a supplement has been evaluated on station and on farm in dual-purpose cattle systems, mainly in Central America. Resulting milk yields vary depending on the milking potential of cows. In Nicaragua, Sánchez and Ledin (2006) supplemented medium-producing (7–9 kg/day) milking cows that were fed sorghum silage and found that, when adding 2 or 3 kg of molasses-sprayed fresh cratylia to the silage, DM intake increased by 18 and 32%, respectively. While milk production increased on average by 59% with the addition of cratylia, the concentrations of milk fat, total solids, protein, and organoleptic characteristics (smell, taste, and color) were not different among diets. In contrast, Laguna-Gámez (2018) found no effect on milk yield when ensiled cratylia was added to a Taiwan grass (*Cenchrus purpureus*) diet of low-producing (4 kg/day) cows in Nicaragua, but milk fat increased from 3.6 to 4.0%.

In trials in Costa Rica, Argel et al. (2000) on farm and Romero and González (2004) on station reported that ensiled cratylia successfully replaced concentrate and chicken manure as a protein supplement fed to milking cows. Although feeding cratylia silage had no effect on milk yield, milk fat concentration was increased. At farm level, the benefit:cost ratio of feeding ensiled cratylia was lower than when feeding fresh cratylia, due to high labor costs (Argel et al. 2000). However, an advantage of ensiling cratylia is that forage produced in the wet season can be conserved for dry season feeding.

In general, results reviewed indicate that cratylia can enhance quality of grass silage, economically replace concentrates and, when ensiled and supplemented in cow diets, has variable results on milk yield and composition.

Supplementation and intake

In view of the generally low protein concentration in tropical grasses, particularly during the dry season, and subsequent low forage intake by animals, several studies assessed the effect of supplementing low-quality grass diets with high protein cratylia on forage intake by ruminant animals (Table 3).

Supplementing cratylia to sheep fed a low-quality grass diet showed that total DM intake was not affected when cratylia was offered alone or in mixture with flemingia, a high-tannin shrub legume (Fässler and Lascano 1995). However, urinary N loss was reduced with increased intake of the legume mixture, suggesting less rumen ammonia losses due to protection by CT in flemingia. Other results show that supplementation of low-quality grasses with cratylia in different proportions significantly increased total DM intake, protein intake, NH_4-N in the rumen, flow of total and bacterial N to the duodenum, and apparent absorption of N in the lower gastrointestinal tract, resulting in increased protein retention (Wilson and Lascano 1997; Hess et al. 2004; González-Arcia et al. 2018). In contrast, including cratylia to replace a high-quality grass like *Cynodon dactylon* cultivar 'Tifton 85' in finishing lamb diets did not influence weight gain, dry matter intake, dry matter digestibility, feed efficiency and nitrogen balance (Teixeira et al. 2023).

In most studies reviewed, supplementation with cratylia resulted in substituting the basal grass diet (Fässler and Lascano 1995; Wilson and Lascano 1997; González-Arcia et al. 2018) and decreased – or had no effect on – digestibility of the total diet due to high concentration of indigestible fiber.

Animal production – ruminants

This section summarizes results of studies carried out to measure milk yield (Table 4) and liveweight gain (Table 5) of cattle supplemented with cratylia, either in pens or under grazing.

Milk production. Milk production in most tropical regions is characterized by low yields due to poor quality and low availability of grasses in pastures, particularly in the dry season. In addition, cows used in dual-purpose production systems (milk and meat) have generally low genetic potential with limited response to increased quality of the pasture and supplementation with forage legumes (Lascano and Ávila 1993).

In an on-farm study carried out in Nicaragua, milk yield was quantified with cows supplemented with cratylia (5 kg) + sugarcane (15 kg) offered after milking. Although results were not statistically different due to large variation between animals, a trend was observed where cows supplemented produced 22% and 32% more milk than un-supplemented cows, in the wet and dry seasons, respectively (Morales Lara and Herrera Maradiaga 2009).

Table 3. Overview of intake of *Cratylia argentea* fed to small ruminants and cattle in different forms and levels.

