Feeding Systems with Legumes to Intensify Dairy Farms

A project executed by the Tropileche Consortium

Editors:

Federico Holmann
Carlos Lascano

2004

CIAT

System-wide Livestock Programme

ILRI
INTERNATIONAL LIVESTOCK RESEARCH INSTITUTE

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Project Objectives

The project´s main objective is to use improved legume-based pastures to increase milk production in smallholder dual-purpose systems, thus increasing income return and ensuring the sustainability of natural resources.

List of Abbreviations and Acronyms Used

CATIE	Centro Agronómico Tropical de Investigación y Educación (Costa Rica)
CIAT	International Center for Tropical Agriculture (Colombia)
CODESU	Consorcio para el Desarrollo de Ucayali (Peru)
CORPOICA	Corporación Colombiana de Investigación Agropecuaria (Colombia)
CTAR	Consejo Transitorio Agropecuario Regional (Peru)
DEPAAM	Desarrollo Participativo Amazónico (Peru)
DICTA	Dirección de Ciencia y Tecnología Agropecuaria (Honduras)
ECAG	Escuela Centroamericana de Ganadería (Costa Rica)
FUNDAAM	Fundación para el Desarrollo Agropecuario del Alto Mayo (Peru)
GTZ	German Agency for Technical Cooperation
IDB	Inter-American Development Bank
IDR	Instituto de Desarrollo Agrario (Nicaragua)
IIAP	Instituto de Investigación de la Amazonía Peruana
ILRI	International Livestock Research Institute
IVITA	Instituto Veterinario de Investigaciones Tropicales y de Altura (Peru)
MA	Ministry of Agriculture (Peru)
MAG	Ministry of Agriculture and Animal Husbandry (Costa Rica)
UCR	University of Costa Rica

ADF	Acid detergent fiber
CP	crude protein
DM	dry matter
g	gram
kg	kilogram
ha	hectare
IVDMD	in vitro dry matter digestibility
LAC	Latin America and the Caribbean
LW	animal liveweight
N	nitrogen
NDF	Neutral detergent fiber
NFS	Non-fat solids
masl	meters above sea level
ME	metabolizable energy
MUN	milk urea nitrogen
OM	Organic matter
R&D	Research and Development
SLP	Systemwide Livestock Programme
TS	Total solids

Executive Summary

The project "Feeding Systems with Legumes to Intensify Dairy Farms" is conducted under the CIAT-led Tropileche Consortium that operates under the Systemwide Livestock Programme (SLP) convened by the International Livestock Research Institute (ILRI). The Consortium is composed by scientists from CIAT, ILRI, and national agricultural research institutes in Peru (FUNDAAM, DEPAAM), Costa Rica (MAG, ECAG, CATIE, UCR), Nicaragua (IDR), and Honduras (DICTA). The strategy to improve feeding systems includes:

- Evaluation of new feed resources to satisfy the nutritional requirements of grazing animals
- On-farm evaluation of new legume-based forage components, and
- Economic analysis and acceptability/adoption studies of new technologies

This report includes the results generated during the last four years of the project (1996-2000), which further confirm the significant impact of improved grasses and legumes on animal production.

In Costa Rica's Pacific coastal region, the pasture association *Brachiaria decumbens* + *Arachis pintoi* increased the daily milk production of Jersey cows, even though these animals were receiving a commercial concentrate. Likewise, this association supported a heavier stocking rate than did pastures of *B. decumbens* + *Hyparrhenia rufa* or of *B. decumbens* alone under similar management. In the same region, research on *Cratylia argentea* (cratylia) demonstrated that this legume harvested fresh at 90 days after regrowth and 90 cm high can replace commercial concentrate or 82% of chicken manure given to dairy cows of medium production, and is an excellent feed alternative for the dry season. The use of cratylia supplements could therefore help small milk producers have access to a protein supplement produced on their own farms, thereby increasing their income and cash flow.

Another form of using cratylia in the region is as silage with molasses added and fed to cows, together with chopped sugarcane, during milking. Other studies found that mixed cropping of maize with forage soybean is an excellent alternative for making silage, not only because of the increase in protein in the final product, but also because of the economic benefit from additional milk production and the partial use of harvested maize through the sale of tender maize ears.

At the CIAT-Quilichao station (Department of Cauca, Colombia), researchers found that about 10 mg/dL of urea in the milk comprised an adequate reference point at which to increase the protein content in the animals' diet. Dairy cows would most probably respond to increased protein with significantly higher milk yields (provided that the cows' genetic potential is demonstrated).

In the Colombian Amazon, the use of *Stylosanthes guianensis* (stylo) is an attractive option for raising preweaned calves and milking cows on small farms. The cost of establishing the legume is less than that of other alternatives based on grass and legume mixtures. Moreover, cash flow increases because of increased sales of milk, without sacrificing calf weight gain. Because stylo can persist for 3 or 4 years, this technology can also form part of a crop/pasture rotation system, eliminating the need to rest the land or leave it in fallow. During rotation, the legume improves the soil through N fixation and nutrient recycling.

In Pucallpa, Peru, stylo can fix as much as 50 kg/ha of N when it is established as a pioneer crop for sowing rice and the later establishment of improved pastures. In the Alto Mayo region of Peru, *Centrosema macrocarpum* has a positive impact when used as a supplement feed for Holstein × Gyr cows. Farmers in this region are highly likely to adopt, with positive impact, the technologies developed by the Tropileche Consortium. A high proportion of farmers had already adopted new cut-and-carry forages, improved milking pens and sheds to provide feed supplements to the herd, and installed forage choppers.

An *ex ante* study examined the impact on the herds of small dairy farmers of Costa Rica, Honduras, and Nicaragua of several forage alternatives: level 1 = new germplasm based on cratylia and sugarcane; level 2 = same areas of cratylia and sugarcane as those of level 1, plus areas of the *Brachiaria* varieties used in each country; and level 3 = areas of cratylia and sugarcane larger than those of levels 1 and 2, plus associations of *Brachiaria* + *Arachis* pastures. The results were:

1. Level 1 permitted farmers in the different countries to completely eliminate the purchase of supplements for livestock for the dry season, thereby greatly improving the farmers' cash flow by reducing milk production costs by 11% in Nicaragua, 14% in Costa Rica, and 25% in Honduras.

2. Level 2 not only provided the benefits of level 1 but also helped maintain the same milk production and herd size on smaller areas, releasing areas for alternative uses. The released areas varied from 9% for Honduras, 39% for Costa Rica, to as much as 45% for Nicaragua. This

level of adoption also reduced milk production costs compared with level 1 by 8% in Honduras, 11% in Costa Rica, and 12% in Nicaragua.

3. Level 3 increased milk productivity/ha to 964 kg in Nicaragua, 1390 kg in Costa Rica, and 1530 kg in Honduras.

The potential impact of the adoption of these technologies at the regional level is significant. For level 1, at the time of study, the resources invested totaled US$2.7 million in Honduras, US$5.1 million in Nicaragua, and US$6.4 million in Costa Rica. By reducing production costs, this investment made possible an additional annual net earning of US$9.9 million in Nicaragua, US$11.9 million in Costa Rica, and US$12.6 million in Honduras. Accordingly, the potential benefit of such investment is large, making repayments possible within the year.

In Honduras and Nicaragua, the artisan-scale cheese industry is the principal buyer of milk produced by small and medium-sized dairy farmers. In both countries, in watersheds with seasonal climates, milk production during the rainy season is almost double that produced in the dry season, causing, respectively, an oversupply and scarcity of milk. A survey found that, during the dry season, even though the artisan-scale cheese producers were willing to buy 55% more milk in Honduras and 76% in Nicaragua, milk was unavailable. The main reason was apparently the lack of adoption of improved forage-based feeding technologies.

This situation suggests that an aggressive program to promote the use of the shrub legume *C. argentea* and sugarcane to supplement the herd's feed during the dry season would have much more impact than promoting grasses or legumes for the rainy season. The artisan-scale cheese producers in both countries, but particularly in Honduras, require better quality milk, especially during the rainy season. In Honduras, milk prices would be 9.4% higher during the dry season and 11.2% higher during the rainy season. In Nicaragua, artisan-scale cheese producers would offer 17% higher prices, but only during the rainy season.

In parallel with research, the Tropileche Consortium has developed media for communicating with its partners and users to disseminate research results. Media include a database on dual-purpose production systems, which database is available through Internet on the CIAT/Tropileche web site; the *Hoja Informativa Tropileche* (the *Tropileche Newsletter*), which contains information on the Consortium's research advances; informative brochures on *B. brizantha* cv. Pasto Toledo; publication of results in scientific journals; and videos on the impact of improved forage technologies.

In collaboration with Nicaragua's Instituto de Desarrollo Rural (IDR) and Hondura's Dirección de Ciencia y Tecnología Agropecuaria (DICTA), the Consortium established more than 65 ha of improved forages on 20 farms located at five sites in Nicaragua and Honduras. Other achievements include the spontaneous adoption of *C. argentea* in Costa Rica, where 230 kg of experimental seed and for commercial sowing were distributed to seed companies and 41 farmers at four different sites; the commercial release in October 2000 in Costa Rica of *B. brizantha* CIAT 26110 as cultivar Pasto Toledo; and the expected release of *C. argentea* CIAT 18516/18668 as cultivar Veraniega.

The challenge ahead is to facilitate widespread evaluation of herbaceous and shrub legumes by small farmers and strengthen the production of seed of selected legumes. We are identifying new research needs from problems that are being experienced by farmers evaluating the new technologies. To effectively accomplish these objectives we need to continue to strengthen the alliances with other ILRI and CIAT projects, with partners in national R&D institutions, and the private livestock and seed sectors.

F. Holmann and C.E. Lascano

Achievements attained for each component and activity of the Tropileche Consortium, 1996-2000

Component	Activity	Outstanding achievements
1: Optimizing forage use	1.1: Controlled feeding and grazing trials to determine the relationships between milk production and forage resources	▪ The use of forage legumes as protein supplements during the rainy season increases milk production in cows with high genetic potential. ▪ The use of forage legumes in association with improved grasses makes increasing the stocking rate and reducing weeds possible, while improving the quality of biomass on offer in terms of crude protein and digestibility and favoring pasture sustainability. • Pastures of grasses and legumes in association increase the content of total solids in milk, resulting in better prices for the farmer.
	1.2: Use of forage resources and feed supplements during the dry season	▪ The response of cows in terms of milk production to feed supplements of fresh or ensiled forage legumes + sugarcane is similar to their response to protein sources in commercial concentrates. ▪ Direct grazing of shrub legumes increases milk production, compared with the cut-and-carry system. The legumes provide protein to the forage of the base diet, which is usually deficient in nitrogen. ▪ Highly fermentable carbohydrates can stimulate the degradation of less fermentable fiber. ▪ The use of carbohydrate additives improves the quality of ensiled shrub legumes.
	1.3: Functional relationships between forage resources of contrasting quality, ruminal fermentation, and blood parameters	▪ Concentrations of milk urea nitrogen (MUN) comprise an effective indicator of the protein-energy relationship in the diet. ▪ Concentrations of MUN are useful for increasing the efficiency of use of forage resources on the farm.
2: Developing new feed alternatives for dual-purpose cattle	2.1: On-farm evaluation of different forage systems with dual-purpose cattle	▪ Forage systems for strategic feed supplementation during the dry season reduce the need to buy feed concentrate and increase the income of dual-purpose farms. ▪ The use of legumes with an energy source during the dry season maintains milk production.

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Component	Activity	Outstanding Achievements
	2.2: Evaluating new feed alternatives to permit early weaning	▪ Fattening preweaned calves on legumes during the dry season makes the selling of more milk possible and increases animal liveweight gain as compared with fattening calves on pastures of grass alone.
	2.3: Integration of information, using simulation models of ruminants and nutrition	▪ Simulation models are useful for reducing research costs, predicting nutritional limitations, and facilitating decision making on the priorities of animal nutrition research.
	2.4: Workshops and meetings to analyze and plan research activities	▪ Workshops with the participation of the Tropileche Consortium's partners facilitate coordination, increase research efficiency, reduce the risks associated with duplicated efforts, and permit the prioritization of medium- and long-term activities.
3: Usefulness of the new forage systems	3.1: Diagnosis, economic characterization, and land use in reference sites	▪ *Ex ante* analyses of new improved technologies are useful for identifying constraints to the adoption of new technologies by local farmers. ▪ *Ex post* analyses of new technologies are useful for determining the economic impact of new adopted technologies. A high demand exists for new alternatives based on improved forages to intensify milk production in the Alto Mayo region of the Peruvian Amazon. ▪ The establishment of shrub legumes with sugarcane is a starting point toward achieving greater economic impact on small dual-purpose farms located in the dry tropics of America. ▪ In Central America, the demand for milk from artisanal cheese producers is higher during the dry season than in the rainy season. • The artisanal cheese producers of Central America are willing to pay better prices for milk of better hygienic quality.
	3.2: Disseminating research results	▪ The dissemination of results is integral to research and technology transfer, and is essential in the adoption of new technologies.

Content

FINAL REPORT OF THE TROPILECHE CONSORTIUM

Feeding Systems with Legumes to Intensify Dairy Farms

(A project executed by the Tropileche Consortium)

Federico Holmann and Carlos Lascano

Introduction

The main objective of the Tropileche Consortium is to increase milk and beef production of dual-purpose livestock in smallholder farms by developing improved forage-based feeding systems.

The value of livestock production in Latin America and the Caribbean (LAC) represents nearly 13% of the world production and 47% of the production in developing countries. Milk and meat provide 20% of the protein consumed by the region's population. However, LAC has a 12% deficit in milk production, which is currently compensated by imports.

The livestock population in LAC is about 330 million head and nearly 78% of this population is in the hands of small farmers with dual-purpose cattle systems (i.e., producing milk and beef from the same system). The dual-purpose cattle system accounts for 42% of the milk produced in the region. In addition, there are 590 million hectares of pastureland, most of which is in advanced stage of degradation.

Tropileche is a CIAT-led consortium that operates under the Systemwide Livestock Programme (SLP) convened by the International Livestock Research Institute (ILRI). The Consortium initially selected the dry hillsides of Costa Rica (Central America) and the forest margins of the Peruvian Amazon as benchmark sites for its activities. In these areas, characterized by their fragility and severe erosion, livestock production is an important form of land use and a key economic activity for smallholder wellbeing. The Consortium later extended its activities to the hillsides of Nicaragua and Honduras and the forest margins of Colombia.

In the forest margins, milk production is limited by degraded pastures, which translates into low-quality feed and low feed on offer from degraded pastures. In the seasonally dry hillsides, the major constraint to increasing milk production is the lack of forage.

The following strategies were designed to overcome the above-mentioned constraints: (a) an evaluation of new feed resources that meet nutritional requirements of grazing animals, (b) on-farm participatory evaluation of new legume-based forage components to intensify livestock production and enhance sustainable land use, and (c) characterization of benchmark sites, economic analysis, and acceptability/adoption studies on new technologies.

The Consortium takes advantage of the existing capability of the following entities: CIAT in forage germplasm development and land use characterization; ILRI in livestock production systems; the University of Cornell in nutrient optimization models for ruminants; and national agricultural research organizations active at the project's benchmark sites in Peru (FUNDAAM, DEPAAM), Costa Rica (MAG, ECAG, CATIE, UCR), Nicaragua (MA), and Honduras (DICTA).

The Tropileche Consortium is financed jointly by the Inter-American Development Bank (IDB) and the German Agency for Technical Cooperation (GTZ) through the Systemwide Livestock Programme, coordinated by the International Livestock Research Institute (ILRI).

This report presents the activities carried out for each research component carried out at the benchmark sites.

RESEARCH RESULTS

Component 1: Optimizing Forage Use

Activity 1.1. Controlled feeding and grazing trials to determine the relationships between milk production and forage resources

Highlights

- The use of forage legumes as protein supplements during the rainy season increases the milk yield of cows showing high genetic potential.

- The use of forage legumes in association with improved grasses allows the stocking rate to be increased and weed incidence to be reduced, while improving the quality of edible biomass in terms of crude protein and digestibility, thus making the system more sustainable.

- Pastures of grasses and legumes in association increase the total solids content of milk, increasing the price obtained by the producer.

Evaluation of *Brachiaria decumbens* Alone and Associated with *Arachis pintoi* on Milk Production and Milk Components

Francisco Romero and Jesús González
ECAG, Costa Rica

Arachis pintoi was initially used in association with grasses in the humid tropics. One of the strategies proposed by the Tropileche Consortium for Costa Rica was to search for alternatives to improve livestock feeding in those regions where producers find it difficult to maintain a sustainable production during the dry season. One of these alternatives is the use of *Bracharia decumbens/Arachis pintoi* pastures.

Objectives

- To evaluate milk production and milk components in cows grazing a pasture of *Brachiaria decumbens* alone, *B. decumbens* associated with *A. pintoi*, and *B. decumbens* mixed with *Hyparrhenia rufa*.

- To evaluate the availability, quality, and dynamics of the botanical composition of the above-mentioned pastures.

Materials and Methods

The experiment was carried out at the Escuela Centroamericana de Ganadería (ECAG, its Spanish acronym), located in Balsa de Atenas, Costa Rica, at an altitude of 460 masl. The mean annual temperature is 28 °C, with an average annual precipitation of 1,500 mm and well-defined dry (December to May) and rainy seasons (June to November).

A degraded pasture of *B. decumbens* invaded by jaragua grass (*H. rufa*), another of *B. decumbens* in good conditions, and a 10-year-old pasture of *B. decumbens* associated with *A. pintoi* (CIAT 18744) were used. Each pasture was divided in two paddocks (1.25 ha each). One paddock was used for animal adjustment (7 days) and the other for measurements (7 days). Grazing consisted of 35 days of rest and 7 days of occupation.

The experiment began in October 1995 with the establishment of *A. pintoi* in a degraded *B. decumbens* pasture using plant material sown in furrows spaced 1 m apart. The pasture was first grazed at 30 days, and evaluations began in July 1996 and finished in July 2000. Every year, during the rainy season, samplings were carried out in the paddocks to measure botanical composition, forage availability, and quality of forage on offer. These measurements were performed on Day 1 of the measurement period.

Jersey cows of the ECAG herd, of different categories and stages of lactation, were used. Their milk production was measured the 7 days of the measurement period, and milk components were measured on Day 4.

Results

Forage availability. Table 1 indicates that more forage was available in the associated pasture than in the other pastures evaluated. Results indicate that 33% more forage was available in the associated pasture as compared with the *B. decumbens* + *H. rufa* pasture and 39% more than that of the pasture of *B. decumbens* alone.

Table 1. Forage availability in terms of dry matter (DM), crude protein (CP) content, and IVDMD of pastures evaluated in ECAG, Costa Rica.

Pastures	DM (t/ha per cycle*)	CP (%)	IVDMD (%)
Brachiaria decumbens + *Arachis pintoi*	3.2 a**	14.0 a	69.3 a
B. decumbens + *Hyparrhenia rufa*	2.4 b	10.2 b	63.2 b
B. decumbens	2.3 b	11.4 b	67.8 a
Significance (P <)	0.0018	0.0002	0.0001

* Grazing cycle every 30-35 days.

** Averages with the same letters within the column do not differ significantly ($P < 0.05$), according to Duncan's test.

In addition to the increase in availability of dry matter (DM), the inclusion of the legume had a significant effect ($P < 0.05$) on crude protein (CP) content and on in vitro dry matter digestibility (IVDMD) of pastures on offer. In the first case, an increase of approximately 3% was obtained and in the second, more than 4%. Similar results were obtained by González (1992) and Van Heurck (1990) in pastures of African star grass (*Cynodon nlemfuensis*) alone and associated with *A. pintoi*.

Stocking rate. In 1996, at the beginning of the trial, the same stocking rate was used in all pastures (Table 2). In 1997, the stocking rate was increased in the *B. decumbens* + *A. pintoi* pasture to 3.2 AU/ha but was maintained the same in the other pastures (2.5 AU/ha). During 1998 and 1999 the excellent conditions of the associated legume pasture allowed stocking rates above 4 AU/ha, which was almost 1 AU/ha higher than that of the other pastures.

Table 2. Stocking rate (AU/ha)* of pastures evaluated at ECAG, Costa Rica.

Pastures	Evaluation periods (years)				
	1996	1997	1998	1999	Average
Brachiaria decumbens + Arachis pintoi	2.5	3.2	4.4	4.6	4.6
B. decumbens + Hyparrhenia rufa	2.5	2.5	3.7	3.6	3.6
B. decumbens	2.5	2.6	3.5	3.7	3.7

* 1 AU = 450 kg animal liveweight.

It should be highlighted that these results correspond to the stocking rate used during the rainy season and that cows consumed commercial concentrate at a ratio of 3:1 (1kg concentrate per liter milk produced). On the other hand, it is expected that this increase in stocking rate in non-associated pastures could be non-sustainable over time because of its accelerated degradation.

Botanical composition. Figure 1 shows that the botanical composition of the associated pasture increased from 23% *A. pintoi* in year 1 to 43% in subsequent years of grazing. The percentage of *B. decumbens* was constant (59%), whereas the percentage of weeds decreased. Between 1996 and 1998, both grasses in the *B. decumbens* + *H. rufa* pasture increased slightly (5% for *B. decumbens* and 8% for *H. rufa*). Weed incidence decreased from 19% to 6% during the same period. However, in 1999, the percentage of both grasses tended to decrease while that of weeds increased.

Between 1996 and 1997, in the grass pasture alone, the percentage of *B. decumbens* increased from 70% to 94%, whereas that of other pasture components decreased (Figure 3). In subsequent periods, the percentage of *B. decumbens* decreased from 94% to 83%, and weeds increased 10%.

The botanical composition of the pastures partially explains the changes in stocking rate during the experimental period (Table 2). Therefore, as of 1997, the components of the associated pasture finally stabilized and allowed the stocking rate to be increased to 4.6 AU/ha. In 1998, the increased biomass of the *B. decumbens* + *H. rufa* pasture allowed the stocking rate to be increased by 1 AU/ha, reaching 3.6 AU/ha. This stocking rate, however, was apparently too high and favored pasture degradation.

These results confirm that pastures of grasses and legumes in association can support higher stocking rates than non-associated pastures, without affecting their botanical composition and quality and without increasing the presence of weeds.

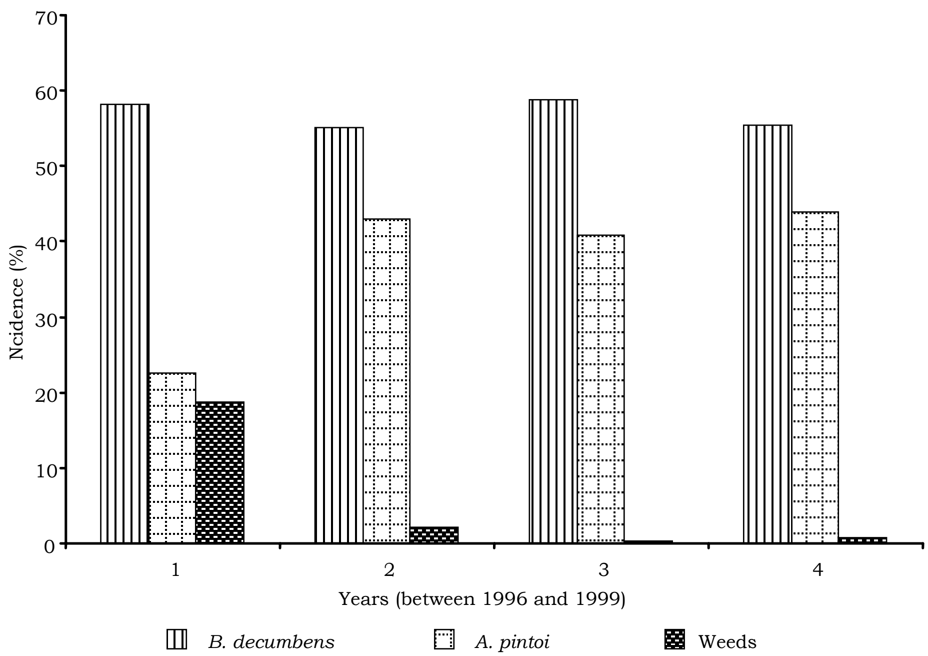

Figure 1. Botanical composition of the pasture *Brachiaria decumbens* + *Arachis pintoi* (ECAG, Costa Rica).

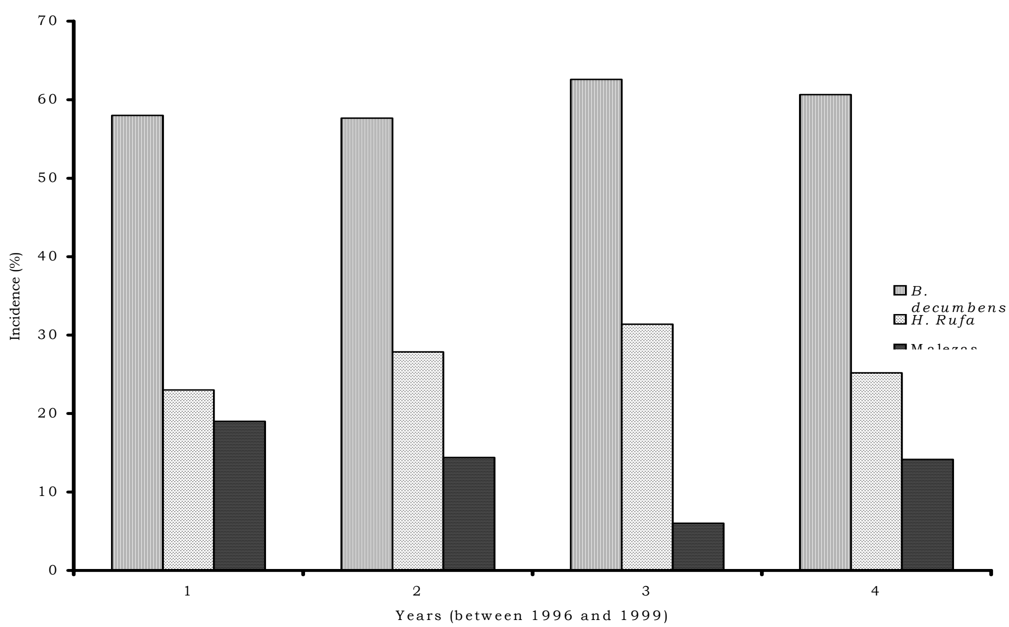

Figure 2. Botanical composition of the pasture *Brachiaria decumbens/Hyparrhenia rufa* (ECAG, Costa Rica).

Figure 3. Botanical composition of a pasture of *Brachiaria decumbens* alone (ECAG, Costa Rica).

Milk production and composition. Table 3 presents the milk production/cow per day in the different treatments. The highest production average (12.4 kg/cow per day) was found in the pasture of *B. decumbens* associated with *A. pintoi*, being significantly higher ($P < 0.011$) than those obtained in pastures of *B. decumbens* + *H. rufa* (11.7 kg/cow per day) and *B. decumbens* alone (11.6 kg/cow per day). These data agree with those obtained by Van Heurck (1990) and González (1992), in which the highest milk production was found in a pasture of African star grass associated with *A. pintoi* as compared with a pasture of African star grass alone.

It is important to highlight that, although the Jersey cows used in the trial received as supplement a feed concentrate of 14% CP and 2.4 Mcal ME, the beneficial effect of *Arachis* on milk production could still be observed.

Table 3 shows the components of the milk obtained from the different pastures. A higher fat content ($P < 0.0004$) was found in milk from cows grazing pastures of *B. decumbens* associated with *A. pintoi* (4.84%) and *B. decumbens* alone (4.85%). This value for the pasture of *B. decumbens* + *H. rufa* was 4.71%. Cipagauta et al. (1998) found similar milk fat values in *B. decumbens* + *A. pintoi* pastures in the Colombian Amazon region, but fat content of milk produced by cows grazing *B. decumbens* alone was even lower than the native pasture. These results, however, differed with those found by González (1992) in which the percentage of fat did not differ among the three pastures evaluated.

Table 3. Effect of three types of pasture on milk production and milk components in Jersey cows receiving a commercial supplement (ECAG, Costa Rica).

Pastures	Production (kg/cow per day)	Fat (%)	Protein (%)	Lactose (%)	Total solids (%)	Non-fat solids (%)
Brachiaria decumbens + *Arachis pintoi*	12.4 a*	4.84 a	3.66 a	4.68 a	13.89 a	9.07 a
B. decumbens + *Hyparrhenia rufa*	11.7 b	4.71 b	3.58 ab	4.70 a	13.63 c	8.96 a
B. decumbens	11.6 b	4.85 a	3.54 b	4.62 b	13.73 b	8.89 a
Significance (P <)	0.011	0.0004	0.0562	0.0381	0.0004	0.1154

* Averages in the same column followed by the same letter do not differ significantly (P < 0.05), according to Duncan's test.

The milk protein content varied among pastures, and was higher in the pasture associated with *A. pintoi* (3.66%), compared with the pasture *B. decumbens* + *H. rufa* (3.58%) and *B. decumbens* alone (3.54%).

Similar values of lactose were found in the milk of cows grazing the *B. decumbens* + *A. pintoi* pasture (4.68%) and *B. decumbens* + *H. rufa* (4.70%), but were higher (P < 0.0381) to that of milk of cows grazing the pasture of *B. decumbens* alone (4.62%).

The total solids content of milk varied among pastures, being highest (P < 0.0004) in the pasture of *B. decumbens* associated with *A. pintoi* (13.89%), followed by *B. decumbens* alone (13.73%) and *B. decumbens* associated with *H. rufa* (13.63%). The levels of non-fat solids (NFS) in milk did not differ significantly among the three pastures.

The effect of the treatments (pastures), without the inclusion of a commercial feed supplement, on milk production and milk components was evaluated over one year in the same Jersey cows. Table 4 shows the significant difference (P < 0.0279) in milk production/cow per day, which was higher in the pasture associated with *A. pintoi* (9.3 kg/cow per day) than in the other pastures. This difference is similar to that obtained with cows fed concentrate at a ratio of 3:1. No differences were found among the three treatments regarding milk components; however, these components differed from those found in the group of cows fed concentrate.

Table 5 shows the availability and quality of the grass offered to cows that were not fed concentrate. The difference observed in milk production can be attributed to the greater availability of forage and its better quality in the associated pasture, as was the case of the pasture of *B. decumbens* associated with *A. pintoi.*

Table 4. Effect of three types of pasture on milk production and milk components of Jersey cows that did not receive a dietary supplement (ECAG, Costa Rica).

Pasture	Production (kg/cow per day)	Fat (%)	Protein (%)	Lactose (%)	Total solids (%)	Non-fat solids (%)
Brachiaria decumbens + *Arachis pintoi*	9.3 a*	5.4	3.7	4.6	14.4	9.1
B. decumbens + *Hyparrhenia rufa*	8.1 b	4.7	3.7	4.6	13.7	9.0
B. decumbens	8.3 b	5.3	3.8	4.6	14.4	9.1
Significance (P <)	0.0279	0.5	0.5	0.5	0.3971	0.5

* Averages in the same column followed by the same letter do not differ significantly (P < 0.05), according to the Duncan's test.

Table 5. Availability and quality of forage offered to Jersey cows that were not fed a commercial concentrate (ECAG, Costa Rica).

Pastures	DM (t/ha per grazing cycle*)	CP (%)	IVDMD (%)
Brachiaria decumbens + *Arachis pintoi*	3.9 a**	14.2 a	63.3 a
B. decumbens + *Hyparrhenia rufa*	3.4 b	10.1 b	62.5 a
B. decumbens	2.7 c	11.7 b	63.0 a
Significance (P <)	0.0018	0.0066	0.9058

* Grazing cycles of 30-35 days.

** Averages in the same column followed by the same letter do not differ significantly (P < 0.05), according to Duncan's test.

Conclusions

Based on study results, we conclude that:

- Pastures of *B. decumbens* associated with *A. pintoi* increase the daily milk production of Jersey cows, even when they receive a commercial feed concentrate. These pastures are also capable of supporting a higher stocking rate than *B. decumbens* + *H. rufa* pastures and *B. decumbens* alone, under similar management conditions.

- The persistence of *A. pintoi* during the 4 years of the evaluation contributed to maintaining production and pasture quality, confirming the high potential of this legume in hillside areas with defined dry season in Central America.

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Rice Yield *(Oriza sativa)* as an Indicator of Soil Fertility with the Incorporation of *Stylosanthes guianensis* Stubble in Pucallpa, Peru

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Stylosanthes guianensis (stylo) is a legume adapted to the humid rainforest conditions of the Peruvian Amazon region, where it presents good growth and high biomass production. Smallholders in this region commonly plant rice (*Oriza sativa*). However, for this crop to develop well, it requires the application of N, which is a high-cost input. This study aims to evaluate the potential of stylo to fix nitrogen and determine the use of this element by the rice crop prior to pasture establishment.

Materials and Methods

The experiment was carried out between October 1998 and February 1999 on the Sara farm, located on km 15 of the road that leads from Pucallpa to Tingo María, on an acid Ultisol with high aluminum content. This area belongs to the seasonal semi-evergreen tropical rainforest ecosystem with annual mean precipitation of 1,900 mm and mean temperature of 26 °C.

Treatments were as follows: T1, soil without application of N (check); T2, soil after incorporating *S. guianensis* stubble without application of N; T3 to T6, soil after incorporating *S. guianensis* stubble with the application of 50, 100, 150, and 200 kg/ha of N. The variables evaluated were rice yield, number of tillers and of spikelets/m^2, number of grains/spikelet, and weight of 1000 grains. Rice variety Chancabanco, with a 90-day vegetative period, was planted. All treatments received a uniform basal application of 50 kg/ha of K_2O/ha as potassium chloride and 50 kg/ha of P_2O_5 as rock phosphate. A completely randomized block design, with six treatments and five replications, was used.

Results

Rice yields, after incorporation of stylo stubble, were higher ($P < 0.05$) than those obtained with the check treatment or equal to those obtained with the application of 50 kg/ha of N, which indicates the potential of this legume to supply N to the soil. However, the best results were obtained with the application of 100 kg/ha of N (Table 1).

Table 1. Effect of incorporating *Stylosanthes guianensis* (stylo) stubble and of applying different levels of fertilizer on rice yield and number of tillers and spikelets on the Sara farm in Ucayali, Pucallpa, Peru.

Treatments	Rice yield (kg/ha)	Tillers (no./m^2)	Spikelets (no./m^2)
T1 = check (no treatment)	380 c*	102 a	136 b
T2 = after incorporation of stylo	520 b	111 a	154 ab
T3 = incorporation of stylo + 50 kg/ha of N	600 b	119 a	154 ab
T4 = incorporation of stylo + 100 kg/ha of N	830 a	125 a	174 ab
T5 = incorporation of stylo + 150 kg/ha of N	870 a	130 a	187 a
T6 = incorporation of stylo + 200 kg/ha of N	890 a	136 a	185 a

* Values in the same column followed by the same letters do not differ significantly ($P < 0.05$), according to Duncan's test.

Study results indicate that, in the Pucallpa region, *S. guianensis* has a high initial capacity for establishment and competition with weeds ("torourco"). However, once animals are introduced, its persistence tends to decrease, possibly because of its superficial growth points or because of reduced soil fertility.

Conclusions

In Pucallpa, Peru, *S. guianensis* is a well-adapted legume with the capacity to fix up to 50 kg/ha of N when established as a pioneer crop for rice and subsequent establishment of improved pastures. Its persistence is, however, low once the pasture is submitted to grazing.

Activity 1.2 Use of forage resources and supplementation of cows during the dry season

Highlights

- The response of cows in terms of milk yield to forage legume supplementation, either fresh or as silage, and sugarcane is similar to that obtained with protein sources from commercial feed concentrates.

- Direct grazing of shrub legumes increases milk yields as compared with the cut-and-carry system.

- Legumes supply protein to forage basal diets that are usually nitrogen deficient.

- Highly fermentable carbohydrates can stimulate the degradation of less fermentable fiber.

- The use of additives in the form of carbohydrates improves the quality of silage from shrub legumes.

Evaluation of Milk Production Systems using *Cratylia argentea*

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Dual-purpose livestock production accounts for 78% of the livestock and 41% of the milk produced in tropical Latin America. This type of exploitation is mainly found on smallholdings (Rivas, 1992) that depend, to a large extent, on forage resources that present nutritional limitations and therefore restrict animal productivity.

Forage legumes are an alternative to improve animal nutrition in dual-purpose systems. This is case of the shrub legume *Cratylia argentea*, a species that adapts well to acid soils and preserves most of its leaves during the dry season. However, the use of cut-and-carry *Cratylia* in some areas of the tropics is not viable because of the high labor costs involved. This study aimed to evaluate the effect of *Cratylia* supplementation to cows in both cut-and-carry system and under direct grazing on *Brachiaria decumbens* pastures.

Materials and Methods

The study was conducted during two contrasting seasons, at the CIAT experiment station in Santander de Quilichao (Cauca, Colombia), located 990 masl, with annual rainfall averaging 1,700 mm. Trial 1 was carried out from August to October 1999, a period corresponding to minimum precipitation (water balance <50 mm). Trial 2 was carried out from May to June 2000 during maximum precipitation (water balance >50 mm).

Trials were arranged in a Latin square design (3 x 3) with the following treatments: T1, *B. decumbens* associated with *C. argentea* under direct grazing; T2, *B. decumbens* with access to *C. argentea* at 1.5% DM live weight (cut-and-carry); and T3, *B. decumbens* alone, as check. Each treatment was assigned to a 1-ha grazing area, divided into two equal sections to allow 7 days for adjustment and 7 days for measurement. The animals spent 14 days in each treatment, for a total of 42 days. The stocking rate for each trial was 2 cows/ha; six crossbred Holstein x Zebu cows with similar lactation status (second third) and milk production levels were used.

Results

Availability of grass forage at the beginning of grazing was greater in Trial 2 as compared with Trial 1. This difference in forage on offer was associated with changes in precipitation.

The quality of the grass varied considerably among treatments, the IVDMD and CP levels being lower in the check treatment (*B. decumbens* alone) in both experiments. The treatment and precipitation significantly affected both amount and quality of the grass.

Milk production of cows on the associated *Cratylia* + *Brachiaria* pasture under direct grazing was consistently higher than that of the check treatment in both minimum (23% more milk) and maximum precipitation (16% more milk), although this difference was not significant (Table 1). The significant increase in milk production in Trial 1 can be partially explained by the low amount and quality of the basal pasture, which was affected by the lower precipitation. These results confirm once more the importance of providing supplementation not only when the basal pasture is deficient but also during the dry season, but not so in the rainy season (Avila, 1999).

Table 1. Milk production of crossbred Holstein x Zebu cows, supplemented with *Cratylia argentea* in a cut-and-carry system as compared with direct grazing (Quilichao, Cauca, Colombia).

Treatment	Trial 1	Trial 2
	Milk yield (kg/cow per day)	Milk yield (kg/cow per day)
Brachiaria decumbens	6.1 b*	6.3 a
B. decumbens + *C. argentea* (cut-and-carry)	6.7 b	6.6 a
B. decumbens + *C. argentea* (direct grazing)	7.5 a	7.3 a

* Values in the same column followed by the same letter do not differ significantly (P < 0.05), according to Duncan's test.

On the other hand, the levels of fat and non-fat solids (NFS) in milk were similar for both trials. The milk urea nitrogen (MUN) levels differed significantly ($P < 0.05$) among treatments for both trials. When *C. argentea* was used as supplement, MUN levels were higher compared with the check treatment. The levels of these indicators without *C. argentea* supplementation were marginal (Table 2). MUN levels ranged from 9 to 10 mg/dL, suggesting a protein deficit (Hammond et al., 1994) and accounting for the lower milk production of the group of cows that did not receive legume supplementation.

Table 2. Quality of milk produced by cows supplemented with *Cratylia argentea* in a cut-and-carry system and under direct grazing (Quilichao, Cauca, Colombia).

Treatment	Trial 1			Trial 2		
	Fat (%)	NFS[a] (%)	MUN[b] (mg/dL)	Fat (%)	NFS (%)	MUN (mg/dL)
Brachiaria decumbens	3.5 a*	8.0 a	9.8 b	3.6 a	8.2 a	3.0 b
B. decumbens + *C. argentea* (cut-and-carry)	3.6 a	8.0 a	33.6 a	3.7 a	8.4 a	11.6 a
B. decumbens + *C. argentea* (direct grazing)	3.7 a	8.2 a	27.3 a	3.7 a	8.2 a	12.5 a

a. NFS = non-fat solids.
b. MUN = Milk urea nitrogen.

- * Values in the same column followed by the same letters do not differ significantly ($P < 0.05$), according to Duncan's test.

Conclusions

The partial information from these trials indicates that the use of *C. argentea* under direct grazing increased milk production the most. Also, direct supplementation with the legume is more viable during the drier season than during the rainy season because the economic response is greater when the basal pasture has limited nutrients during the dry season.

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In Vivo Studies on the Complementarity between Forage Basal Diets and Legume Supplements

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Previous results from confined feeding trials suggested that when supplementing available forage sources on the farm to overcome nutrient deficiencies in ruminants, it is important to synchronize feeding of the higher quality forage supplement with the basal forage so that energy and protein are available concurrently. Also, synergism among forages may vary not only with the types of forages fed but also with how they are fed (for example, amount and frequency).

Materials and Methods

Eight African type wethers (24 kg LW, on average) were fed a low-quality basal grass diet, and were randomly allocated to four supplementation treatments, arranged in a 4 x 4 Latin square design, consisting of sugarcane (60%) mixed with *Cratylia argentea* (40%). Treatments were as follows: T1, low level of supplementation (0.5% LW) fed once a day (a.m.); T2, high level of supplementation (1.0% LW) fed once a day (a.m.); T3, low level of supplementation (0.5% LW) fed twice a day (a.m.+ p.m.); and T4, high level of supplementation (1% LW) fed twice a day (a.m. + p.m.). Measurements included quality of the basal diet, intake of supplements offered, digestibility, and N balance.