Country, region/site	Study	Results[1,2]	Reference
Colombia, Cauca (CIAT-Quilichao)	Intake by sheep fed a low-quality grass (*U. humidicola* cultivar 'Llanero' with CP 5.1%) supplemented with cratylia (51%), cratylia (37%) + flemingia (10%) or cratylia (26%) + flemingia (19%)	Intake (g DM/animal/day) Grass alone: 457 Grass + cratylia: 476 Grass + cratylia + low flemingia: 510 Grass + cratylia + high flemingia 511	Fässler and Lascano (1995)
Colombia, Cauca (CIAT-Quilichao)	Intake by sheep fed a low-quality grass hay (*U. humidicola* cultivar 'Llanero' with CP 6.9%) supplemented with incremental additions of cratylia	Intake (g DM/kg BW/day) Grass alone: 21.6c Grass + 10% cratylia: 23.5ab Grass + 20% cratylia: 24.7a Grass + 40% cratylia: 25.5a	Wilson and Lascano (1997)
Colombia, Cauca (CIAT-Quilichao)	Intake by sheep fed a low-quality grass (*U. humidicola* cultivar 'Llanero' with CP 3.9%) supplemented with different levels of cratylia (+ concentrate)	Intake (g DM/kg $BW^{0.75}$/day)[3] Grass alone: 70.0 Grass + 33% cratylia: 74.1 Grass + 66% cratylia: 76.8	Hess et al. (2004)
Mexico, Veracruz (Atzalan)	Intake by bullocks fed a low-quality grass (*U. arrecta* with CP 6.2%) supplemented with incremental additions of cratylia	Intake (g DM/kg $BW^{0.75}$/day)[3] Grass alone: 113.7 Grass + 15% cratylia: 124.4 Grass + 30% cratylia: 145.0 Grass + 45% cratylia: 149.4	González-Arcia et al. (2018)
Brazil, Minas Gerais (Central)	Intake by lambs supplemented with different levels of cratylia hay to replace hay (*Cynodon dactylon* cultivar 'Tifton 85' with CP 18%)	Intake (kg DM/animal/day) Grass alone: 1.4 20% cratylia: 1.4 40% cratylia: 1.3 100% cratylia: 1.5	Teixeira et al. (2023)

[1]Results followed by different letters differ significantly (P<0.05).
[2]Units for intake vary by experiment.
[3]Metabolic weight.

Table 4. Overview of supplementation with *Cratylia argentea*: Effect on milk yield in different utilization systems.

Country, region/site	Study	Results[1,2]	Reference
Colombia, Cauca (CIAT-Quilichao)	Controlled access of cows grazing *Urochloa decumbens* to a protein bank of immature or mature cratylia	Immature cratylia: Grass only: 10.0 Grass + legume: 9.8 Mature cratylia: Grass only: 10.5 Grass + legume: 10.4	Aparicio et al. (2002)
Colombia, Cauca (CIAT-Quilichao)	Cows supplemented with cratylia (1.5% of BW) in a cut-and-carry system or with access to a *U. decumbens* - cratylia association (dry season)	Grass only (control): 6.1b Supplemented: Cut-and-carry: 6.7b Direct grazing: 7.5a	Lascano et al. (2004)
Costa Rica, Puntarenas (San Miguel de Barranca)	Effect of feeding cratylia (1 kg DM/100 kg BW) to cows grazing *Hyparrhenia rufa* supplemented with molasses (0.5 kg/cow) in the wet season	Without cratylia: 5.9 With cratylia: 5.8	Franco Valencia (1997)
Costa Rica, Alajuela (Atenas)	Milk yield of cows fed cratylia (6 kg) ensiled or fresh, supplementing a basic diet of 12 kg sugarcane + 0.6 kg rice polishing	Basic diet + ensiled cratylia: 5.1b Basic diet + fresh cratylia: 5.5a Basic diet + chicken manure: 5.3a,b	Lobo and Acuña (2004)
Nicaragua, Managua	Milk yield resulting from incremental levels of cratylia to cows in confinement fed with sorghum silage	Without cratylia: 3.7 With cratylia (2 kg DM/d): 4.9 With cratylia (3 kg DM/d): 5.4	Sánchez and Ledin (2006)
Nicaragua, Región Autónoma del Atlántico Sur (Nueva Guinea)	Milk yield of cows supplemented with a 75:25 mixture of sugarcane and cratylia during the dry and wet seasons	Dry season: Control: 4.4 Supplemented: 5.8 Wet season: Control: 3.7 Supplemented: 4.5	Morales Lara and Herrera Maradiaga (2009)

[1]Results followed by different letters differ significantly ($P<0.05$); [2]kg/cow/day.