Results

The low-quality basal grass diet was low in CP (4.8%) and high in cell wall content (79% NDF and 44% ADF). On the other hand, chopped sugarcane, fed as an energy supplement, was low in CP (3.1%) but had low cell wall content (39% NDF and 24% ADF). The legume (*Cratylia* leaves) fed had high CP (21%) and high cell wall contents (67% NDF and 37% ADF). Thus the supplement fed was high in energy and medium in protein (10% dry basis). Intake of the basal diet did not differ among treatments, but there were differences in supplement intake due to treatments. As expected, intake of sugarcane and *Cratylia* tended to be higher when fed at the highest level. However, it is interesting to note that when supplements were offered at the high level, intake of sugarcane and *Cratylia* increased with twice-a-day feeding compared with once-a-day feeding (Table 1).

Table 1. Effect of level and frequency of supplementation with sugar cane and *Cratylia* on intake and digestibility of African wethers fed a low-quality basal grass diet (Quilichao, Cauca, Colombia).

Parameter	Frequency and level of supplementation[a]				
	a.m.[b] 0.5% LW	a.m. 1% LW	a.m. + p.m.[c] 0.5% LW	a.m. + p.m. 1% LW	SE[d]
DM intake (g/kg LW per day)					
Basal diet (grass)	25.7	25.2	25.2	25.7	0.8
Sugarcane	2.5 b*	3.3 b	2.8 b	4.0 a	0.4
Cratylia	2.0 c	3.1 b	2.0 c	3.6 a	0.1
Digestibility (%)					
IVDMD	53.0	53.0	55.4	56.6	1.7
NDF	54.1	54.3	57.7	57.1	1.8
ADF	51.6	50.7	54.3	53.1	1.9

a. 60% sugarcane + 40% *Cratylia argentea* (leaves).
b. Supplement fed once a day at 0.5% or 1% LW.
c. Supplement fed twice a day at 0.5% or 1% LW.
d. Standard error.
* Values in the same column followed by the same letters do not differ significantly ($P < 0.05$), according to Duncan's test.

These differences in intake of supplements were not reflected in significant changes in DM or cell wall digestibility. Nevertheless, there was a tendency for higher digestibility with twice-a-day feeding at both levels of supplementation.

As expected, N intake was highest with increased level of supplementation (Table 2); however, intake was highest when wethers were fed twice a day. Because fecal and urinary N did not change with treatment, N retention was greater when sheep were given the forage-based supplements at the high level and twice a day.

Table 2. Effect of frequency and level of supplementation of sugarcane and *Cratylia* on nitrogen utilization by African wethers fed a low-quality basal diet (Quilichao, Cauca, Colombia).

Parameter	Frequency and level of supplementation[1]				
	a.m.[2] 0.5% LW	a.m. 1% LW	a.m. + p.m.[3] 0.5% LW	a.m. + p.m. 1% LW	SE[4]
N intake (g/day)	5.6 a	6.2 b	5.6 a	6.7 c	0.01
Fecal N (g/day)	3.5	3.5	3.3	3.5	0.1
Fecal N (% N intake)	62.5 a	57.1 b	59.9 a	52.0 c	2.0
Urine N (g/day)	1.4	1.5	1.5	1.6	0.2
Urine N (% N intake)	25.4	25.8	28.6	24.7	3.7
Retained N (g/day)	0.8 e	1.2 d	0.8 e	1.6 a	0.2

1. 60% sugarcane + 40% *Cratylia argentea* (leaves).
2. Supplement fed once a day at 0.5 or 1% LW.
3. Supplement fed twice a day at 0.5 or 1% LW.
4. Standard error.

* Values in the same column followed by the same letters do not differ significantly ($P < 0.05$), according to Duncan's test.

Conclusions

This study evidenced that the level and frequency of supplementary feeding had a significant effect on N utilization by growing African-type wethers. Results indicate, however, that feeding twice a day would only be justified when high levels of forage-based supplements are offered. When the high level (1% LW) of sugarcane and *Cratylia* was fed twice a day, there was a 33% increase in N retention relative to feeding the same amount of supplement once a day. This was not the case when the low level (0.5% LW) was offered.

Effects of Feeding Fresh and Ensiled *Cratylia argentea* during the Dry Season on Milk Production and Milk Components

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One of the strategies of the Tropileche Consortium in Costa Rica is the search for feeding alternatives for cows during the dry season. The results of previous work carried out by the Escuela Centroamericana de Ganadería (ECAG) indicate that sugarcane is an alternative energy source for cows under grazing. Its protein content, however, is low. The study aimed to evaluate the use of fresh and ensiled *Cratylia argentea* as a protein source. The study was based on the hypothesis that the protein quality of fresh and ensiled *C. argentea* was similar to that of yellow maize and soybean flour, which are sources of protein for commercial concentrates.

Materials and Methods

The experiment was carried out between 25 February and 20 April 1999 at ECAG, located in Balsa de Atenas, Costa Rica, at 460 masl, with a mean annual temperature of 28 °C. Average precipitation was 1,500 mm/year, with two well-defined climatic seasons: a dry season from December to May and a rainy season from June to November.

Forage Management

Silage. The heap silage method was used. Silage was made during November 1998, using a 6-month-old *Cratylia* regrowth, which was cut to a height of 30 cm above the ground. Usable parts (leaves and tender stems) were separated and chopped to a size of 2.5 cm. Chopped material was then spread out in 20-cm layers and compacted. Molasses was then added at a proportion of 10:1 (10 kg *C. argentea:*1 kg molasses*).*

Fresh *Cratylia argentea.* A 3-month-old regrowth was used. Plants were cut every day to a height of 30 cm above the ground, then chopped and offered to cows mixed with sugarcane.

Sugarcane. Whole sugarcane was offered chopped (2.5-cm size) on a daily basis. Its nutritional content was 2% CP and 3.0 Mcal ME.

Concentrate. This concentrate was based on maize and soybean and prepared at the ECAG feed plant. Its nutritional content was 14% CP and 2.3 Mcal ME.

Semolina. Commercial rice semolina, with 12% CP and 2.8 Mcal ME, was used.

Animal Management

Six multiparous Jersey cows, at 50 days postpartum, were assigned at random to three treatments in a Latin square design repeated simultaneously. Treatments and amounts of products (between parenthesis as % LW) were as follows: T1, sugarcane (1%) + semolina (0.5%) + concentrate (1.48%) + urea (0.02%); T2, sugarcane (1.3%) + concentrate (0.5%) + fresh *C. argentea* (1.2%); and T3, sugarcane (0.1%) + concentrate (0.5%) + silage of *C. argentea* (2.4%).

Measurements

Because of the limited amount of silage, each period covered 12 days, 7 of which corresponded to animal adaptation and to of sampling. Samplings were made on days 1, 3, and 5.

Intake and quality of DM on offer and rejected. DM intake was calculated as the difference between the amount of material on offer and that rejected on days 1, 3, and 5 during each 5-day evaluation period. Composite samples for that week were sent to the ECAG laboratory to determine crude protein (CP) and *in vitro* dry matter digestibility (IVDMD).

Milk production and quality. During the five days of each evaluation period, individual milk production (kg/cow) at both milkings was weighed.

To measure milk quality, two milkings proportional to production were sampled. Each sample was cooled for conservation and then analyzed for fat, protein, lactose, total solids (TS), and non-fat solids (NFS).

Results

No major difference was observed among the three rations offered regarding total DM intake. In the case of fresh *C. argentea,* intake was 10.7 kg/cow per day (3.0% animal LW) and that of silage was 10.4 kg/cow per day (2.9% animal LW), indicating that *Cratylia* does not present problems of consumption when offered fresh or as silage together with sugarcane (Table 1).

Table 1. Daily intake of dry matter (DM), crude protein (CP), and metabolizable energy (ME) by cows offered different feeding treatments (ECAG, Costa Rica).

Treatment	Daily intake			
	DM (kg)	DM (% LW)	CP (kg)	ME (Mcal)
Concentrate	10.8	3.1	1.3	24.2
Fresh *Cratylia argentea*	10.7	3.0	1.3	23.6
Ensiled *C. argentea*	10.4	2.9	1.4	21.9
Significance (P <)	0.5924	0.5	0.1470	0.5304

Table 2 indicates that the different treatments did not affect milk production of cows significantly. These results do not coincide with those reported by Argel et al. (1999), where milk production differed depending on whether fresh or ensiled *C. argentea* was used (5.5 vs 5.1 kg/cow per day).

Except for protein, the values of all other milk components did not vary among treatments (Table 2). However, fat content tended to be slightly higher (P < 0.0627) in treatments that included *C. argentea* silage, which could benefit producers selling cream or milk, when the latter is paid based on the percentage of fat.

Table 2. Production and composition of milk from cows offered different feeding treatments (ECAG, Costa Rica).

Treatment	Milk (kg/cow per day)	Fat (%)	Protein (%)	Lactose (%)	TS (%)	NFS (%)
Concentrate	11.1	3.53	3.36	4.80	12.39	8.86
Fresh *Cratylia argentea*	10.9	3.69	3.24	4.84	12.47	8.78
Ensiled *C. argentea*	10.7	3.81	3.22	4.76	12.49	8.68
Significance (P <)	0.268	0.063	0.014	0.353	0.736	0.095

But, most importantly, the milk production levels achieved with rations of *C. argentea,* either fresh or ensiled (10.9 and 10.7 kg/cow per day, respectively), were comparable to those obtained with a typical concentrate for dairy cows (11.1 kg/cow per day), in which the protein comes from maize and soybean. The production levels reached with *C. argentea* during the dry season would be fairly acceptable for medium and small producers. Furthermore, this legume could replace sources of energy and protein (maize and soybeans) used to manufacture concentrates that are usually beyond their reach.

Fresh *C. argentea*, with 3 months regrowth, presents, on average, 19.9% CP and 53.4% IVDMD (Table 3). This last value agrees with that reported by Lascano (1995), but differs from those found by Perdomo (1991) and Xavier and Carvalho (1995). In ensiled *C. argentea*, the average values of CP (14.7%) and IVDMD (40.6%) were slightly lower than those of fresh *Cratylia*; this level of PC, however, fulfills the requirements of the animals used in the trial.

Table 3. Nutritional composition of fresh and ensiled *Cratylia argentea* (ECAG, Costa Rica).

Evaluation periods	Fresh *Cratylia argentea*		Ensiled *Cratylia argentea*	
	CP (%)	IVDMD (%)	CP (%)	IVDMD (%)
I	19.2	56.0	15.3	40.4
II	19.1	50.2	15.2	40.3
III	21.4	54.1	13.6	41.1
Average	19.9	53.4	14.7	40.6

Production Costs

Costs were calculated based on the costs appearing in Table 4. The biomass production of *Cratylia* at 3 months regrowth when plants reach their best leaf:stem ratio and produce larger amounts of edible material, thus reducing labor costs.

Table 4. Feeding costs and milk components in cows fed concentrate and two forms of *Cratylia argentea* at 3 months regrowth (ECAG, Costa Rica).

Treatment	Cost ($/kg)	Milk components (%)				
		Fat	Protein	Lactose	TS[a]	NFS[b]
Concentrate	0.21	5.85	6.15	4.30	1.67	2.33
Fresh *Cratylia*	0.17	4.56	5.19	3.48	1.35	1.92
Ensiled *Cratylia*	0.18	4.63	5.48	3.71	1.41	2.03

a. TS = Total solids.
b. NSF = Non-fat solids.

Calculations considered the following costs per kg product on offer: concentrate (processed at the ECAG plant), semolina, sugarcane, fresh *C.*

argentea (taking into account cutting, carrying, and chopping) and ensiled *C. argentea* (preparation).

Table 5 shows that, although gross income was higher when the concentrate was used (US$3.13) compared with fresh or ensiled *Cratylia* (US$3.10 and US$3.05, respectively), costs were also higher and the net income was US$0.84. When fresh *Cratylia* was used in the diet, net income was US$1.26 and with ensiled *Cratylia* it was US$1.16.

In addition to the economic benefit, the use of the legume is environmentally beneficial in terms of nutrient recycling and sustainability of the system.

Table 5. Daily income and expenditures (US$/cow per day) obtained with test diets (ECAG, Costa Rica).

Treatment	Income	Expenditures	Difference
Concentrate	3.13	2.30	0.84
Fresh *Cratylia*	3.10	1.83	1.26
Ensiled *Cratylia*	3.05	1.89	1.16

Conclusions

The results of this study indicated the following: (1) fresh *C. argentea*, at 3 months regrowth, is a good alternative to feed milking cows; (2) under ECAG conditions, *Cratylia* should be harvested at 3 months regrowth to prepare silage because the leaf:stem ratio is best then; and (3) fresh or ensiled *C. argentea* can replace the use of a commercial concentrate in dairy cows of intermediate milk production during the dry season.

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Evaluation of *Cratylia argentea* as Substitute of Chicken Manure in Diets for Cows Grazing *Hyparrhenia rufa* Pastures

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The production and quality of forage biomass from grasses is drastically reduced in ecosystems with prolonged droughts, such as the Central Pacific region of Costa Rica. Producers solve this limitation by supplementing with agricultural by-products, such as chicken manure. Several years ago this by-product was inexpensive but its price in real terms has increased in view of the growing demand. Producers are therefore interested in evaluating alternatives to replace chicken manure. The results of three on-farm trials are reported: two trials evaluated the substitution of chicken manure with *Cratylia argentea* and the other trial evaluated *Cratylia* fed fresh or as silage.

Materials and Methods

Experiment 1. This trial was conducted during the dry season (April 1999) on a small farm in Miramar, located at 250 masl in the Central Pacific region of Costa Rica. The mean annual temperature is 28 °C and the mean precipitation, 2,400 mm. The following treatments were evaluated: T1, control, only grazing (naturalized grass and jaragua grass); T2, 12 kg sugarcane + 8 kg *C. argentea* + 0.6 kg rice polishing + grazing; and T3, 12 kg sugarcane + 3 kg chicken manure + 0.6 rice polishing + grazing. Cows in T2 and T3 received molasses.

The nutritional characteristics of the feed were as follows: sugarcane, 2% CP and 3.0 Mcal ME; chicken manure, 19.5% CP and 1.8 Mcal ME; rice polishing, 12% CP and 3.0 Mcal ME; fresh *Cratylia*, 20% CP and 1.8 Mcal ME (from 90-day regrowth cut at 30 cm); and *Cratylia* silage, 16.4% CP and 1.9 Mcal ME (from 180-day regrowth cut at 30 cm).

A Latin square design with three treatments was used, each treatment with two selected cows in the second month of lactation. The experiment lasted for 30 days, and animals were rotated through each treatment at 10-day intervals (7 days for adjustment and 3 for data collection).

Experiment 2. This trial was conducted in a small farm in Barranca, located at 280 masl in the Central Pacific region of Costa Rica. The mean annual temperature is 28 °C and mean precipitation of 2,500 mm.

Treatments evaluated were: T1, 12 kg sugarcane + 6 kg silage of *C. argentea* + 0.6 kg rice polishing; T2, 12 kg sugarcane + 6 kg fresh *C. argentea* + 0.6 kg rice polishing; and T3, 12 kg sugarcane + 3 kg chicken manure + 0.6 kg rice polishing.

A Latin square design with three treatments was used, each treatment with two cows as in the above experiment. Animals were managed in individual groups. The experiment lasted for 30 days and animals were rotated on each treatment at 10-day-intervals (7 days for adjustment and 3 for data collection).

Experiment 3. This on-farm trial was conducted as part of a student thesis program on a small farm in Barranca, located in 280 masl in the Central Pacific region of Costa Rica. The trial was conducted in the middle of the dry season (February-May 1998), with a mean annual temperature of 28 °C and a mean precipitation of 2,500 mm. Treatments evaluated were: T1, chicken manure and molasses; T2, chicken manure, sugarcane, molasses, and wheat bran, T3, chicken manure, molasses, *C. argentea*, and wheat bran.

Details of the different diets are presented in Table 1. Different amounts of supplements were used to balance the diets isonitrogenously and isocalorificly. *Cratylia argentea* satisfied more than 75% of the CP requirements of animals, but a small amount of chicken manure was included in the diet because observed *C. argentea* intake was not sufficient to balance N requirements. Animals had access to *H. rufa* pastures. *Cratylia* CP content was 19.2% and IVDMD, 58.4%; the respective values for *H. rufa* were 3.9% and 33.9%.

Table 1. Diets offered to animals and milk yields for all treatments.

Diets	Consumption (kg/animal per day)	Milk yield (kg/cow per day)
Diet 1		5.9
Chicken manure	6.0	
Molasses	2.5	
Diet 2		6.0
Chicken manure	5.0	
Sugarcane	5.0	
Wheat bran	0.7	
Molasses	0.12	
Diet 3		6.1
Chicken manure	1.0	
Molasses	4.12	
Wheat bran	0.7	
Cratylia argentea	6.0	

A 3 x 3 Latin square changeover design with three replications was used with a total of 9 crossbred cows between 60-80 days into lactation. Each of the three experimental periods consisted of 10 days for adaptation to treatment and 5 days for collection of experimental data.

Results

Experiment 1. Table 2 shows milk yield and composition, feeding costs, income from milk, and the cost:benefit ratio for the different treatments evaluated. Milk yields of T2 and T3 did not differ significantly (P = 0.076), indicating that *C. argentea* can be used to substitute chicken manure without reducing milk production. Furthermore, feeding costs are lower and the cost:benefit ratio is higher when *C. argentea* is used, which makes this alternative more economically attractive to farmers.

Table 2. Average milk production and composition, cost of supplementary feeding (*Cratylia argentea* and chicken manure), income from milk, and cost:benefit ratio of diets offered to dual-purpose cows.

Treatments	Milk yield (kg/cow per day)	Total solids (%)	Fat (%)	Cost of supplementary feeding ($/kg milk)	Income ($/kg milk)	C:B ratio
Only grazing	5.45 b*	11.2	3.1	-	0.24	
Grazing + *Cratylia*	5.85 a b	11.5	3.2	0.11	0.25	2.22
Grazing + chicken manure	6.29 a	11.2	2.9	0.22	0.24	1.08

* Values in the same column followed by the same letters do not differ significantly (P < 0.05), according to Duncan's test.

Experiment 2. Table 3 shows that the feeding alternatives based on *C. argentea*, both ensiled and fresh, were more economical than the one that used chicken manure as supplement. Not only are *Cratylia* rations more economical, but the milk yields of cows consuming *Cratylia*, either fresh or ensiled, were similar to those of cows supplemented with chicken manure. However, milk yields of cows consuming *Cratylia* silage were lower than those of cows consuming fresh *Cratylia.* Nevertheless, *Cratylia* silage can be used as a substitute for chicken manure because of the lower feed costs.

Table 3. Average milk production and composition, cost of supplementary feeding (fresh or ensiled *Cratylia argentea* and chicken manure), milk income, and cost:benefit ratio of diets offered to dual-purpose cows.

Treatments	Milk yield (kg/cow per day)	Total solids (%)	Fat (%)	Cost of supplementary feeding ($/kg milk)	Income ($/kg milk)	C:B ratio
Ensiled *Cratylia*	5.09 b*	12.3	3.7	0.17	0.27	1.58
Fresh *Cratylia*	5.47 a	12.2	3.5	0.11	0.27	2.37
Chicken manure	5.26 a b	11.7	3.0	0.22	0.26	1.14

* Values in the same column followed by the same letters do not differ significantly ($P < 0.05$), according to Duncan's test.

Experiment 3. Table 3 shows the effect on milk yield per treatment. Milk yield averaged 6.0 kg milk/cow/day and there were no significant differences between treatments. Milk fat was lower (2.7%) for the treatment that had a higher amount of sugarcane in the diet, but differences were not significant. The results clearly show that Cratylia can be used as a substitute for chicken manure, at least up to 82% of the diet.

Conclusions

In recent years, most farmers with dual-purpose cattle have produced milk during the dry season using chicken manure. Results clearly show that *Cratylia* can largely replace chicken manure as a protein supplement, without significantly reducing milk yield. The growing demand for chicken manure to supplement dairy cows has increased its price in many tropical regions and farmers can no longer afford to buy it. By introducing *C. argentea* to cattle production systems in the Pacific region, the use of chicken manure has decreased in farms participating in the Tropileche Consortium to such degree that this year practically none was purchased. Therefore, the legume technology being promoted for dual-purpose cattle farms could allow small producers to have access to a farm-grown protein supplement and increase their cash flow and profits. In addition, spontaneous adoption of *C. argentea* is occurring in other locations in Costa Rica. During the last 12 months, 84 kg of experimental seed has been sold to 28 farmers located in three different sites: Guanacaste, Nicoya, and around Esparza.

The most economical option for a producer in the dry season is to supplement cows with fresh *Cratylia*. The next best option is to supplement with ensiled *Cratylia*. The least economical option is to supplement cows with chicken manure. As a result, the use of legume silage such as *C.*

argentea is recommended over the use of chicken manure. In addition, the use of legume silage allows producers to use smaller areas because more edible biomass is produced for dry season supplementation, especially in situations where the opportunity cost for labor during the rainy season is low.

Use of Additives for Making *Cratylia argentea* Silage

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In the dry tropics of Costa Rica (0-800 masl, 1,200-1,800 mm of precipitation; 6 months of dry season), *Cratylia argentea* has been successfully introduced into dual-purpose farms to solve the problems of low forage availability during summer months. Mixing *Cratylia* forage and chopped sugarcane has proved useful to maintain milk yields of 6-6.5 kg/cow per day in crossbred Zebu x European dairy cows (Argel and Lascano, 1998; Lobo and Acuña, 1998).

Producers value *Cratylia*'s high CP content (more than 15%) and its adaptability and persistence. Furthermore, one of its advantages is that surplus forage can be ensiled for use during times of feed shortage. This is especially important because cows do not readily consume *Cratylia* forage when the offer of other forage grasses in the pastures is high.

This study aims to evaluate the process of making silage from *Cratylia*, using several fermentative and nutritive additives. Overall, legumes are more difficult to ensile than grasses because they have a high buffer capacity that hinders adequate acidification of anaerobic media, in addition to its low soluble carbohydrate content.

Materials and Methods

The foliage of 90-day legume regrowth was manually harvested and chopped to a 16-mm bite size. Microsilos made of double polyethylene plastic bags, with approximately 1.5-kg capacity, were used. *Cratylia* was mixed with three additives: cane molasses (M), pineapple pulp (PP) and chopped sugarcane (CSC). Each additive was incorporated at three levels: M, at 10%, 20%, and 30%; PP and CSC, at 25%, 50%, and 75%, all on fresh basis (w/w). Treatments were arranged in a completely randomized design with three replicates.

Cratylia foliage was obtained from an experimental plot at the Escuela Centroamericana de Ganadería (ECAG), located in Atenas, Costa Rica, at 460 masl. Pineapple pulp was collected at the Del Oro plant in Santa Cecilia de la Cruz, Guanacaste, and the sugarcane was gathered at a private farm located in the Hojancha canton, also in Guanacaste.

The silos were left to ferment for 60 days and, upon opening, pH and organoleptic characteristics (odor and color) were assessed. Part of each sample was oven-dried at 60 °C and a subsample was frozen to later analyze ammonium nitrogen. Laboratory tests were conducted to determine dry matter (DM), organic matter (OM), crude protein (CP), ammonium nitrogen (Nam), and rumen degradability of DM (D).

A scale, from 1 to 3, was used for the organoleptic evaluation.

Organoleptic characteristics	Scores and properties of silage		
	1 = Poor	2 = Intermediate	3 = Good
Odor	Butyric (rancid)	Acetic	Lactic
	Degraded amino acids or N sub-products (spoiled)	Alcoholic	Slightly acetic or alcoholic with lactic essence
Color	Dark brown Black Moldy	Light brown Yellowish	Original green Light green

Results and Discussion

All silages presented a strong lactic odor, except for those with high CSC content (75%), which presented an alcoholic odor with a lactic essence (Table 1). The silage with 25% PP and high levels of CSC presented a light brown color.

The pH correlated highly with lactic and acetic acid contents. A pH lower than 4 is considered a good indicator of superior fermentation in moist substrata such as the ones used in this project and, accordingly, of a good-quality end product. When carbohydrate levels are very high or very low, fermentation is altered, yielding final products and pH values that fall outside the optimal range. In the case of 75% CSC, the high levels of soluble carbohydrates (SC) induced fermentation tending more toward an alcoholic base, with a pH of almost 5. In the case of 25% PP, because of the high moisture content of this substratum, its SC contribution (dry basis) was small, causing lactic acid production to be poor. Therefore pH was almost 4.5.

Table 1. Characteristics* of *Cratylia argentea* silage using three types of additives.

Additive	Ratio (w/w, %)	Odor	Color	pH
Molasses	10	3	3	4.12
	20	3	3	4.00
	30	3	3	4.05
Pineapple pulp	25	3	2.33	4.45
	50	3	3	3.90
	75	3	2.83	3.45
Chopped sugarcane	25	3	2.5	3.37
	50	3	2.5	4.00
	75	2.83	2.33	4.73

* Silage quality: 1 = poor; 2 = intermediate; and 3 = good.

The "buffer" effect was evident in *Cratylia*, especially in the treatment with 10% molasses. In elephant grass (*Pennisetum purpureum*), the addition of 10% cane molasses increases the SC content to more than 11%. Fermentation is also optimal with pH values close to 3.5 (Vargas et al., 1981; Chacón, 1987). Furthermore, buffer capacity could limit carbohydrate use and lactic fermentation and, accordingly, high pH values in several other treatments, especially those with higher/lower SC contents.

Conclusions

Based on available data, the following conclusions and recommendations were made:

- The addition of 10% molasses should be sufficient to obtain good *Cratylia* silage.

- Pineapple pulp added at levels higher than 25% improves fermentation of *Cratylia* silage, although this material has a high water content that increases transportation costs.

- Chopped sugarcane, added at 25%, contributes SC for good lactic fermentation; at higher levels, there is a risk of promoting an alcoholic process.

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Planting Maize in Association with Forage Soybean for Silage Production on the Pacific Coast of Costa Rica

I. Economic effect of partial sale of tender corn harvest

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In the tropics no other forage is superior to maize as silage. However, high production costs are the main constraint faced by both small- and medium-scale producers in Latin America.

In recent years, beef cattle herds are quickly becoming dual-purpose herds along Costa Rica's North Pacific Coast. The milk produced by these farms is marketed as cheese, sold fresh to consumers, or delivered to industrial cooperatives. Except for the milk destined to the cooperatives, summer prices (December to May) are higher because of the low supply and steady demand.

To increase the availability of milk, the shortage and poor quality of forage on offer during the dry season must be corrected. Some dairy cattle farms in the region are using sugarcane and feed supplements, for example chicken manure, urea, and molasses. These products, however, do not meet the requirements of genetically improved cows, which need forages of higher nutritive value to allow animals to best express this potential during the dry season.

The Alfredo Volio Mata dairy cattle experiment station and the School of Zootechny of the University of Costa Rica, with the collaboration of the Ministry of Agriculture and Animal Husbandry of Costa Rica (MAG), are carrying out a project to evaluate new feeding technologies on 16 farms with genetically improved cows. During project execution new challenges have arisen that need to be resolved, for example, the lack of better-quality forages to meet animal requirements during the dry season.

This study aimed to evaluate the factors that intervene in the production of maize and soybean silage, with special emphasis on the costs involved in cultivation and silage making.

Materials and Methods

In August 1999 a locally adapted white maize hybrid (Cristiani Burkard HS-5G) and a soybean variety for grain and forage (CIGRAS 10), developed by the Grain and Seed Research Center of the University of Costa Rica and successfully tested in the region, were planted. Maize was planted at a rate of 6 seeds/m of furrow and soybean at 15 seeds/m of furrow. In both cases, distance between furrows was 0.80 m. Main plots consisted of furrows of each crop as follows: (1) associated (1:1); (2) intercropped (4:4); and (3) monoculture. A split-split plot design was used in which subplots consisted of three forms of crop harvesting before silaging: (1) removal of 50% of the baby corn (at mid-flowering); (2) removal of 50% of mature maize (tender grain); and (3) removal of nothing. Experiment variables consisted of planting method and percentage of removal at harvest of mature maize or baby corn. Each treatment was replicated three times.

Maize was planted in association to improve CP content of the final product. Modifications at harvest were included to estimate the economic impact of selling part of the agricultural harvest and the capacity to recover either partially or totally the high investment made in the crop and silaging process.

The yields of baby corn, mature maize or tender grain, and forage of each crop were determined as well as the detailed costs of maize cultivation and silage making.

Results and Discussion

Table 1 details the costs per hectare for planting, maintenance, harvest, and silage making, assuming equal areas of each associated crop. Table 2 summarizes crop yields for all treatments, forage being expressed in both fresh and dry basis.

The average sale of baby corn was 7,533 units/ha, at US$0.02 each, totaling US$150.66. If costs of growing maize and making silage are deducted from the harvest of baby corn, their sale only recovers 37.5% of total costs/ha. In the case of mature maize, the average harvest was 7,312 units at US$ 0.0425/unit, representing a total income of US$310.76, which covered 77.4% of the costs.

The average yield in terms of maize ears per plant was less than 1, which is much lower than that expected, significantly affecting results. With acceptable plant density (from 4 to 5 plants/m of furrow) and with 1 ear or more per plant, 50% of baby corn or mature maize can be harvested, which would represent from 25,000 to 30,000 units/ha.

The maize produced approximately 30 t fresh forage/ha and soybean, 11 t/ha, which are equivalent to 10.5 and 3.5 t DM/ha. In the case of maize, optimal yields are between 40 and 45 t/ha. These yields can be improved by applying a more balanced fertilization and by correcting the poor drainage in some plots. Soybean yields were 50% of those obtained in monoculture in the Carrillo canton (Costa Rica), in very similar soil and climatic conditions.

Table 1. Production costs of maize for silage making (Pacific Coast, Costa Rica, 1999).

Cost component	Units/ha	Unitary cost (US$)	Total cost (US$)
Land preparation (h)	4	11.70	46.80
Planting			
Maize seed (kg)	18.0	0.85	15.30
Soybean seed (kg)	16.0	0.40	6.40
Inoculant (kg)	0.32	13.35	4.27
Fertilizer (10:30:10) (kg)	100	0.30	30.00
Labor (h)	36	1.09	39.24
Crop maintenance			
Fertilizer (urea, kg)	300	0.20	60.00
Herbicide (atrazine, L)	2	5.00	10.00
Labor (h)	12	1.09	13.08
Harvest			
Baby corn (h)	14	1.09	15.26
Mature maize (h)	14	1.09	15.26
Forage (cut-and-carry) (h)	40	1.09	76.00
Stationary chopper (t)	25	0.17	4.25
Silage (heap silo)			
Plastic (t)	25	0.42	10.50
Compaction (t)	25	1.12	28.00
Labor (h)	25	1.09	27.25
Total (US$)			401.61

Conclusions

Mixed cropping of maize and soybean for silage making has great potential in the Pacific region of Costa Rica, not only for increasing the amount of protein in the final product, but also because of the economic effect on the final value of the product and partial use of the maize harvest. Results show that it was possible to pay 77.5% of the cost of making silage, including planting, harvest, and maintenance.

Table 2. Yields per hectare in different methods of cultivating maize and soybean for silage making (Pacific Coast, Costa Rica, 1999).

Treatment	Production (no./hectare)		Forage			
			Fresh (kg/ha)		Dry (kg/ha)[c]	
	BC[a]	MM[b]	Maize	Soybean	Maize	Soybean
In association						
Harvest of 50% BC	14,780	0	28,194	10,278	9,365.4 (74.9)	3,014.6 (25.1)
Harvest of 50% MM	0	15,870	29,584	7,084	11,131.2 (82.9)	2,285.4 (17.1)
No harvest	0	0	40,834	11,458	14,150.8 (79.0)	3,679.0 (21.0)
Alternate						
Harvest of 50% BC	14,890	0	26,528	13,820	9,829.4 (70.4)	4,158.4 (29.6)
Harvest of 50% MM	0	13,358	24,930	12,362	8,999.8 (71.2)	3,597.0 (28.8)
No harvest	0	0	33,958	14,270	12,267.4 (73.0)	4,248.0 (23.0)
Monoculture						
Harvest of 50% BC	15,533	0	31,944	10,556	9,795.2 (76.8)	3,002.8 (23.2)
Harvest of 50% MM	0	14,645	24,306	10,278	8,448.4 (70.9)	3,239.4 (29.1)
No harvest	0	0	30,972	11,216	11,386.8 (74.6)	3,872.8 (25.4)
Averages						
Harvest of 50% BC	15,067	0	28,888.7	11,551.3	9,663.3 (74.0)	3,391.9 (26.0)
Harvest of 50% MM	0	14,624	26,273.3	9,908.0	9,526.5 (75.0)	3,040.6 (25.0)
No harvest	0	0	35,254.7	12,314.7	12,601.7 (75.5)	3,933.3 (24.5)
In association			32,870.7	9,606.7	11,549.1 (78.6)	2,993.0 (21.4)
Alternate			28,472.0	13,484.0	10,365.5 (71.5)	4,001.1 (28.5)
Monoculture			29,074.0	10,683.3	9,876.8 (74.1)	3,371.7 (25.9)
General	15,067	14,624	30,138.9	11,258.0	10,597.2 (75.0)	3,455.3 (25.0)

a. BC = baby corn.
b. MM = mature maize.
c. In parenthesis, the percentage of each associated component in total dry matter.

In this case, if cropping conditions are improved, especially in terms of appropriate fertilization and improved soil drainage in some plots, then yields will improve and more mature maize can be sold, allowing 100% or more of the initial investment to be recovered.

Planting Maize in Association with Forage Soybean for Silage Production on the Pacific Coast of Costa Rica

II. Several indicators of silage quality

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The incorporation of a legume into the crop when making silage improves the quality of the end product. Also, the sale of part of the baby corn in maize fields could reduce production costs.

On Costa Rica's North Pacific coast, cattle owners have very sound dual-purpose dairy farms but face problems to feed cows during the dry season. Under these conditions, the use of good-quality silage—for example, maize plus forage soybean—would allow these farmers to maintain milk production during this season.

The study was carried out at the Alfredo Volio Mata dairy cattle experiment station and the School of Zootechny of the University of Costa Rica, and complements previous studies. It aims to evaluate the quality of silage made from maize grown in association with soybean.

Materials and Methods

Microsilos made of double polyethylene plastic bags, with approximately 3-kg capacity, were prepared with recently harvested maize and forage soybean in different proportions (Table 1). As in the previous study, the following maize forage conditions were considered: (a) removal of 50% of the baby corn (at mid-flowering); (2) removal of 50% of mature maize (tender grain); and (3) removal of nothing. Maize was harvested one week after tender grain was harvested and soybean when it reached phenological state R6 (seed formed and beginning to fill).

Table 1. Treatments evaluated for making maize + forage soybean silage (Pacific Coast, Costa Rica).

Treatment	Maize:soybean ratio	Condition of forage
T1	1:1	No removal of ears
T2	1:1	Removal of 50% tender maize
T3	1:1	Removal of 50% baby corn
T4	2:1	No removal of ears
T5	2:1	Removal of 50% tender maize
T6	2:1	Removal of 50% baby corn
T7	3:1	No removal of ears
T8	3:1	Removal of 50% tender maize
T9	3:1	Removal of 50% baby corn

The microsilos were left open after 70 days fermentation and pH and organoleptic characteristics (odor and color) were assessed according to the following scale:

Organoleptic characteristics	Scores and properties of silage		
	1 = Poor	2 = Intermediate	3 = Good
Odor	Butyric (rancid)	Acetic	Lactic
	Degraded amino acids or N sub-products (spoiled)	Alcoholic	Slightly acetic or alcoholic with lactic essence
Color	Dark brown	Light brown	Original green
	Black	Yellowish	Light green
	Moldy		

Part of each sample was oven-dried at 60 °C and a subsample was frozen to later analyze ammonium nitrogen (Nam). Laboratory tests were conducted to determine: (1) dry matter (DM), organic matter (OM) and crude protein (CP) contents; (2) Nam; and (c) rate of rumen degradability of dry matter (D). Treatments were organized in a completely randomized design with three replicates.

Results and Discussion

The organoleptic characteristics of the silage are indicated in Table 2. The odor ranged from slightly acetic to lactic, as evidenced by the pH values obtained. These values correlated with lactic fermentation. As reference, three replicates of pure soybean were fermented and their average results were pH, 5; odor, 2; and color, 3. The high pH indicates the high buffer capacity of legumes that can affect final fermentation results, even with as good a substratum as maize. The use of a lactobacillus as inoculum could improve fermentation characteristics. All silos showed an excellent conservation of the original color.

Table 2. Odor, color, and pH of maize:soybean silage in different proportions (Pacific Region, Costa Rica).

Treatment[a]	Maize:soybean ratio	Odor	Color	pH
T1	1:1	2.50	3.00	4.25
T2	1:1	2.50	3.00	3.50
T3	1:1	3.00	3.00	3.95
T4	2:1	—	—	—
T5	2:1	2.50	3.00	4.00
T6	2:1	2.00	2.50	4.20
T7	3:1	2.50	3.00	3.80
T8	3:1	2.50	3.00	3.65
T9	3:1	2.75	3.00	3.68

a. Treatments are described in Table 1.

Soybean undoubtedly improves CP content, reaching almost 12% in a mixture with equal parts of maize:soybean (w/w) in fresh basis (Table 3). The CP content of similar silage made only of soybean was 15.6%. According to data of the University of Wisconsin, the average CP content of 1996 samples of maize silage, collected over 10 years in Iowa and Wisconsin, was 7.6 ± 0.81% (Lauer et al., 1999). Crude protein tends to decrease with decreasing percentage of soybean in the mixture, reaching values close to 8%. Therefore the data obtained in this experiment agree with normal values for maize silage (7.6 ± 0.81%). The DM contents of the mixtures were very similar and the addition of soybean had no effect, which is advantageous because it would not reduce animal DM intake.

Table 3. Dry matter and crude protein contents of maize:soybean silages in different proportions (Pacific Region, Costa Rica).

Treatment[a]	Maize:soybean ratio	DM (%)	CP (%)
T1	1:1	29.3	12.0
T2	1:1	26.5	11.6
T3	1:1	27.4	11.9
Average*		27.7	11.8 a
T4	2:1	—	—
T5	2:1	26.9	9.8
T6	2:1	26.1	9.2
Average		26.5	9.5 b
T7	3:1	26.9	8.1
T8	3:1	27.7	8.8
T9	3:1	30.2	8.7
Average		28.3	8.5 c

a. Treatments are described in Table 1.
* Averages followed by the same letter do not differ significantly ($P \leq 0.05\%$), according to Duncan's test.

Titterton and Maasdorp (1997) worked with silage (1:1) of maize and 15 legumes in monoculture. They found that all legumes presented acceptable levels of fermentation (pH ranging between 3.7 and 4.5; NH_3:N > 12%). They also found that protein content (dry basis) increased from 77 g/kg in pure maize silage to 93 g/kg in yellow lupine and 153 g/kg in soybean forage.

Conclusions

- Based on the organoleptic evaluation and pH values obtained, the silages obtained in this study can be considered as of very good quality. DM contents, which ranged between 26.5% and 28.3%, are acceptable and associated with a low loss of effluents.

- Silage quality values are within the normal ranges cited in literature and clearly evidence the advantage of using soybean forage in mixtures with maize for silaging.

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Activity 1.3 Functional relationships among forage resources of contrasting quality, rumen fermentation, and blood parameters

Highlights

- Milk urea nitrogen (MUN) concentrations can be a good indicator of the protein:energy ratio in the diet.

- MUN concentrations prove useful to increase the efficiency in use of on-farm feed resources.

Defining Milk Urea Nitrogen Concentrations for Optimum Recommendations of Protein-to-Energy Ratios in Tropical Forage Diets

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When there is an excess of nitrogen relative to energy in the rumen, ruminal ammonia concentration increases. Unused ruminal ammonia enters the portal blood through the rumen wall and is transferred to the liver where it is detoxified by conversion to urea. The liver also produces urea from deamination of amino acids rising from postruminal digestion and systemic protein turnover. Urea then circulates in the blood to the kidneys and is excreted with the urine or it can be diffused from the blood into milk. When there is a deficiency of dietary proteins, ruminal ammonia concentrations are relatively low and the proportion of nitrogen recycled back to the rumen as urea increases. As a result of these metabolic transactions, blood urea nitrogen (BUN) is highly correlated with ruminal ammonia and milk urea nitrogen (MUN). Therefore, in healthy ruminants, MUN concentrations could be a good indicator of the protein-to-energy ratio in the diet.

The study aimed to determine the level of urea in the milk that could be used as reference to increase the protein content to supplement diets, with a high probability that cows will respond by increasing milk production.

Materials and Methods

The study was carried out between 1992 and 1995 at the CIAT-Quilichao experiment station on contrasting pastures of *Andropogon gayanus* and *Brachiaria dictyoneura*. Two groups of four Brahman x Holstein cows were submitted to grazing on each pasture, with a 7-day period to adjust cows to the diet and 7 days of measurements. Milk yields were recorded during the 7-day measurement period, and milk samples for urea content were taken on days 1, 4, and 7 of each period. A 4 x 4 Latin square experiment design was used.

Results

Figure 1 shows the relationship between milk yield increase and MUN of cows supplemented with *Cratylia argentea* and sugarcane. Four groups can be identified, one in each quadrant. In the first group, cows showed an increase in milk yield when offered a legume supplement when the level of urea in milk was <10 mg/dL. These observations corresponded mainly to crossbred cows. In the second group, cows did not respond to legume supplementation even when the urea level was <10 mg/dL. These observations corresponded to crossbred and Brahman cows in similar proportions. The third group included cows with urea level >10 mg/dL that showed a modest increase in milk production. This group was composed of both crossbred and Brahman cows in similar proportions. The fourth group included those cows who did not respond to legume supplementation with an increase in milk yield when urea level in milk >10 mg/dL. This group was mostly composed of Brahman cows.