When cows grazed the low-quality grass, *Hyparrhenia rufa*, in the Pacific region of Costa Rica, supplementation during the dry season with fresh cratylia, and molasses, did not affect milk yield, but increased milk solids (Franco Valencia 1997). Also in Costa Rica, Ibrahim et al. (2004) reported that supplementing cratylia to cows grazing the same low-quality grass in the dry season replaced chicken manure and improved profitability per liter of milk produced.

One alternative for the utilization of shrub legumes is to allow milking cows to have controlled access to pure stands (protein banks). In Colombia, crossbred Zebu × Holstein cows grazing *U. decumbens* had access to an immature or a mature cratylia stand for 2 hours after milking (Aparicio et al. 2002). Although there was no difference in milk yield between the 2 groups, concentration of milk urea-N (MUN) was higher in cows with access to the immature (18.7 mg/dL) and mature (14.9 mg/dL) cratylia protein banks relative to the control (10.9 mg/dL). According to Jonker et al. (1998), these differences in MUN suggest an energy-to-protein imbalance in the rumen fermentation process of cows with access to the protein bank. At the same location, milk yield of cows was 23% higher in a period of low rainfall when cows had access to a *U. decumbens* pasture associated with cratylia as compared with the grass alone, or when cratylia was offered in a cut-and-carry system. No differences in milk yield were observed among treatments in the wet season (Lascano et al. 2004).

Milk yield response of supplementation with cratylia in cut-and-carry systems is variable and, as indicated previously, dependent on the genetic potential of cows (Lascano and Ávila 1993). However, the utility of cratylia as a supplement in tropical milking systems cannot be limited to increases in milk yield as shown in a study in the Andean piedmont of Colombia (Plazas and Lascano 2005). There, a total of 6.5 ha cratylia were established in 9 representative farms to supplement cows with fresh legume forage in the milking parlor. Milk yield per cow did not increase with the supplemented cratylia relative to no supplementation (6.4 vs. 6.8 kg/cow/day). However, other benefits of cratylia not contemplated by researchers were observed: (a) feeding cows with cratylia in the wetter part of the rainy season, when grazing in the pastures was limited due to excess rainfall and high soil moisture; (b) partial replacement of expensive commercial concentrates in the dry and wet seasons; and (c) improvement of body condition of cows for better reproduction.

For the same Andean piedmont region, an ex-ante simulation study on the benefits of using cratylia in form of cut-and-carry showed that cost of producing milk was reduced by 13, 7 and 11% when fed fresh alone, with the addition of molasses or in combination with Napier grass, respectively (Holmann et al. 2002). Utilizing cratylia under grazing in association with grass (2,500 plants cratylia/ha re-established every 5 years) resulted in the greatest cost reduction (19%) in milk production. It had an additional benefit of freeing 18–25% of land under pastures for other uses, indicating that when livestock numbers remain unchanged, there was an increase in carrying capacity of the farm with the introduction of cratylia.

Liveweight gain. In a dual-purpose cattle system in Colombia, pre-weaned calves in a 7-month period gained 16% more weight on a grass pasture (*Urochloa* hybrid cultivar 'Mulato') in association with cratylia than those grazing the grass alone but supplemented with a mixture of chicken manure + corn bran + sugarcane (Benavides-Calvache et al. 2010). The authors only indicate that cratylia was browsed but did not report on acceptance or frequency of browsing.

In the humid tropics of Mexico, daily weight gain of F1 Holstein × Zebu heifers was measured in 3 periods in pastures of *U. brizantha* cultivar 'Toledo' alone or in association with cratylia. Heifers on the pasture with cratylia gained on average 53% more weight than those on the grass alone pasture (Valles-de la Mora et al. 2017).

In the Andean piedmont of Colombia, Rincón (2005) evaluated a fattening system of steers that combined grazing and feeding a mixture of cratylia with sugarcane in confinement (3 PM to 8 AM of the following day). Results showed that LWG of both Zebu steers and cross-bred steers were very low, possibly due to low intake of the supplement by animals in partial confinement.

Table 5. Overview of supplementation with *Cratylia argentea*: Effect on liveweight gain (LWG).

Country, region/site	Study	Results[1]	Reference
Colombia, Meta (Andean piedmont)	Performance of Zebu and cross-bred steers grazing *U. decumbens* vs. grazing from 8 AM to 3 PM and supplemented in a corral from 3 PM to 8 AM with sugarcane (5 kg/steer) + cratylia (3 kg/steer)	LWG (g/animal/day) Control (grazing without supplementation): Zebu: 522 Cross-bred: 637 Limited grazing with supplementation: Zebu: 78 Cross-bred: 125	Rincón (2005)
Colombia, Meta (Andean piedmont)	Supplementation of Zebu and cross-bred steers grazing *U. decumbens* with sugarcane (5 kg/steer) + cratylia (3 kg/steer)	LWG (kg/ha) Control (without supplementation): Zebu: 498 Crossbred: 630 With supplementation: Zebu: 1,239 Crossbred: 1,171	Rincón (2005)
Colombia, Meta (Andean piedmont)	Supplementation of heifers grazing *U. decumbens* + *U. brizantha* cultivar 'Toledo' with cratylia (30%) + sugar cane (70%) silage or grazing only grass	LWG (g/animal/day) Grazing: 603 Grazing + silage supplement: 765	Corpoica (2017)
Colombia, Caldas (Anserma)	LWG of pre-weaned calves grazing *Urochloa* hybrid cultivar 'Mulato'; comparison of a conventional supplement with cratylia	LWG (kg/calf/7 months) Conventional supplement: 59.1 Cratylia: 68.7	Benavides-Calvache et al. (2010)
Mexico, Veracruz (Atzalan)	LWG of heifers grazing an association of *U. brizantha* cultivar 'Toledo' and cratylia	LWG (g/animal/day; average of 3 periods) Control (grass only): 400 Grass + cratylia: 610	Valles-de la Mora et al. (2017)

[1]Units for live weight gain vary by experiment.

In a second experiment, steers grazed only *U. decumbens* grass or were supplemented in the pasture with the same mixture of cratylia and sugarcane fed to confined animals (Rincón 2005). Daily LWG of steers did not differ between animals supplemented in the pasture with sugarcane + cratylia (660 g) and those not supplemented (618 g). In this study the advantage of supplementing cratylia with sugarcane was in terms of carrying capacity, which was 2.5 times greater in the pasture where animals were supplemented (2 animals/ha vs. 5 animals/ha). The economic analysis performed indicated that supplementation of grazing animals with cratylia + sugarcane resulted in twice the profitability as compared to no supplementation, even though animals substituted the less expensive grass in the pasture with the cratylia + sugarcane supplement.

In a third experiment in the same region, heifers grazing an *Urochloa*-based pasture were supplemented with cratylia/sugar cane silage silage and gained 27% more weight than those not supplemented. A major advantage of supplementation with cratylia/sugarcane silage was that carrying capacity of the pastures was increased from 1.4 animals/ha to 2.8 animals/ha (Corpoica 2017).

Results reported from Mexico and Colombia confirm that associations of cratylia with grasses are an economic alternative resulting in increased liveweight gain and milk yield. Results from the Andean piedmont of Colombia indicate that a major advantage of supplementing cratylia + sugarcane to grazing animals is in increasing carrying capacity of the pasture, which has significant economic implications. In addition, results suggest that fattening systems with confined animals should ensure adequate intake of the cratylia + sugarcane supplement.

Animal production – non-ruminants

Smallholder production systems aim at achieving economic impact by using forage legumes as alternatives to replace concentrate in poultry, swine and rabbit diets.

Poultry. In Puebla, Mexico, González-Martínez (2016) found that mature sun-dried, ground cratylia leaves (15.8% CP concentration) did not improve LWG of broilers raised in a backyard system, regardless of their proportion in a mixture with maize (5, 10 or 15%). In a study with penned broilers in Colombia, Silva Higuera et al. (2013) replaced protein in a balanced diet that contained animal protein (meat meal) with increasing levels of cratylia (0, 5, 10 and 15%). Results showed that LWG of animals was negatively affected (-10 to -20%) at all substitution levels. However, the authors conclude that a 5% inclusion of cratylia can be recommended given that feed conversion was similar to the control (2.8 vs. 3.2). From these few studies it can be inferred that cratylia forage may not be the preferred option to replace protein in the diet of growing broilers even at low levels, possibly related both to low protein quality in terms of essential amino acids and to high fiber concentration.