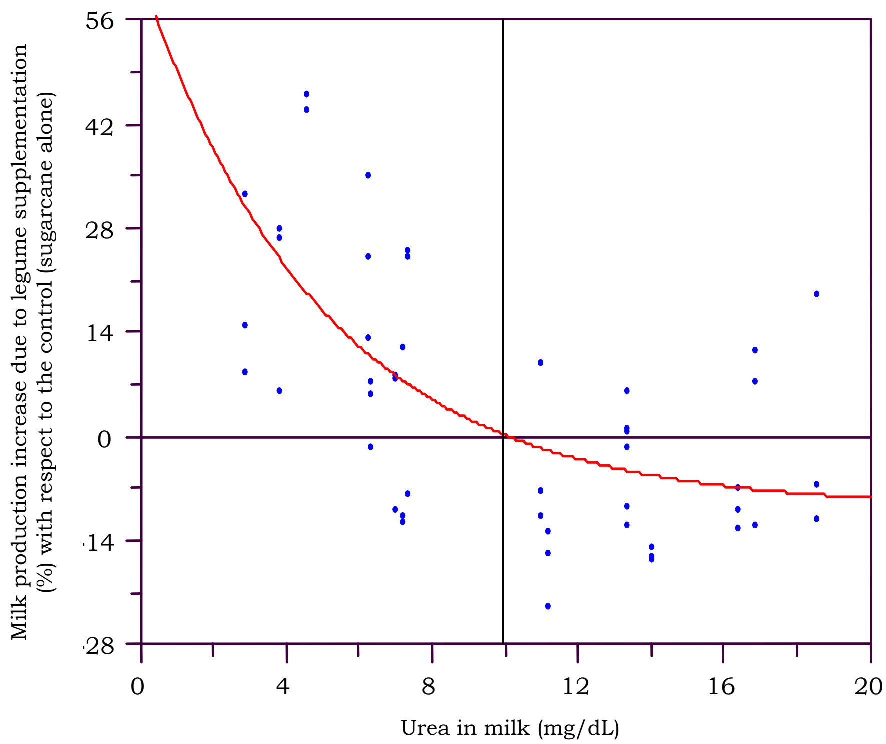

Figure 1. Relationship between milk yield increase and urea level in milk of grazing cows supplemented with *Cratylia argentea* and sugarcane.

Conclusions

These results suggest a urea level in milk of about 10 mg/dl could be used as a benchmark figure to increase dietary protein content with a high probability that milking cows will respond with increased milk yields provided demonstrated genetic potential. Furthermore, these results suggest that crossbred cows respond to legume supplementation, even when MUN levels are above 10 mg/dL. This did not seem to be the case for most Brahman- or Zebu-type cows.

RESEARCH RESULTS

Component 2: Developing New Feeding Systems for Dual-Purpose Cattle

Activity 2.1. On-farm evaluation of different forage systems for beef cattle in dual-purpose systems

Highlights

- Forage-based feeding systems for strategic supplementation during the dry season reduce the need to purchase animal feed concentrates and increase the income in dual-purpose farms.

- The use of legumes with an energy source during the dry season maintains milk production.

Milk Production in Dual-Purpose Cows Grazing Pastures of *Brachiaria brizantha* cv. La Libertad Alone and Associated with *Arachis pintoi* cv. El Porvenir in the Subhumid Tropics of Costa Rica

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Costa Rica has a land area of 51,023 km^2, of which 25,100 km^2 (49.2%) are under agricultural and livestock exploitation according to the 1984 National Agricultural and Livestock Census. Of the area under cultivation, grasses occupy the largest proportion—16,500 km^2, in other words, 65.7%. Beef cattle are raised on 51,000 farms; their population is estimated at 2,150,000 heads of cattle, of which 75% have been crossbred, at different levels, with Zebu breeds.

Among the main problems affecting beef cattle development in Costa Rica are low meat and milk productivity, low reproductive rates, nutritional deficiencies (especially because of the low forage availability and quality during the dry season), and health problems.

Forage is the most available and inexpensive source of feed for livestock in Costa Rica; however, a high percentage of pastures are now degraded, reducing forage availability and quality.

The improvement of both the quality and quantity of forage resources through the recovery of degraded pastures is important to increase overall livestock productivity. The study aims to evaluate milk production of dual-purpose cows grazing a recovered pasture of *Brachiaria brizantha* cv. La Libertad alone and associated with *Arachis pintoi* cv. El Porvenir and *Centrosema brasilianum*.

Materials and Methods

The trial was carried out on a farm located in San Jerónimo de Esparza, in the subhumid tropical central Pacific region of Costa Rica, at an average altitude of 250 masl. The region is characterized by having well-defined dry (December-May) and rainy (June-November) seasons, with an average annual precipitation of 2,500 mm. Four hectares of *Brachiaria brizantha* cv. La Libertad were planted in a paddock where a degraded pasture of *Brachiaria ruziziensis* existed. The area was divided in half and 2 ha were planted in association with *A. pintoi* CIAT 18744 cv. Porvenir and *C. brasilianum* CIAT 5234.

Forage availability (dry basis) and botanical composition of both pastures (alone and associated) were determined using the Botanal method.

A group of 26 milking cows of different breeds—predominantly Brown Swiss—and weighing, on average, 450 kg were used; a Brahman bull was also included. This group grazed the 2 hectares of sole cropped pasture for 4 consecutive days and the associated pasture for 5 days. Milk production was measured on days 1 and 4 in the sole cropped pasture and on days 1, 3, and 5 in the associated pasture. The production of both groups was compared with that obtained by cows grazing pastures sown to *B. ruziziensis*, the grass traditionally used on farms.

During the rainy season, pastures were rotated; the grazing cycle consisted of 4 or 5 days of occupation and 27 days of rest. During the dry season, grazing was continuous.

The Student's (t) test (Steel and Torrie, 1988) was used to compare milk production averages. The averages of cows grazing the sole cropped pasture were compared with the averages of cows kept on the native pasture and with those of cows grazing the associated pasture. The stocking rates of the native pasture, the sole cropped pasture, and the associated pasture were calculated using the method proposed by Paladines and Lascano (1983), which takes into account animal units and grazing system.

Results

Forage availability and botanical composition. Table 1 presents mean DM availability and botanical composition of both pastures during the rainy season over three consecutive periods. The percentage of *C. brasilianum* found in the associated pasture is so low that it was included in the percentage of legumes present in the associated pasture.

Forage availability was found to increase in pastures under recovery as the trial advanced. At the beginning of the trial, forage availability in these pastures was 3 t/ha, increasing to 6.3 t/ha in late 1999 in the sole cropped pasture with improved grasses and to 7.1 t/ha in the associated pasture. This clearly shows the benefits of the method used to recovery these pastures.

Increased forage availability is reflected in the increased stocking rate of pastures, which in the case of native pastures was 1.5 AU/ha compared with 2.0 AU/ha for the sole cropped pasture and 2.4 AU/ha for the associated pasture. Also, the percentage of weeds was reduced in the associated pasture.

Table 1. Forage availability and botanical composition of a pasture of *Brachiaria brizantha* cv. La Libertad alone and associated with *Arachis pintoi* and *Centrosema brasilianum* during the rainy seasons of 1997-1999 (Esparza, Costa Rica).

Year	Sole cropped pasture					Associated pasture				
	t/ha	Grasses (%)	*A. pintoi* (%)	Legumes[a] (%)	Weeds (%)	t/ha	Grasses (%)	*A. pintoi* (%)	Legumes (%)	Weeds (%)
1997	4,113	62	0	22	16	5,105	57	18	13	12
1998	4,483	67	0	18	15	5,408	58	24	4	14
1999	6,306	88	0	8	3	7,155	54	42	5	1
Av.	4,967	72	0	16	11	5,889	56	28	7	9

a. *Calopogonium mucunoides*, *Zornia* spp., and *Aeschynomene* spp. were found in addition to *C. brasilianum.*

Milk production. The average milk production of cows grazing the native pasture and sole cropped pasture of *B. brizantha* were similar (Table 2). However, the average production obtained on the associated pasture was higher than that obtained on the native pasture (Table 3). Both trials were carried out independently, using the native pasture as check.

During 1997, the increase in milk production was higher compared with that of 1998 and 1999, because cows received a daily supplementation of 5 kg chicken manure and 1.5 kg of soybean hulls.

Table 2. Average milk production of dual-purpose cows grazing native pastures and *Brachiaria brizantha* during the rainy seasons of 1997-1999 (Esparza, Costa Rica).

Year	Milk production on two types of pasture (kg/cow per day)[a]	
	Native[b]	*Brachiaria brizantha* alone
1997	8.6	9.0
1998	7.5	7.7
1999	7.6	7.8
Average	7.9 a*	8.2 a

a. Average of 26 milking cows.
b. Mainly *B. ruziziensis*.
* Averages in the same row followed by the same letter did not differ significantly (P = 0.2271) using the Student's (t) test.

Table 3. Average milk production of dual-purpose cows grazing native and associated pastures during the rainy seasons of 1997-1999 (Esparza, Costa Rica).

Year	Milk production on two types of pasture (kg/cow per day)[a]	
	Native[b]	*Brachiaria brizantha* + *Centrosema brasilianum*
1997	8.6	9.3
1998	7.5	7.9
1999	7.6	8.1
Average*	7.9 a	8.4 b

a. Average of 26 milking cows.
b. Mainly *B. ruziziensis*.
* Averages in the same row followed by the same letter did not differ significantly (P = 0.0246) using the Student's (t) test.

The average increase in milk production during the three years of the evaluation in the sole cropped pasture as compared with the native grass was 3.8%, whereas the increase for cows grazing the associated pasture was 6.3%. Besides this increase in milk production, producer's income also increased because of the larger amount of milk sold.

Differences in milk production between sole cropped and associated pastures were 250 g/animal per day, which agrees with results found by Ullrich et al. (1994) who worked with dual-purpose cows grazing *B. decumbens* alone and associated. At the Escuela Centroamericana de Ganadería (ECAG) in Atenas, Costa Rica, milk production of Jersey dairy cows increased 9% when grazing a *B. decumbens* + *A. pintoi* cv. El Porvenir pasture, as compared with cows grazing the sole cropped pasture and offered a commercial concentrate as supplement (Romero and González, 1998). These results are similar to those found in this study, despite these being dairy cows well known for their milk production that received concentrate. This confirms once more the beneficial effect of the legumes on milk production.

Besides the benefits in milk production when improved pastures are used, there is a significant increase in milk production/hectare as shown in Table 4.

Cipagauta et al. (1998) found that half-bred Holstein x Zebu dairy cows, grazing *B. decumbens* alone and associated with legumes (20% of the pasture) in the Amazon piedmont of Caqueta, Colombia, produced 52% more milk/ha on the sole cropped pasture as compared with the native pasture, and 94% more milk on the associated pasture. The estimated milk production/ha of cows grazing associated pastures differed by 23% from that of cows grazing sole cropped pastures. Increases obtained for both pastures in the study are slightly lower (37% for the associated pasture; 70% for the sole cropped pasture) as compared with the native pasture. The increase in milk production between the associated pasture and the sole cropped pasture was 24%.

Table 4. Average milk production (kg/ha) of dual-purpose cows grazing different types of pastures during the rainy seasons of 1997, 1998, and 1999.

Type of pasture	Milk production[a] (kg/ha)
Native pasture[b]	11.6 a
Native pasture[b]	11.6 a
Sole cropped pasture	15.9 b **
Associated pasture	19.7 b ***

a. Average production of 26 cows.
b. Native grasses, mainly *Brachiaria ruziziensis*.
** $p = 0.0001$; *** $p = 0.0253$ (comparison of averages using the Student's (t) test)

González et al. (1996) found that Jersey cows, a local Central American race of dairy cows, and crossbred cows between both of the former produced 14% more milk/ha in pastures of African star grass (*Cynodon nlemfuensis*) associated with *A. pintoi* than in pastures of the grass fertilized with 100 kg N/ha per year. This increase in milk production was lower than that found in our study, but the stocking rate was similar (2.6 AU/ha).

Lascano and Avila (1991) cite that the production of fat-corrected milk increased, on average, by 20% in associations of *B. dictyoneura* with *C. acutifolium* and *C. macrocarpum*, as compared with the grass pastures alone. In the case of *Andropogon gayanus* associated with the same legumes, the increase in milk production of the associated pastures was, on average, 15% as compared with the sole cropped pasture.

Conclusions

In this study the recovery of degraded pastures by establishing improved grasses increased milk production as well as pasture stocking rate. The introduction of legumes, such as *A. pintoi* made it possible to increase milk production and pasture stocking rate more as compared with native and improved sole cropped pastures. Pasture rehabilitation together with the introduction of improved grasses and legumes, enhances forage availability and, as a result, increases the pasture's stocking rate.

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Effect of Age of Regrowth and Cutting Height on Productivity of *Cratylia argentea* cv. Veraniega in the Subhumid Tropics of Costa Rica

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Livestock development in the tropics, which is characterized as being extensive, is based on the use of grasses; however, in farms that are a little more intensive, as is the case of dual-purpose and semi-specialized dairies, animal nutrition is complemented with agroindustrial by-products during the dry season.

More and more, these by-products are not used because of their highly variable nutritive quality and price. Furthermore, in several of these regions these by-products must be treated with heat, which affects their nutritive quality.

Therefore the use of shrub legumes has been studied in recent years to offer cattle a better source of on-farm feed while reducing feeding costs.

Cratylia argentea is a shrub legume native to the Amazon region and parts of Brazil, Peru, and Bolivia. It is characterized by its adaptation to a broad range of soils, mainly well-drained, low-fertility acid soils, and its capacity for regrowth during the dry season. Its crude protein (CP) content is high, its *in vitro* dry matter digestibility (IVDMD) is intermediate, and the consumption of this forage becomes more appealing during the dry season.

This study aims to evaluate the productivity (production and nutritive value) of *C. argentea* cv. Veraniega, at two ages of regrowth and three cutting heights, in Costa Rica's central Pacific region.

Materials and Methods

At the beginning of the 1996 rainy season, a forage bank of *C. argentea* was established on a farm in San Juan Grande de Esparza (250 masl with annual average precipitation of 2,400 mm and a 6-month dry season). Distance between plants was 50 cm and distance between rows was 1 m. The soil was a clay loam Ultisol, with the following characteristics: pH, 5.4; Ca, 7.2 cmol/L; Mg, 0 2.6 cmol/L; P, 6 mg/L; and 3.1% of OM.

One year after the bank was established and submitted to cutting during the dry season, an area with 210 plants was selected for the present study. To determine the productivity of cv. Veraniega, a uniformity cut was performed at test heights in April 1998. Two ages of regrowth (60 and 90 days) and three cutting heights (30, 60, and 90 cm above the ground) were assessed.

At each cutting, the height of all plants was evaluated and 15 plants of each plot were selected at random to perform the cutting at the corresponding age and height; the number of sprouts in each was measured as well as DM yield/plant. The percentage of CP, acid and neutral detergent fiber, and lignin contents were determined in the laboratory. A Latin square design was used, and the averages were separated by the Waller-Duncan test (Steel and Torrie, 1988).

Frequent analyzes were also made to determine the effect of the legume on soil fertility.

Results and Discussion

The effect of the age of regrowth and cutting height on yield of *C. argentea* during 1998-2000 is indicated in Table 1. All cutting heights tested tended to increase DM production per plant and per hectare. As cutting height increased from 30 to 90 cm, DM production doubled. Likewise, the number of sprouts/plant tended to increase with increasing cutting height.

Table 1. Average DM yield, plant height, and number of sprouts of *Cratylia argentea* cv. Veraniega at two ages of regrowth and at three cutting heights during 1998-2000 (Esparza, Costa Rica).

Age of regrowth (days)	Characteristic	Cutting height (cm)			Average
		30	60	90	
60[a]	Height of regrowth	0.5	0.5	0.6	0.5
	No. of sprouts/plant	10.5	12.3	17.1	13.3
	DM (g/plant)	89.7 a* (40)[c]	110.6 a (43.4)	178.1 a (44.5)	126.1(42.6)
	DM (t/ha)	1.3 a (40.7)	1.7 a (42.4)	2.7 a (44.2)	1.9 (42.9)
90[b]	Height of regrowth	0.9	0.8	0.9	0.9
	No. of sprouts/plant	11.7	15.0	17.1	14.6
	DM (g/plant)	256.9 b (27)	304.9 b (34)	494.9 b (28.3)	352.2 (29.9)
	DM (t/ha)	3.9 b (27.3)	4.6 b (34.1)	7.4 b (28.4)	5.3 (29.9)

a. Average of 11 cuttings
b. Average of 8 cuttings.
c. In parentheses, percentage of total DM production during the dry season.
* Averages of the same cutting height and row followed by the same letters do not differ significantly (P = 0.05), according to Duncan´s test.

Average DM yields/plant at 60 days regrowth fell within the range cited by Argel and Valerio (1996): 110-190 g/plant in cuttings performed between weeks 8 and 14 at sites with 5- to 6-month dry seasons. Yields obtained at 90 days regrowth averaged 352 g/plant, being higher than those cited by the same researcher.

The average forage production at 90 days regrowth is over 4 t/ha more than that obtained at 60 days. In addition, average forage production during the dry season accounts for approximately 43% and 30% of total production at the two ages of regrowth (60 and 90 days, respectively).

Figure 1 shows average DM production for the treatments. Within a single cutting height, significant differences occurred between the two ages of regrowth, the yield always being higher at 90 days regrowth. Table 2 shows the effect of age of regrowth and cutting height on nutritive quality of *C. argentea* during 1998-2000. Forage quality at the three cutting heights showed that the CP content tended to increase with increasing cutting height from 30 to 90 days, as well as NDF and lignin contents. The CP content of plants harvested at 30 cm height did not differ significantly at both ages of regrowth. On the contrary, plants harvested at 60 and 90 cm height differed significantly (P = 0.08) in CP because of the effect of age of regrowth.

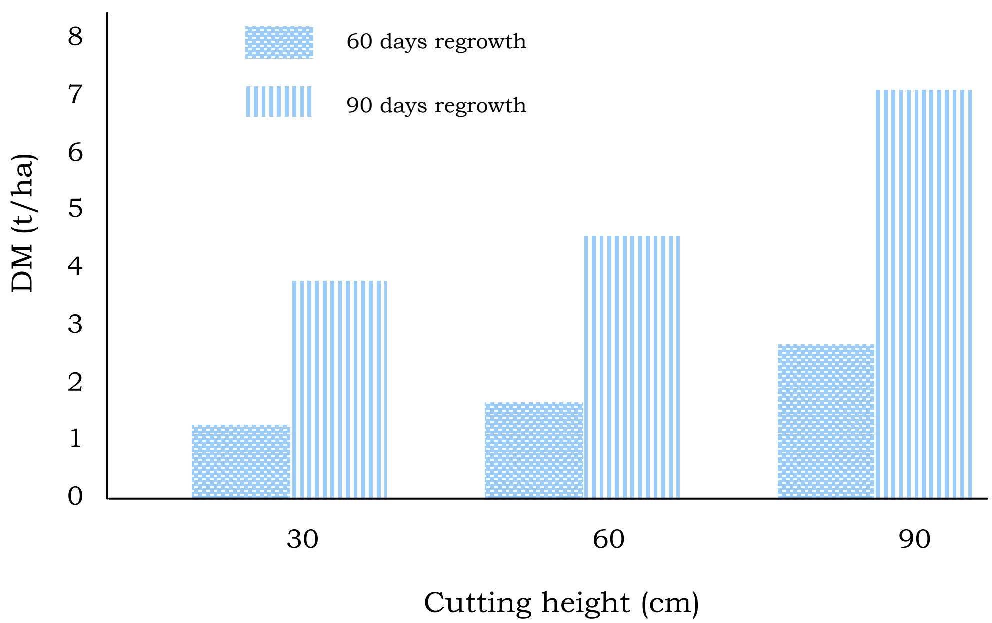

Figure 1. Average dry matter yield (t/ha) of *Cratylia argentea* at two ages of regrowth and three cutting heights during 1999-2000 (Esparza, Costa Rica).

Table 2. Nutritive quality of *Cratylia argentea* at two ages of regrowth and three cutting heights during 1999-2000 (Esparza, Costa Rica).

Age of regrowth (days)	Quality (%)	Cutting height (cm)			Average
		30	60	90	
60[a]	Crude protein	17.4 a*	17.2 a	17.7 a	17.4
	NDF	53.5 a	55.9 a	58.3 a	55.9
	ADF	43.1 a	43.0 a	44.1 a	43.4
	Lignin	14.8 a	16.0 a	16.1 a	15.6
90[b]	Crude protein	15.4 a	15.0 b	15.6 b	15.3
	NDF	58.6 b	58.5 a	61.2 a	59.4
	ADF	44.9 a	44.7 a	44.1 a	44.6
	Lignin	15.8 a	16.3 a	16.2 a	16.1

a. Average of 11 cuttings.
b. Average of 8 cuttings.
* Averages in the same column followed by the same letters do not differ significantly (P < 0.05), according to Duncan´s test.

The CP content in *C. argentea* varies broadly from 25% at 12 weeks of age (Franco, 1997) to 20% at 8 weeks regrowth (Valerio, 1994). Xavier and Carbalho (1995) reported that, at 84 days, nitrogen content of *C. argentea* is low, approximately 3%, which is equivalent to 20% CP. These values are within the limits observed for other tropical legumes. Franco(1997) found CP values of 23% at 2 months regrowth and values of 21% at 3 months regrowth. These values were higher than those found in the present study.

Significant differences in NDF content occurred between the two ages of regrowth when the cutting height was 30 cm (P = 0.0245). However, the highest NDF values always occurred in cuttings at 90 days because the amount of woody material is greater then (Figure 2).

In addition to the contribution of *C. argentea* to the quality of forage-on-offer, in the analysis carried out in 1999 soil OM increased 1% (3.1% in 1996 vs. 4.1% in 1999) because of the high amounts of recycled material, especially leaves.

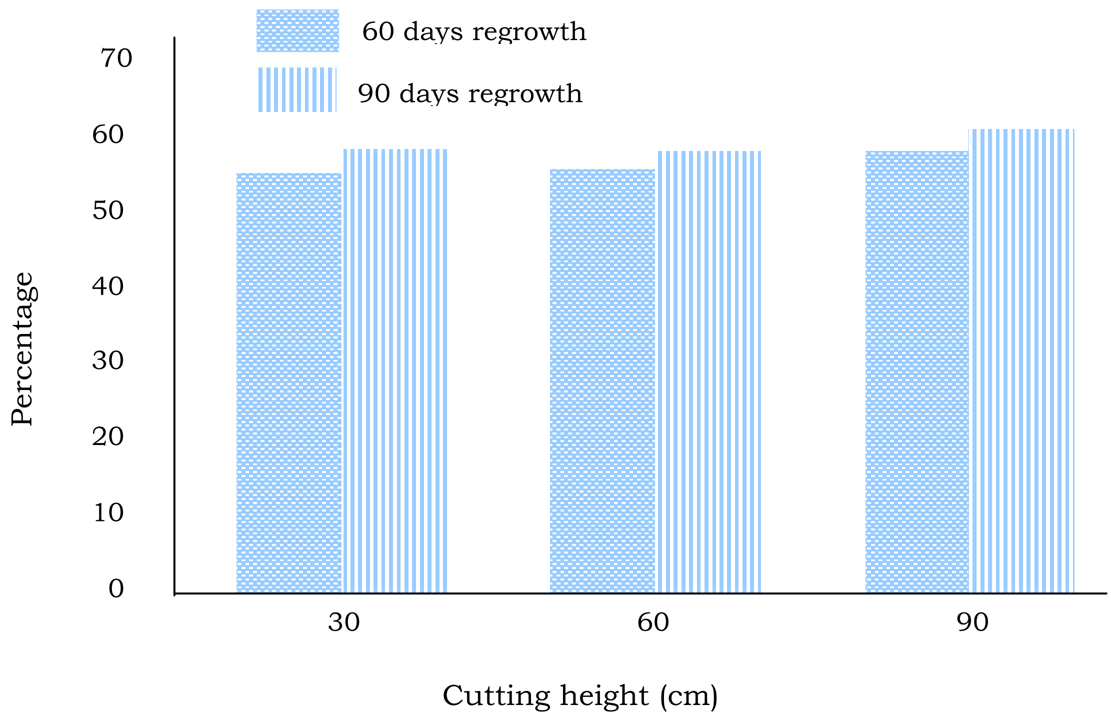

Figure 2. Average percentage of neutral detergent fiber in forage of *Cratylia argentea* harvested at two ages of regrowth and three cutting heights (Esparza, Costa Rica).

Conclusions

The following conclusions can be reached:

- At 60 days regrowth, *C. argentea* produces good quality forage, regardless of the cutting height. Plant CP content was not affected by cutting height, but NDF content was. At greater regrowth age, dry matter production was higher, protein content was lower, and percentage NDF was greater.

- *C. argentea* cut at 90 days regrowth and at a height of 90 cm produces good DM production of acceptable quality.

- Soil OM content at sites where *C. argentea* is established increased by 1% between 1996 and 1999.

- Because of the high forage production of this legume during the rainy season, a uniformity cut should be performed at the beginning of season to ensilage material and use it during the dry season. In case this is not feasible, a uniformity cut should be performed at the end of

October to improve the quality and quantity of forage during the dry season.

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Effect of Supplementing Fresh and Ensiled *Cratylia argentea* cv. Veraniega on Milk Production of Dual-Purpose Cows in the Subhumid Tropics of Costa Rica

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This study aims to evaluate the effect of the shrub legume *Cratylia argentea* cv. Veraniega, on milk production when offered as fresh forage or ensiled to dual-purpose cows.

Materials and Methods

Trials were carried out on two farms located in Costa Rica's subhumid tropical Central Pacific region, between 0 and 250 masl, and well-defined dry (December-April) and rainy (May-November) seasons. The average temperature is 26 °C and the average annual precipitation is 2,500 mm.

Experiment 1. Six cows of third parturition and in second month of lactation were selected from a herd of 45 milking cows that presented broad genetic variation, on a farm located in Barbudal de Barranca, Miramar. Cows produced, on average, 5.5 kg milk/day.

After a 12-day period of adjustment to the new diets, each animal was offered the forage supplement for 3 hours/day after milking. The trial lasted 30 days, during which 6 animals were rotated per treatment over a 10-day period, which was divided into 7 days of adjustment and 3 days for individual measurement of milk production per cow. Milk quality, especially in terms of fat and total solids contents, was determined.

The treatments evaluated were as follows: T1, check animals grazing the pasture alone; T2, supplement of 12 kg sugarcane, 8 kg *C. argentea*, 0.6 kg semolina, and 0.5 kg molasses; and T3, 12 kg sugarcane, 3 kg chicken manure, 0.6 kg semolina, and 0.5 kg molasses.

The plants of *C. argentea* used had approximately 4 months regrowth, with an average nutritive value of 16% CP and 33% DM.

A Latin square design was used in a changeover system (Lucas, 1983), with three treatments and two animals per treatment. The separation of averages was performed by the Waller-Duncan test (Steel and Torrie, 1988).

Experiment 2. Six milking cows of third parturition were selected from a group of 11 animals with similar breed characteristics (3/4 Swiss Brown and 1/4 Zebu) on a farm located in San Miguel de Barranca, Esparza. All cows were in their second month of lactation and producing, on average, 5.5 kg milk/day. After milking, forage supplements were offered individually for 3 hours. The experiment design and animal management used were similar to those of Experiment 1.

The treatments evaluated were as follows: T1, 12 kg sugar cane, 6 kg *C. argentea* silage, and 0.6 kg semolina; T2, 12 kg sugarcane, 6 kg fresh *C. argentea*, and 0.6 kg semolina; and T3, 12 kg sugarcane, 3 kg chicken manure, and 0.6 kg semolina.

For T2, a heap silo was built for *C. argentea* plants at 4 months regrowth that had been previously chopped. Molasses was gradually added at 10% weight basis of material for ensilage as the silage was being compacted. Silage was first used 4 months after being ensiled and its quality was determined by measuring pH, percentage of CP, DM content, and several organoleptic characteristics such as odor and color.

Results

Experiment 1. Milk production differed significantly between treatments (P = 0.076) (Table 1). Higher milk production was obtained when chicken manure was offered as protein supplement. No significant differences occurred between treatments when chicken manure was replaced with *C. argentea*. Milk production of cows not receiving protein supplement was similar to that reached with T2. This could be attributed, among other factors, to the high availability of fruits of the cohune palm (*Acrocomia vinifera*) existing in the pastures and to which the cows had access, as well as the consumption of several other sources of feed available during the dry season.

The results of greatest interest in this study are reflected in the economic indicators, for example, the cost of supplements, the income obtained by sale of milk, and the cost:benefit ratio. Replacing chicken manure with *C. argentea* reduces the costs/kg supplement from US$0.217 to US$0.11, thus doubling the benefits of the investment.

The consumption of *C. argentea* was good and was not rejected by the animals.

Table 1. Average milk production, total solids content, and cost:benefit ratio of dual-purpose cows receiving supplements of different protein sources (Experiment 1).

Treatment	Milk production (kg/cow)	Total solids (%)	Fat (%)	Cost of supplement (US$/kg)	Price of milk (US$/kg)	Cost:benefit ratio
1	5.5 b*	11.2	3.1	-	0.235	-
2	5.9 a b	11.5	3.2	0.109	0.241	2.2
3	6.3 a	11.2	2.9	0.217	0.235	1.1

* Values in the same column followed by the same letter do not differ significantly (P = 0.076), according to Waller-Duncan's test.

Experiment 2. Milk production was highest in the treatment in which fresh *C. argentea* was offered; however, this treatment did not differ statistically from the treatment offering chicken manure or from the treatment offering ensiled *Cratylia* (Table 2).

The silage obtained was highly palatable and of good quality (pH 4.5, 16.5% CP, and 36% DM). Silage quality can accordingly be ranked as excellent (González et al., 1990).

Milk quality did not differ among treatments; however, total solids and fat in milk were slightly higher in T1 (ensiled *C. argentea*) and T2 (fresh *C. argentea*) than in T3, which included chicken manure.

The lowest production costs occurred in T2 and the highest in T3. However, the highest income per sale of milk was obtained with T1 and the lowest with T3. These results indicate that the highest economic benefit was obtained with T2, followed by T1 and T3.

Table 2. Average milk production, total solids content, and cost:benefit ratio in dual-purpose cows supplemented with different sources of protein (Experiment 2).

Treatment	Milk production (kg/cow)	Total solids (%)	Fat (%)	Cost of supplement (US$/kg)	Price of milk (US$/kg)	Cost:benefit ratio
1	5.1 b*	12.3	3.6	0.164	0.260	1.6
2	5.5 a	12.2	3.4	0.109	0.256	2.3
3	5.3 a b	11.7	3.0	0.217	0.245	1.1

* Values in the same column followed by the same letter do not differ significantly (P = 0.08), according to Waller-Duncan's test.

As in Experiment 1, the consumption of fresh and ensiled *C. argentea* was good and the percentage of rejection by animals was 10%, mainly stems.

The experience with legume silage in the tropics is limited. In Cuba, Ojeda (1999) found that grass/legume silage had good quality. Reagen (1999) found that *Cassia* silage presented 12% CP and 58% IVDMD. In the process of ensiling legumes, fermentation is mainly dominated by clostridia, which can be attributed to the high buffer capacity, low soluble carbohydrate content in water, and, to a less extent, to the low DM content (Pezo et al., 1989). Kass and Rodríguez (1987), cited by Pezo et al. (1989), observed a high amount of volatile nitrogen (ammonium) and low levels of lactic acid in silage of *Gliricidia sepium.*

Conclusions

The following conclusions were reached:

- *Cratylia argentea,* used as a protein supplement during the dry season, can substitute chicken manure completely in milk cows, while it reduces the farmer's dependency on off-farm resources and improves the quality of the diet offered.

- The nutritional quality of the milk produced by cows on diets of fresh or ensiled *C. argentea* is better in terms of fat and total solids.

- Profits were higher when milk production involved fresh and ensiled *C. argentea* than when chicken manure was used because of the higher production and better-quality milk.

- Additional studies should be conducted on milk quality and maximum voluntary consumption of *Cratylia.* Different types of silos and silage systems should also be studied.

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Effect of Using *Centrosema macrocarpum* on Milk Production in the Alto Mayo Region of the Peruvian Amazon

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The inclusion of forage legumes is a production strategy that allows production to be optimized and nutritional deficiencies of grass pastures to be overcome. This alternative also makes better use of animal genotypes, land, and producer's capacities.

The Alto Mayo region covers 630,735 hectares, of which 346,452 hectares are suitable for grasslands. Of these 40% are not being used. A survey carried out in March of this year indicated that the Alto Mayo region has potential for livestock activities. Additional surveys indicated that the region offers good possibilities of livestock production on pastures planted to *Brachiaria decumbens*, *B. brizantha* and cut-and-carry grasses. On the other hand, *Centrosema macrocarpum* in protein banks and as cut-and-carry forage has proved to be a good alternative to improve the diets offered to grazing animals.

The experiment aimed to: (1) measure the increase in milk production and the weight gain in calves attributed to the use of *C. macrocarpum* to feed dairy cows; and (2) compare the farmers' traditional system with a system based on *Centrosema* in terms of economic merit.

Materials and Methods

Two 1-ha plots were planted on two farms located in Nueva Cajamarca and Soritor during September 1999. Planting density of *Centrosema* in both plots was high, with 0.4 m x 0.4 m between plants and 8 kg seed/ha. A 95% coverage was reached at 5.5 months.

A completely randomized design was used with three treatments and seven cows/treatment, over a 10-week period. The following model was used:

$$Y_{ij} = U + T_j + E_{ij}$$

where:
Y_{ij} = milk production

U = overall mean
T_j = effect of the n-nth treatment (i=3)
E_{ij} = experimental error

Treatments were as follows: T1, cut-and-carry grass (king grass) restricted to milking; T2, 50% amount of cut-and-carry grass provided in T1 and 50% of *Centrosema* provided in T3, restricted to milking; and T3, 100% *Centrosema* restricted to milking.

Milking was done manually, once a day with calf on foot. After milking, calves were allowed to suckle for 5 minutes and were then transferred to pens. Crossbred dairy Gyr x Holstein cows were used and left to graze on the pasture 6 hours/day, after which they were taken to a pen where they received chopped king grass.

Control variables were: consumption of supplementary forage; milk production, kg/cow per day during periods of maximum and minimum precipitation; production costs of supplementary feed: and economic evaluation of results.

To measure consumption of supplementary forage (kg DM/cow per day), *Centrosema* and king grass were separately cut, carried, and chopped with machete and supplied at milking. Forage on offer and forage rejected were monitored the first 15 days of adjustment to determine the amount of forage needed during the experimental phase and thus estimate average intake per treatment.

Milk production (kg/cow per day) was measured 4 days per week. To date of this report, production data had already been determined for two periods of maximum and minimum precipitation.

Costs of producing supplementary feed considered establishment costs and maintenance costs per hectare and the cost of cutting and transporting forage.

The following evaluations were carried out to calculate total volume of forage (*C. macrocarpum* and king grass)/ha per year: forage availability (kg DM/ha) in random samples taken at the beginning of each grazing cycle; time of pasture recovery: and pasture coverage at 20, 45, and 60 days after initiating grazing.

Economic merit was evaluated using the following formula:

$$EM = \frac{\text{Cost of feeding/cow period}}{\text{Milk production (kg)}}$$

Results

Consumption of supplementary forage. Average consumption of DM at milking was 0.87, 0.96, and 0.90 kg/cow per day for T1, T2, and T3 respectively, in addition to the voluntary consumption of *Brachiaria* during grazing and king grass supplied in closed pens during the day and in the afternoon. A trend to consume more grass + legume mixture was observed so it can be inferred that the inclusion of the legume increases consumption by 23% in T2 and 11% in T3.

Milk production. The higher milk production was reached in cows supplemented exclusively with *Centrosema* (6.65 kg/cow per day), differing significantly ($P < 0.05$) with the treatment supplemented with *Centrosema* + king grass (5.56 kg/cow per day) and the treatment of only king grass (4.11 kg/cow per day). Therefore supplementation with *Centrosema* had a positive impact on milk production.

Effect of number of parturitions. No differences were observed in milk production between cows of two and three parturitions (4.66 kg/day) and cows of four and five parturitions (4.40 kg/day). Significant differences were observed, however, between these groups and first-calf cows (3.02 kg/day).

Effect of season on milk production. The average milk production of cows during the period of maximum precipitation was 5.13 kg/day, while it was 5.72 kg/day during the period of minimum precipitation, the difference being significant ($P < 0.001$). This indicates the importance of the legume as a nutritional supplement of cows during the dry season.

Economic merit. The cost/kg DM for each alternative was taken into account, which included the depreciation in a 6-year period of the establishment costs of *Centrosema* and king grass, maintenance costs, and harvest costs.

In the case of *Centrosema*, an establishment cost of US$380/ha was used, together with an annual maintenance costs of US$40/ha, and a harvest cost equivalent to 0.6 man-days per each 50 kg of fresh biomass. Annual productivity was estimated at 15 t in 5 cuttings. Thus, the total cost per kilogram of DM was estimated at US$0.105.

In the case of king grass, estimated establishment cost was US$295/ha with annual maintenance costs of US$110/hectare and harvest costs equivalent to 1.4 man-days for each 100 kg of fresh biomass. Annual productivity was estimated at 25 t in 4 cuttings. Therefore, total cost per kilogram of DM matter was about US$0.184.

The economic merit for each alternative appears in Table 1, which yielded indexes of 0.055 (T1), 0.056 (T2), and 0.047 (T3). Although production improved in T2 (32%) as compared with T1, the economic merit of this treatment did not improve, attributable to the high consumption recorded in this treatment, which increased, in turn, the cost of supplementary feeding. T3, on the other hand, presented a better economic index as compared with T1 and T2.

Table 1. Calculating economic merit of several forage alternatives in the Alto Mayo region of the Peruvian Amazon.

Treatment	Feed consumed (kg)	Cost (US$)		
		King grass	Centrosema	Total cost
T1	0.87	0.16	--	0.160
T2	0.96	0.10	0.098	0.196
T3	0.90	--	0.178	0.178

Milk production/treatment	Economic merit
T1, x Milk production = 4.11	0.037
T2, x Milk production = 5.56	0.035
T3, x Milk production = 6.65	0.027

Conclusions

Results indicate that supplementation with *Centrosema* had a positive impact on milk yields when offered at milking to crossbred Gyr x Holstein cows.

Supplementation with *Centrosema* also presented the best economic merit, ratifying the important role this legume plays in improving milk production efficiency. The significant increase in milk production recovered additional expenses involved and maintained an additional margin of profit.

Effect on Milk Yield of the Association of *Brachiaria brizantha* with *Arachis pintoi* in the Alto Mayo Region of the Peruvian Amazon

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The inclusion of legumes in pastures of *Brachiaria decumbens* and *B. brizantha* in the Alto Mayo region is a feasible alternative to increase animal productivity. This study therefore aimed to evaluate the effect of *Arachis pintoi* cv. Maní forrajero associated with *Brachiaria* on milk production and stocking rate of grazing cows.

Materials and Methods

The treatments evaluated were: T1, *B. brizantha* in monoculture; and T2, *A. pintoi* associated with several species of *Brachiaria.*

Plots of the associated pasture, 4 ha in size, were established on a small farm in Soritor. Initial availability of forage, milk production, and stocking rate were recorded. Crossbred Gyr x Holstein cows were used in this evaluation. These same animals grazed both types of pastures.

Each pasture was divided into two equivalent paddocks and animals grazed each paddock for 7 days. Milk production was measured in each paddock as of Day 3, during maximum precipitation. Forage availability and botanical composition were measured with random samplings in each paddock at the beginning of the grazing cycle.

Results

During the experimental period the producer controlled the rest/occupation periods and the number of animals grazing. The stocking rate of each pasture was calculated on the basis of these indicators: 2.07 AU/ha on pastures of *B. brizantha* and 4.13 AU/ha in the associated pasture.

Forage availability and components of evaluated pastures indicated that total available DM in the associated pasture *B. brizantha/A. pintoi* was 7.59 t/ha at the beginning of grazing, with legumes accounting for 6% and weeds for 11% of the botanical composition of the pasture. The pasture of *B. brizantha* alone produced 6.29 t DM/ha, with 9% weeds.

Milk production during the season of maximum precipitation was, on average, 5.98 kg/cow per day when the cows grazed the associated pasture, compared with 4.99 kg/cow per day when they grazed the *B. brizantha* pasture.

Conclusions

Although these results are preliminary and correspond to a single evaluation, farmer expectations are high because the stocking rate of the associated pasture doubled that of the sole cropped pasture and milk production/cow increased by 10%.

Activity 2.2. Evaluation of new feeding alternatives to allow early weaning

Highlights

- Supplementing pre-weaned calves with legumes during the dry season results in more milk for sale and higher liveweight gain compared with calves grazing a sole cropped grass pasture.

Use of *Stylosanthes guianensis* for Strategic Supplementation of Pre-Weaned Calves in the Peruvian Amazon

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In the region of Pucallpa, in the Peruvian Amazon, milk price is very high due to a captive market of fresh milk. Pre-weaned calves usually consume between 15%-20% of milk production from dam (residual milk). Therefore, developing a feeding alternative to partially substitute the milk consumed by pre-weaned calves with a high quality legume could have a great impact on the income of smallholders because they could sell more milk and improve their cash flow.

Materials and Methods

The following treatments were evaluated: T1, access of calves to native grass pastures during 8 hours/day, together with dam, and the remaining 16 hours in a pasture of *Stylosanthes guianensis* + residual milk; T2, access of calves to native grass pastures 24 hours/day, without the presence of the dam + residual milk + concentrates; and T3, control (access to native grass pasture 24 hours/day + residual milk).

Results

Table 1 presents trial results. Average daily weight gain of calves grazing stylo pastures were similar those obtained in the traditional pasture management system, but milk sales increased by 23% (0.89 kg additional milk/cow per day). This was reflected in a 25% increase in income. The treatment with sylo + concentrate presented similar milk sales to those of the treatment without concentrate, but higher daily weight gains. However, the variable cost was also higher, resulting in similar total net incomes as when only stylo was used.

Conclusions

This improved feeding alternative can have significant impact on the quality of life of small farmers. Stylo can be used to replace concentrates and thus increases cash flow and income, as well as milk productivity without sacrificing a reduction in weight gain of pre-weaned calves.