Swine. Pig rearing is a common smallholder livelihood activity in many tropical regions. However, in these systems poorly balanced pig diets, particularly low protein concentration, is a major cause of low growth rates and poor reproductive performance. The alternative of feeding pigs in smallholder systems with legumes is an option not as well researched in tropical America as it is in Southeast Asia (Stür et al. 2010). In Colombia, Sarria and Martens (2013) compared silages of 3 legumes (cratylia, *Clitoria ternatea* or *Centrosema brasilianum*) and a grass silage (*Urochloa* hybrid cultivar 'Mulato II') offered ad lib to growing pigs as supplements of a balanced diet. Intake of cratylia or *Clitoria ternatea* silages was 17% higher than grass silage and similar to a balanced diet with commercial concentrate. It was concluded that cratylia silage could be offered up to 500 g/kg of diet DM as a supplement to a commercial concentrate despite its high fiber concentration. Future studies should evaluate the substitution effect of cratylia fed fresh and ensiled in LWG of growing pigs.

Rabbits. For adequate growth, rabbits require diets with fiber, which, in traditional commercial systems, is supplied by alfalfa meal given its nutritional attributes. Câmara (2017) evaluated the feasibility of replacing alfalfa by cratylia leaf meal in Brazil. When feeding rabbits with either a balanced concentrate ration with 42% alfalfa or the concentrate ration where 20% cratylia leaves replaced alfalfa, the diet influenced neither intake nor LWG.

Strengths and weaknesses

Strengths and weaknesses of cratylia as livestock feed are:

Strengths

- High leaf+ fine stem protein concentration
- Increased milk yield of cows of medium to high genetic potential when associated with grasses
- Improved liveweight gain when associated with grasses
- Increased livestock carrying capacity of pastures when offered as a supplement
- Replacement of concentrates when offered fresh or as silage to milking cows
- Anthelmintic property when offered to sheep
- Absence or low concentrations of condensed tannins
- Suitability for cut-and-carry, grazing, silage, leaf meal
- Suitability for integrated agropastoral production systems

Weaknesses

- Labor requirements for forage harvest in cut and carry systems
- Low intake of fresh forage by animals not accustomed to the legume

Technology adoption

Lack of data on the actual use of cratylia through area planted, number of users or quantities of seed sold, impedes assessing the adoption and impact of this legume. Based on literature consulted and personal information obtained, we conclude that within the 20 years after the release of cratylia cultivars (in Costa Rica and Colombia), and in spite of promising on-farm experimental results the rate of adoption has probably been low.

Slow establishment and high labor requirements probably play a significant role in low adoption, along with lack of access to commercial quality seed at affordable prices. Low cratylia adoption is also the result of the technology being developed with a focus on tropical America. In this region, cattle production, regardless of farm size, is based traditionally on grasses with less management requirements than legumes. It is only now that, within the discussions related to sustainable intensification and environmental impact of agriculture, incentives and pressure may be starting to build to support the use of legumes (Schultze-Kraft et al. 2018). The potential of cratylia should be considered in regions with long dry seasons and acid, infertile soils where well-known shrub/tree legumes such as leucaena are not adapted.

Another explanation for the slow adoption of cratylia, could be that with the changes in research and development strategies in major research centers during past years, there are a lack of whom Shelton et al. (2005) called "champions" - motivated individuals, who interact with farmers and institutions and explore and promote the use of a new technology through participatory research.

Research suggestions

Although many of the suggested studies raised at the 1995 workshop (Pizarro and Coradin 1996) were carried out during the past 30 years, some have not yet been addressed and new research needs have been identified with the following considered as priority:

Feed value. Further evaluation of feeding mixtures of cratylia with other acid-soil adapted but high-CT legumes such as flemingia and calliandra for cattle should be done to improve overall feed intake, reduce enteric CH_4 production and N losses in urine. Existing interest could be pursued on deploying cratylia to control gastrointestinal parasites in ruminants to respond to the growing resistance of parasites to anthelmintic drugs and the control obtained by feeding legumes with CT and lectins. Even though seed extracts and forage from cratylia controlled parasites in sheep, the question remains if this control is associated with CT since only traces are measured using recommended chemical assays. Thus, accessions of cratylia should be screened for the monomer units that form the chemical structure of CT and for other secondary compounds like lectins.

Utilization in livestock production systems. Priority should be given to grazing management studies with cratylia as a protein bank and in agropastoral systems in association with grasses, because in many regions direct grazing of cratylia may be the preferred use of the legume by farmers, owing to labor costs involved in cut-and-carry systems. Future studies should also explore the use of cratylia as a feed resource in swine production in smallholder systems.

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(Note of the editors: All hyperlinks were verified 23 May 2024).

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