Table 1. Average volume of milk sold/cow per day, liveweight increase of calves, and cash value of milk and beef per treatment (Pucallpa, Peru).

Item	Treatments		
	Stylo	Stylo + concentrate	Check
Milk sold/cow per day (kg)	4.73	4.71	3.84
Milk price (US$/kg)	0.31	0.31	0.31
Daily weight increase (LW, g/calf)	540	760	530
Beef price (US$/kg)	1.03	1.03	1.03
Income from sale of beef (US$/calf per day)	0.56	0.78	0.55
Total value of production (US$/cow-calf per day)	2.03	2.24	1.74
Variable cost (US$/cow-calf per day)	0.58	0.80	0.58
Net income (US$/cow-calf per day)	1.45	1.44	1.16

Use of *Stylosanthes guianensis* with Pre-Weaned Calves in Dual-Purpose Production Systems in the Forest Margins of Colombia

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The main outputs of dual-purpose cattle production systems are (a) milk and (b) weaned calves for fattening. Under traditional management, farmers usually prefer to sell as much milk as possible to improve their cash flow, but, as a result of this practice, calf growth is slow and mortality rates high. Therefore, the development of feeding systems that allow farmers to obtain more milk for sale and increase the number of pre-weaned calves with adequate weight is a priority in this type of systems.

The use of *Stylosanthes guianensis* (stylo) for grazing pre-weaned calves has been tested in Pucallpa, Peru. (See information presented in this document.) Results indicate that with this alternative farmers can sell almost one more liter of milk/cow per day and still maintain adequate calf growth, which has important economic implications. This study aimed to validate the results obtained in Pucallpa, using pre-weaned calves. The study was conducted at the experiment station of the Colombian Corporation for Agricultural Research (CORPOICA, its Spanish acronym) in Macagual (Caqueta, Colombia).

Materials and Methods

Two groups of six calves each, aged 1 to 3 months, were used. One group of calves had access to a 2-ha paddock of stylo after each milking and also received residual milk. The six calves in the control treatment received milk equivalent to one-fourth of the udder at milking and had access to a grass pasture after milking. In all cases calves remained with their dam for 3 to 4 hours after milking, before accessing the grass or legume pasture, depending on the treatment.

Results

The amount of milk for sale that resulted from the use of stylo for pre-weaned calves was 21% higher than that recorded with cows that had calves managed in the traditional systems (Table 1). In addition, daily liveweight gain of calves with access to legume was 30% higher than that of the control group during the 90 days of the experiment.

Table 1. Volume of milk for sale and growth of pre-weaned calves with and without access to *Stylosanthes guianensis* in Caquetá, Colombian Amazons.

Parameter	Treatment	
	Control	*Stylosanthes guianensis*
Milk for sale (kg/cow per day)	3.3	4.0
Liveweight gain of pre-weaned calves (g/day)	297	389

Conclusions

The results of this study agree with those obtained on small dairy farms of Pucallpa, Peru. This technology could be very attractive to small dairy producers given that the establishment cost of this legume is less than that of other alternatives based on legume-grass associations. Furthermore, cash flow increases because of the higher sale of milk, without affecting calf liveweight gain.

In addition, this technology could form part of a crop-pasture rotation system to improve soil fertility, thus eliminating the need to fallow land.

Activity 2.3. Integration of information using ruminant and feed system models

Highlights

- Simulation models are useful tools to reduce research costs, predict nutritional deficiencies, and facilitate decision-making regarding research priorities in the area of animal nutrition.

Decision Tools to Overcome Nutrition Constraints in Dual-Purpose Cattle in Agro-Silvopastoral Systems

Net Carbohydrate and Protein System Model

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The Cornell Net Carbohydrate and Protein System (CNCPS) model was developed to predict the nutrient requirements of cattle and feed utilization by different types of animals with diverse environmental and management conditions. It is a structure that was designed to integrate and apply nutritional knowledge to:

- Solve feeding problems and reduce feed cost/production unit
- Set research priorities
- Design sensitive experiments
- Interpret experimental results
- Teach the application of biological principles through the integration of knowledge, and
- Minimize nutrient excretion into the environment per unit of product produced.

The CNCPS simulates the effects of nutrient intake, ruminal fermentation, intestinal digestion, absorption, and metabolism on nutrient utilization and cattle performance. Specific uses of the model are to:

- Predict the effects of feed composition and quantity on cattle performance
- Predict the effects of digestive and metabolic modifiers on cattle performance
- Evaluate and balance rations for the host animal and rumen bacteria
- Adjust cattle requirements and estimates of performance for different environmental conditions, and
- Simulate and predict the effects of gastrointestinal parameters on feed utilization

Thus, this model predicts nutrient requirements and nutrient pool sizes interacting with changing diet composition available to animals.

Application of the Model to Research Results at the Quilichao Station

Data were collected from several trials with crossbred cows grazing *Brachiaria decumbens* at three stocking rates (2, 3, and 4 AU/ha) and supplemented with sugarcane and varying levels of *Cratylia argentea*.

Chemical composition included NDF, CP, lignin, IVDMD, and DM for *B. decumbens*, sugarcane, and *Cratylia* for all trials. However, it was not possible to perform two important analyses that are also required by the model: solubility of protein (solP) and non-protein nitrogen (NPN). Thus, without these values it was not possible to calculate the protein and carbohydrate fractions. As an alternative, the values of solP and NPN for *B. decumbens* generated by a PhD student at Cornell for the gulf coast of Mexico were used in order to run the model as well as those for *Gliricidia sepium* (to emulate *Cratylia*) and for sugarcane available in literature.

Other data from Avila (1999) included environmental and management variables. Tables 1 to 3 include composition of diets, forage consumption and availability, and actual milk yields vs. those predicted by the model.

Table 1. Chemical composition of *Brachiaria decumbens*, sugarcane, and *Cratylia argentea* for the different trials at Quilichao, Colombia.

Composition	*Brachiaria decumbens*	Sugarcane	*Cratylia argentea*
Intermediate stocking rate (3 AU/ha)			
Dry matter (%)	35.0	30.5	33.5
Crude protein (%)	4.4	2.1	22.4
Neutral detergent fiber (%)	70.4	43.1	66.4
Lignin (%)	3.4	5.3	17.4
TDN (%)	52.0	66.1	48.7
Low and high stocking rate (2 and 4 AU/ha)			
Dry matter (%)	39.0	27.1	35.5
Crude protein (%)	3.7	2.1	20.4
Neutral detergent fiber (%)	69.0	43.1	63.4
Lignin (%)	3.2	5.3	16.1
TDN (%)	54.0	68.6	50.2

The model predicts expected milk yield from three different sources: from metabolizable energy (ME), from protein (P), and from amino acids availability (AA). However, the discussion will be centered on the results obtained from the first two sources because there was no information on the AA composition of the forages obtained from Quilichao nor was information available from the tropical forages library.

Table 2. Consumption of sugarcane and *Cratylia* and predicted intake of *Brachiaria decumbens* for the different trials at Quilichao, Colombia.

Trial[a]	Sugarcane	*Cratylia*	*Brachiaria decumbens*	Total	DM (% LW)
ISR + sugarcane	4.43	0	5.04	9.47	2.12
ISR + 75% sugarcane + 25% legume	2.64	1.16	5.81	9.61	2.15
ISR + 50% sugarcane + 50% legume	1.48	2.28	5.83	9.59	2.15
ISR + 25% sugarcane + 75% legume	0.45	4.16	5.03	9.64	2.16
LSR + sugarcane	2.00	0	7.48	9.48	2.30
LSR + sugarcane + legume	2.92	0.62	6.02	9.56	2.32
HSR + sugarcane	2.00	0	6.96	8.96	2.17
HSR + sugarcane + legume	2.92	0.70	5.60	9.22	2.24

a. ISR = intermediate stocking rate; LSR = low stocking rate; and HSR = high stocking rate.

As can be observed, the CNCPS model predicted the observed milk yields in both the low and high stocking rate trials, but failed to predict the observed milk yields for the intermediate stocking rate trials. This underprediction came from both the energy and protein portions, but the bias was larger in predicting milk yields using the protein portion.

The probable cause of the low prediction of milk yields for the intermediate stocking rate using the protein portion is the indigestible dry matter which causes low microbial growth, due to high levels of NDF from both *B. decumbens* (69%-70%) and *C. argentea* (63%-66%). Based on Dr. Alice Pell's comments, the high lignin content found in *Cratylia* could be the reason why the CNCPS model underpredicted observed milk yield. Based on Pell's experience, lignin content of *Cratylia* leaves and stems should have been around 7%-8% but not the 16%-17% as found in the Quilichao work. The secondary compounds may be confounded with lignin, masking the overall effect of diet.

Table 3. Actual and predicted milk yield using the CNCPS model for the different trials at Quilichao, Colombia.

Trial	Predicted milk yield	Actual milk yield	
		Energy	Protein
Intermediate stocking rate (3 AU/ha)			
+ Sugarcane	6.0	4.9	1.4
+ 75% sugarcane + 25% legume	6.5	6.5	7.4
+ 50% sugarcane + 50% legume	6.4	4.5	5.1
+ 25% sugarcane + 75% legume	6.6	1.9	3.1
Low stocking rate (2 AU/ha)			
+ Sugarcane	7.9	7.3	7.9
+ Sugarcane + legume	8.2	8.1	8.1
High stocking rate (4 AU/ha)			
+ Sugarcane	6.1	6.4	6.3
+ Sugarcane + legume	7.0	7.5	8.0

Based on the Quilichao results, several hypotheses can be drawn:

- Cows were selecting *B. decumbens* with a higher CP content than actual lab results.
- Digestion rates for carbohydrate and protein fractions used were wrong.
- Information about the pool sizes is inadequate.

In addition, Table 4 presents the level of urea nitrogen found in milk (MUN) as well as the level predicted by the model. The difference could be due to the soluble protein level in the diet, which was higher than the CNCPS prediction.

Because of the slow digestion rates associated with the B3 protein fraction, the CNCPS predicts that the neutral detergent insoluble protein (NDIP) makes little contribution to the rumen N pool. However, the NDIP contribution of tropical grasses to rumen N balance may be higher than that predicted by the CNCPS model. Thus, hypotheses (2) and (3) are probably valid.

Increasing the CP content in the diet does not increase the protein available for milk yields in the same proportion because both the *B. decumbens* and the *Cratylia* diets are energy-deficient. However, the model was very sensible when the degradation rate of fiber (B2 carbohydrate fraction) was changed.

Table 4. Level of urea nitrogen found in milk (MUN) and MUN levels predicted by the CNCPS model for the various trials conducted in Quilichao, Colombia.

Trial	MUN observed	MUN predicted
Intermediate stocking rate (3 AU/ha)		
+ Sugarcane	10	3
+ 75% sugarcane + 25% legume	11	3
+ 50% sugarcane + 50% legume	14	7
+ 25% sugarcane + 75% legume	17	11
Low stocking rate (2 AU/ha)		
+ Sugarcane	8	0
+ Sugarcane + legume	12	0
High stocking rate (4 AU/ha)		
+ Sugarcane	6	0
+ Sugarcane + legume	12	1

To better understand why the model is not adequately predicting the results of intermediate stocking rate trials, we should have the following additional information: (1) chemical analysis of feed refused (sugarcane + *Cratylia*) during trials to better predict nutrient pool sizes consumed; (2) body weights at weekly intervals for all trials and treatments to adjust for average tissue mobilized or deposited; (3) biomass availability of *B. decumbens* after grazing (it was only measured at the beginning of grazing) to estimate growth; (4) estimate of pasture growth by taking forage samples at 2-week intervals, thus simulating cow grazing; (5) weekly milk yield and composition; and (6) body condition of animals.

Usefulness of the CNCPS Model

The Tropileche Consortium can benefit from a close collaboration with the University of Cornell by developing a broad database on tropical forages and by calibrating the model for tropical conditions. Potential benefits of the CNCPS for Tropileche include:

- This tool may help joint efforts to identify alternatives with potential to increase animal productivity by identifying nutritional constraints, for example alternative diets.
- It is the basis to evaluate on-farm production systems and propose alternatives to select diets.
- It compliments the CIAT farm-level model developed by R.D. Estrada to conduct *ex-ante* and *ex-post* analysis at the farm and watershed levels.
- It increases Tropileche's menu of options to support and complement the activities of partners and producer organizations, which could finance forage research.
- High return on investment because Tropileche will invest marginally to complement more than 10 years of research to develop the CNCPS at its current state.

Activity 2.4. Workshops and meetings to analyze and plan research activities

Highlights

- Workshops among Consortium partners facilitate coordination, increase the efficiency of research, reduce risks associated with duplication of efforts, and facilitate the establishment of research priorities for the short- and medium-term.

Annual Meeting
February 1998, Costa Rica

Federico Holmann, Carlos Lascano, and Alberto Ramírez
CIAT, Colombia

In February 1998, the Tropileche Consortium held a work meeting with all its partners in Costa Rica to: (a) present the 1997 activity reports for benchmark sites (Costa Rica and Peru) and extrapolation sites (Nicaragua and Honduras); (b) define new activities for 1998; (c) monitor in the field the research carried out by Tropileche-Costa Rica and confront producers on the benefits of the new forage alternatives being evaluated; (d) assess the need for strategic and participatory research as related to demand; and (e) analyze new forms of collaboration with other national institutions in Costa Rica and elsewhere in the region.

The workshop was attended by 21 researchers from Peru, Colombia, Costa Rica, Nicaragua, Honduras, and the United States participating in the Tropileche Consortium.

Annual Workshop
June 1999, Peru

Federico Holmann, Carlos Lascano, Peter Kerridge and Alberto Ramirez
CIAT, Colombia.

The Tropileche Consortium held a workshop to plan and discuss its present and future activities in South America from 27 June to 2 July, 1999, in Moyobamba, Peru. The workshop aimed to: (a) present the research achievements obtained by the Consortium in Peru and pose future research needs; (b) define new activities to be conducted in Peru for 1999-; (c) participate in a field visit to understand and identify opportunities and needs of animal production systems in the Alto Mayo region of the Peruvian Amazon; (d) review strategic and participatory research based on needs and constraints; and (e) analyze and discuss new forms of collaboration with other institutions in other countries of South America, especially Ecuador, Bolivia, and Brazil.

Invited participants included 22 researchers from Peru, Colombia, Ecuador, Bolivia, and Brazil.

Regional Consultation Meeting
October 1999, Costa Rica

Federico Holmann, Pedro Argel, Carlos Lascano, and Alberto Ramírez
CIAT, Colombia

A regional consultation meeting was held in Atenas, Costa Rica, to plan future activities of Phase II of the Consortium in Central America and the Caribbean. The objectives of the regional consultation were to: (a) present the status of Consortium activities and achievements to date; (b) present and discuss opportunities to improve the dual-purpose production systems of each of the six countries that will participate in Phase II of Tropileche; (c) participate in a field visit to observe and discuss the technologies being promoted among producers; (d) develop profiles of research proposals for Central America and the Caribbean and for each one of the six participating countries; and (e) identify potential sources of funding.

A common vision of the future of regional production systems was developed at the regional consultation meeting, and specific activities to be carried out by each country, according to its specific priorities, were defined. There were 29 participants at the consultation meeting, including researchers, producers, and milk plant processing representatives from Costa Rica, Jamaica, Honduras, Nicaragua, Panama, and Dominican Republic.

RESEARCH RESULTS

Component 3. Usefulness of New Forage Systems

Activity 3.1. Diagnosis and economic characterization of land use at benchmark sites

Highlights

- Ex-ante analysis of improved technologies is useful to identify constraints to potential adoption of new technologies by local producers.

- Ex-post analysis of new technologies is useful to determine the economic impact as a result of the adoption process.

- There is a high demand for new improved forage-based alternatives to intensify milk production in the Alto Mayo region of the Peruvian Amazon.

- The entry point to achieve greatest economic impact on small dual-purpose farms, located in the dry subtropics, is through the establishment of shrub legumes with sugarcane.

- In Central America, the milk market for small artisan rural cheese factories has a higher demand in the dry season than during the rainy season.

- Small artisan rural cheese factories in Central America are willing to pay a higher price for milk of better hygienic quality.

Ex-Ante Analysis of New Forage Alternatives on Dual-Purpose Cattle Farms in Peru, Costa Rica, and Nicaragua

Federico Holmann
CIAT-ILRI, Colombia

One of the objectives of the Tropileche Consortium is to develop new feeding alternatives based on improved grasses and legumes. To achieve this, new germplasm generated at CIAT is tested and validated with the participation of producers at different benchmark sites. In addition, *ex-ante* economic analyses are also performed to estimate the potential impact of these new technologies and possible constraints to their adoption.

The objective of this study was to carry out an ex-ante economic evaluation of new forage alternatives available to producers in the lowland tropics of Latin America, using as case studies the collaborating producers of the Tropileche Consortium in the forest margins of Pucallpa (Peru) and the hillsides of the dry tropics in Esparza (Costa Rica) and Esquipulas (Nicaragua).

Materials and Methods

Data for this study was obtained through direct interviews with each collaborating producer of the Tropileche Consortium at benchmark sites to understand their production systems, use of resources, inputs and product prices, technologies utilized, as well as information about the main characteristics of the watersheds where farms were located. For this analysis a CIAT-developed linear programming farm model was used. The model, based on an electronic spreadsheet, maximizes income.

Results

Table 1 shows several indicators for herds on dual-purpose cattle farms in Peru, Costa Rica, and Nicaragua. Larger herds were found in Costa Rica (47 cows and 72 AU), followed by Peru (31 cows and 50 AU) and Nicaragua (29 cows and 48 AU). Milk production was higher in Costa Rica (5.0 kg/cow per day) and Nicaragua (3.7 kg/cow per day) and lower in Peru (3.0 kg/cow per day). These differences in milk production with Peru can be attributed to (a) milk market restrictions and not to differences in animal genotype, and (b) the low percentage of milking cows found in Peru (42%) compared with Costa Rica (60%) and Nicaragua (58%).

Table 1. Averages of livestock inventory, milk production, and land use in dual-purpose cattle farms in Peru, Costa Rica, and Nicaragua.

Variable	Peru (n=9)	Costa Rica (n=7)	Nicaragua (n=4)
Livestock inventory (no.)			
Milking cows	10.6	28.0	16.9
Dry cows	20.1	19.3	12.0
Heifers	21.9	16.1	14.5
Calves	15.7	35.1	15.3
Bulls	1.3	2.0	1.3
Total animal units (AU)[a]	49.8	71.7	45.3
Total milk production/cow (kg)	32.1	139.9	62.5
Milk production/cow (kg)	3.0	5.0	3.7
Milking cows (%)	41.5	60.1	58.5
Land use (ha)			
Native pasture	48.3	69.1	37.5
Improved pasture	8.4	8.7	12.2
Agriculture	1.5	4.6	0.7
Forest/fallow	17.7	9.1	2.3
Total	75.9	91.6	52.7
Area under improved pastures (%)	14.8	11.2	24.5
Stocking rate (AU/ha)	0.88	0.92	0.91

[a] Cows = 1.0, heifers = 0.7, female calves = 0.3, and bulls = 1.3.

Most of the farm area is in pastureland, ranging from 75% in Peru to 95% in Nicaragua. The highest forest area/farm ratio was found in Peru (23%) while in Nicaragua this ratio was very low (4%). The area dedicated to agriculture in Peru and Nicaragua is small (0.7-1.5 ha/farm) and limited to subsistence crops (rice, beans, maize) while in Costa Rica this area is larger and more diversified (4.6 ha including rice, maize, beans, sugarcane, and fruit trees such as mango, cashew, and melon).

Most of the area under pastures is covered with “naturalized” species, such as *Hyparrhenia rufa* in Costa Rica and Nicaragua; a small percentage is covered with improved pastures (11% in Costa Rica, 15% in Peru, and 24% in Nicaragua) in different states of degradation. No pasture rehabilitation measures are applied, resulting in a low and similar stocking rate for all countries: 0.9 AU/ha.

Resource prices and capital investment. Table 2 shows resource prices and capital invested in dual-purpose systems in each country. The farmgate price of milk differs broadly among countries, ranging from US$0.22/kg in Esquipulas, Nicaragua, to US$0.32/kg in Pucallpa, Peru. The price in Costa Rica is intermediate between both the above prices: US$0.28/kg. The milk price received in Peru and Nicaragua is for raw milk while the price received in Costa Rica is for milk cooled to 5 ˚C on the farm, which makes it a better quality product.

Table 2. Resource prices and capital invested in dual-purpose farms in Peru, Costa Rica, and Nicaragua.

Variable	Peru (n=9)	Costa Rica (n=7)	Nicaragua (n=4)
Prices (US$)			
Milk (/kg)	0.32	0.28	0.22
Beef (/kg cull cows)	0.60	0.60	0.50
Labor (/day)[a]	4.40	8.80	1.75
Land (/ha)	200	2,364	347
Pasture rental (/cow per month)	3.00	4.30	3.00
Cow (/unit)	500	550	350
Heifer (/unit)	450	500	250
Weaned calf (/unit)	150	170	100
Bull (/unit)	700	700	600
Establishment of improved grass (/ha)	250	270	225
Establishment of *Arachis* with grass (/ha)	340	370	310
Establishment of *Stylosanthes* (/ha)	150	165	150
Establishment of *Cratylia* (/ha)	400	420	390
Establishment of sugarcane (/ha)	--	550	500
Invested capital (US$/farm)			
Land	15,244	216,522	18,287
Livestock	29,561	42,260	18,538
Shed, corral, and equipment	2,000	12,896	2,125
Improved pastures[b]	1,050	1,175	1,372
Fences[c]	4,752	6,822	4,597
Total	53,147	279,675	44,919

a. Includes social benefits estimated at 24% for Peru, 43% for Costa Rica, and 17% for Nicaragua.
b. Invested capital is estimated at 50% of establishment cost multiplied by the area under improved pastures on each farm.
c. An average of 5280 lineal meters for the farms in Pucallpa, 7580 lineal meters for farms in Costa Rica, and 5108 lineal meters for the farms in Nicaragua, with an average investment of US$$0.90/lineal meter with four strands of wire separated by posts spaced every 3 m.

The price of beef (as culled cows) was similar in Peru and Costa Rica (US$0.60/kg LW), but lower in Nicaragua (US$0.50/kg LW). However, the price of the animals was higher in Costa Rica, followed by Peru. Nicaragua had the lowest prices for beef and live animals for all categories.

The labor cost also differs dramatically among countries, ranging from US$1.75/day in Nicaragua to US$8.80/day in Costa Rica, including social benefits. These differences in labor cost affect the establishment cost of forage alternatives most, which are higher in Costa Rica and lower in Nicaragua.

Similarly, the commercial value of land also contrasted, ranging from US$200/ha in Pucallpa, Peru, to US$2,364/ha in Esparza, Costa Rica. The main reason for this contrast lies in the high level of public infrastructure and proximity to markets found in Costa Rica, as well as its long social and economic stability compared with Pucallpa (Peru) or Esquipulas (Nicaragua).

All factors indicated above contribute to a higher capital investment per farm in Costa Rica, with a commercial value of US$280,000/farm, compared with an average value of US$53,000/farm in Peru and US$45,000/farm in Nicaragua. Of these figures, land and livestock are the main investment in all countries. Therefore, the value of land accounts for 77% of the capital invested in Costa Rica, 44% in Nicaragua, and 28% in Peru, while livestock represents 15% in Costa Rica, 41% in Nicaragua, and 56% in Peru.

Production costs and income. Table 3 presents an estimate of direct production costs (variable + cash costs) during 1997, gross income, net cash flow, and current profitability on invested capital. Labor cost is the most important production cost in Peru (43%) and Costa Rica (63%), and the second most important in Nicaragua (32%). This category includes family labor valued as minimum wage. The second most important category is supplementation costs, except in Nicaragua, where it was the most important cost.

Total production cost of milk differed significantly in the three countries, ranging from US$0.20/kg in Esquipulas (Nicaragua) to US$0.23/kg in Esparza (Costa Rica) to US$0.29/kg in Pucallpa (Peru). The principal reason for the low production cost in Nicaragua is because labor cost is 5 times lower than in Costa Rica and 2.5 times lower than in Peru.

Table 3. Direct production costs, gross income, net cash flow, and family labor retribution in dual-purpose systems in Peru, Costa Rica, and Nicaragua.

Variable	Peru (n=9)	Costa Rica (n=7)	Nicaragua (n=4)
Direct production cost (US$/farm per year)			
Hired labor	257	5,586	1,155
Family labor	1,606	3,212	630
Total permanent labor (no./farm)	1.16	2.74	2.83
Animal supplementation	683	2,848	2,205
Animal health	784	224	390
Maintenance infrastructure & equipment	727	1,617	817
Others	318	549	427
Total	4,375	14,036	5,624
Cost/kg of milk	0.29	0.23	0.20
Cost of labor as % of total	43	63	32
Gross income (US$/farm per year)	6,018	17,856	6,759
Milk-derived income	3,643	13,572	5,019
Sale of culled cows	970	1,490	760
Sale of calves	1,405	2,794	980
Net cash flow			
US$/farm per year	1,643	3,820	1,135
US$/ha per year	29	49	23
US$/cow per year	54	81	39
Retribution to family labor (US$/day)	8.90	19.27	4.83
Number of times minimum wage	2.02	2.19	2.76
Annual profitability on invested capital (%)	2.87	1.37	2.53

Production costs in Pucallpa, Peru, are high and above the international price of milk (US$2,000/t, equivalent to 130 g of powdered milk/liter of fluid milk, or US$0.26/kg fluid milk), mainly because of the low milk yields/cow (3.0 kg/cow per day) and the small proportion of milking cows (41.5%) regarding its counterparts in Costa Rica and Nicaragua.

Regarding gross sales, most come from milk (60% in Peru, 76% in Costa Rica, and 74% in Nicaragua). The rest of income is represented by the sale of weaned calves and culled cows.

Estimated monthly family income was US$270 for Pucallpa (Peru), US$586 for Esparza (Costa Rica), and US$147 for Nicaragua. However, this income was approximately double the minimum wage in Peru and Costa Rica, but almost 3 times more that in Nicaragua.

The profitability on invested capital during 1997 was very low in Costa Rica (1.37%), followed by Nicaragua (2.53%), and Peru (2.87%). The reason why Costa Rica obtained the least profitability despite having the highest family income and labor retribution was because the farms in Costa Rica have a high commercial value (US$280,000/farm) due to high land values, which is not the case for Peru or Nicaragua.

***Ex-ante* analysis for Costa Rica.** Figure 1 shows the production cost/kg milk for the different forage options. In Esparza (Costa Rica), the production cost using traditional pasture (*Hyparrhenia rufa*) makes it necessary for producers to supplement their milking herd during the 5-month dry season. With an average production of 1,350 kg/lactation, milk production costs were US$0.31/kg while the milk price received was US$0.28/kg. With the sale of weaned calves, an equilibrium was reached with a salary similar to the minimum wage.

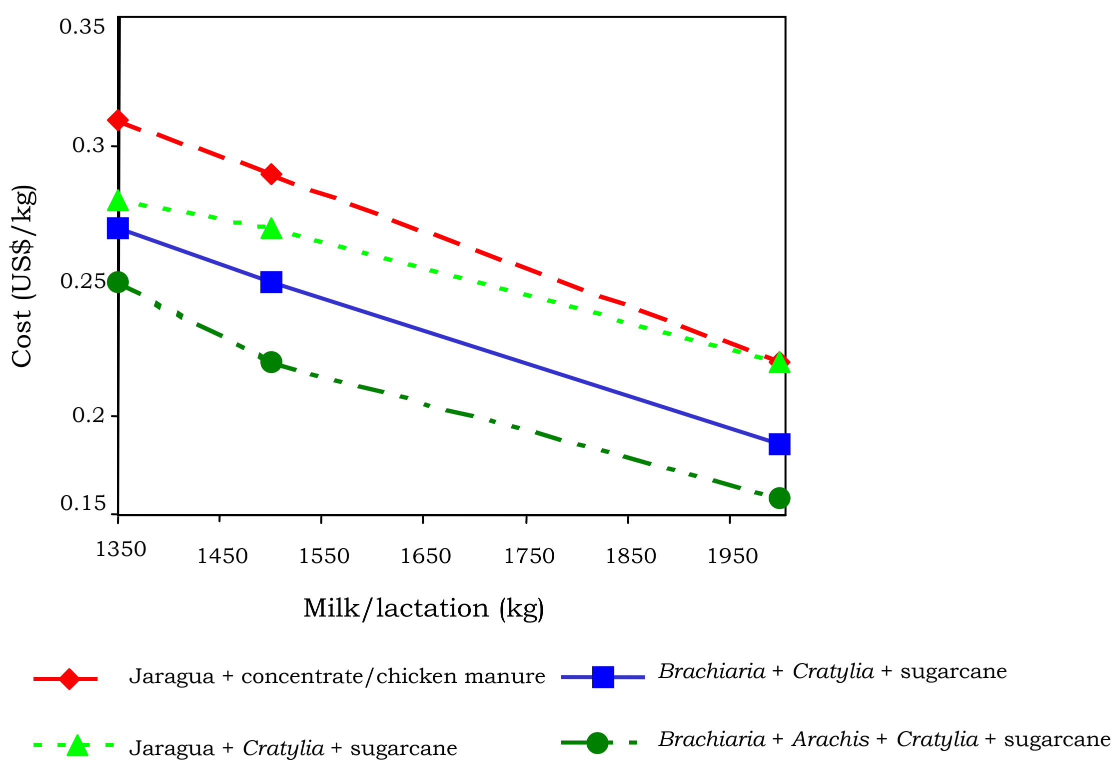

Figure 1. Milk production costs of different forage feeding alternatives in Costa Rica, assuming the same herd size.

Production costs decreased as productivity increased. Therefore, going from a lactation producing 1,350 kg (5.0 kg/cow per day) to 1,500 kg (5.55 kg/cow per day) reduced the costs/kg from US$0.31 to US$0.29. With a lactation producing 2,000 kg, milk production costs decreased to US$0.23/kg, with cows grazing on *H. rufa* pastures and receiving supplementation year-round of chicken manure and molasses to satisfy those nutritional requirements that *H. rufa* cannot satisfy.

***Cratylia* with sugarcane in Costa Rica.** With this forage option it is possible to completely eliminate the need to purchase feed concentrates, molasses, or chicken manure during the dry period. This option is capable of maintaining the production even when lactating cows are producing 2,000 kg/lactation (7.4 kg/day). The production cost/kg of milk is reduced by 13% compared with the current feeding system and 9% less with production levels of 1,500 kg/lactation. The investment required to implement this option in a farm with an average herd of 47 cows in Esparza (Costa Rica) costs around US$6,000, which includes the establishment of 8.9 ha of *Cratylia*, 1.8 ha of sugarcane and the purchase of a cane-chopper.

Figure 2 shows the real interest rate that could be paid for this investment, depending on the productivity per cow, assuming that the producer allocates 50% of the marginal income obtained as a result of implementing this forage alternative. The real interest rate in Costa Rica during the study was set at 13% (24% nominal interest minus 11% inflation rate) and the available credit was for a 5-year term with 1 year of grace. Under this situation, it was not feasible to pay this credit unless cows achieved a production of 2,000 kg/lactation. With productivities of 1,500 kg/lactation, it would have been possible to pay this credit if real interest rates had been lower (5%-10%) and longer payback time periods (close to 10 years).

This situation should be analyzed for purposes of livestock policy and competitiveness. In an economic scenario of open markets operating without subsidies, producers should have the option to obtain credits with real interest rates that reflect the opportunity cost of money at the international level, which is currently at 5%-7% in real terms, with 15 years to pay.

Other alternatives analyzed, for example, establishing *Brachiaria brizantha* with or without *Arachis pintoi*, yielded similar results. However, the establishment of these options releases fragile lands that could be put to other alternative uses, such as reforestation. Figure 3 shows the percentage of pastureland that could be released for other uses in Costa Rica.

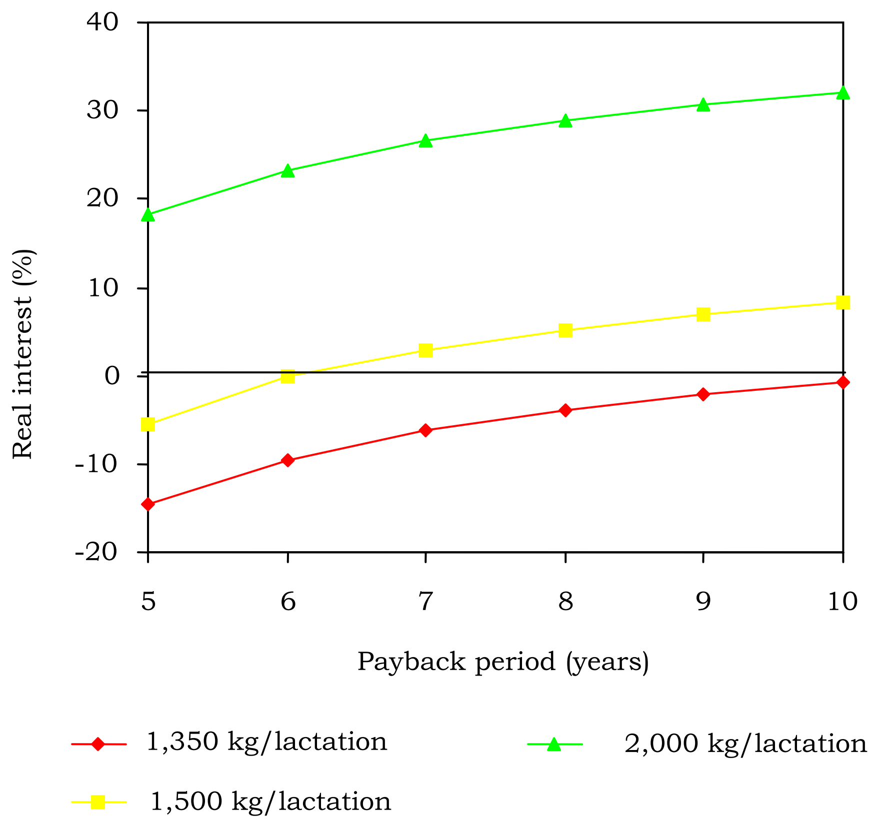

Figure 2. **Real interest rate that could be paid by adopting *Cratylia* and sugarcane, based on alternative milk yields in Costa Rica.**

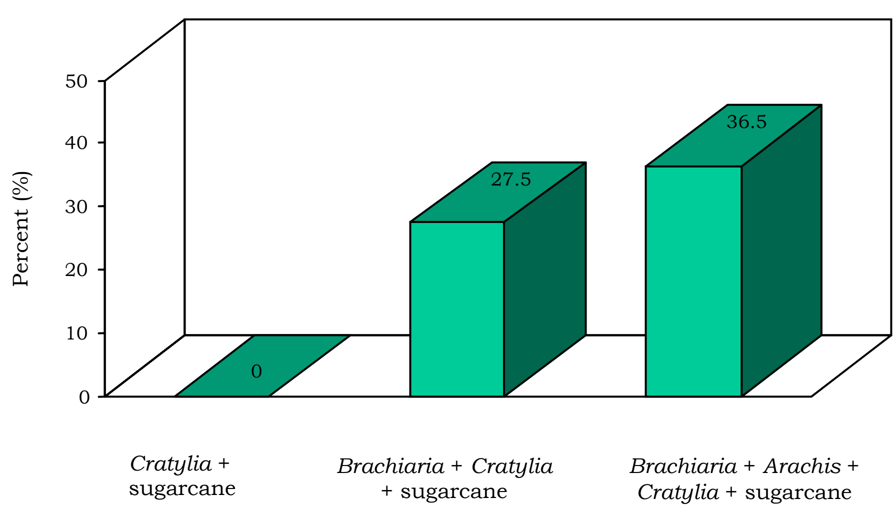

Figure 3. **Percentage of pasture area that could be allocated to alternative uses because of the adoption of improved forage alternatives, with the same herd size in Costa Rica.**

***Ex-ante* analysis for Nicaragua.** The situation in Esquipulas, Nicaragua, was similar to Costa Rica; in other words, the forage alternatives evaluated in this study significantly reduced production costs. Figure 4 shows the cost of producing milk with different forage options according to cow productivity. Under study conditions, milk production cost was US$0.26/kg while the price received was US$0.22/kg. With the income obtained from the sale of weaned male calves, producers obtain an income similar to the minimum wage.

This situation, however, could improve even with the current situation if cow productivity was higher. The quality of *H. rufa* is enough to maintain cows yielding up to 1,500 kg/lactation, without additional supplementation during the rainy season and cows yielding 2,000 kg/lactation, with energy and protein supplementation year-round, but with *H. rufa* it is possible to reduce milk production costs to US$0.20/kg based on grazing management (for example, good degree of coverage of pastures, weed control, rotation of paddocks, shade, availability of water for grazing animals, and adequate resting period).

***Cratylia* with sugarcane in Nicaragua.** With this forage option, as well as in the case of Costa Rica, it is possible to completely eliminate the need for supplementation during the dry season. The production cost was reduced by 31% (from US$0.26/kg to US$0.18/kg) with the same productivity of the existing herd. Similarly, it is possible to reduce the production cost to US$0.14/kg with a cow productivity of 1,500 kg/lactation. It is even possible to reduce it to US$0.12/kg with a cow productivity of 2,000 kg/lactation. The investment required to establish this forage option, on an average farm of 29 cows at this benchmark site, was approximately US$4,600. This investment covered the establishment of 5 ha of *Cratylia*, 2.4 ha of sugarcane, and the purchase of a cane chopper with diesel or gasoline engine because very little rural electrification infrastructure exists at this site.

Figure 5 shows the real interest rates that could be paid for this investment, depending on the productivity per cow, assuming that the producer allocates 50% of the marginal income to pay back the loan regarding the base scenario (*H. rufa* + feed concentrate). During the study, the Nicaraguan financial system offered a real interest rate of 18% for farm/livestock credits with a 5-year payback period.

In this situation and with the prevailing milk productivity at that time, it was not be possible to adopt this forage alternative because it was not economically viable. However, with productivities per cow of 1,500 kg/lactation, the payment of a credit was perfectly viable under the conditions prevailing in the country at the time of the study because it was possible to pay a real interest rate up to 22%, with a payback period of 5 years. With production levels of 2,000 kg/lactation, the situation would have been even more viable.

The MAG-WFP dairy development project in Nicaragua offers credits to small milk producers at a real interest rate of 10% with a 5-year payback period, although the allowable maximum amount is up to US$3,000/farm. This was an excellent opportunity for small producers to adopt these new improved forage-based technological alternatives, which allow them to significantly improve their competitiveness and income by reducing production costs.

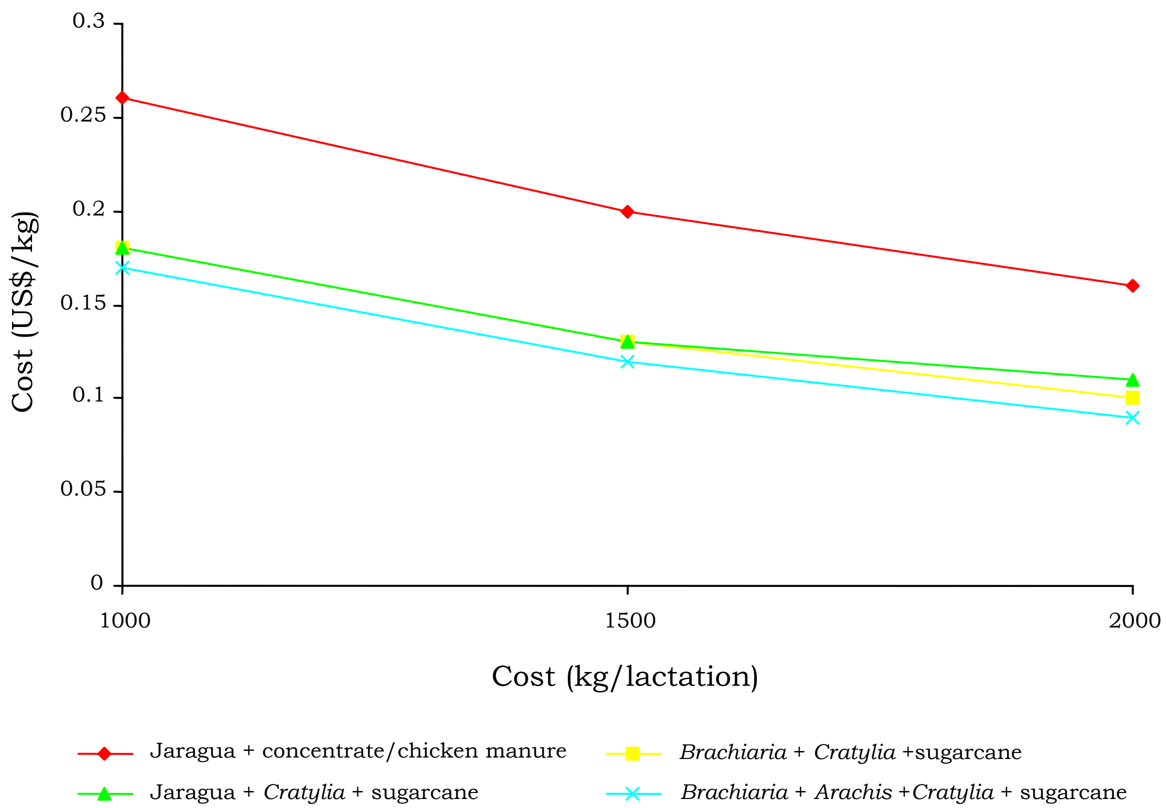

Figure 4. Milk production costs in Nicaragua, assuming the same herd size.

***Ex-ante* analysis for Peru.** The case of Pucallpa, Peru, is different from that of Costa Rica and Nicaragua. A characteristic of this region is the higher annual precipitation (2,000 mm vs 1,200 mm in Costa Rica and Nicaragua) and its more even distribution. In consequence, the dry season in Pucallpa is only 3 months long and not 6 months as in the case of Esparza (Costa Rica) and Esquipulas (Nicaragua). As a result, the climatic conditions in Pucallpa allow pastures to grow year-round.

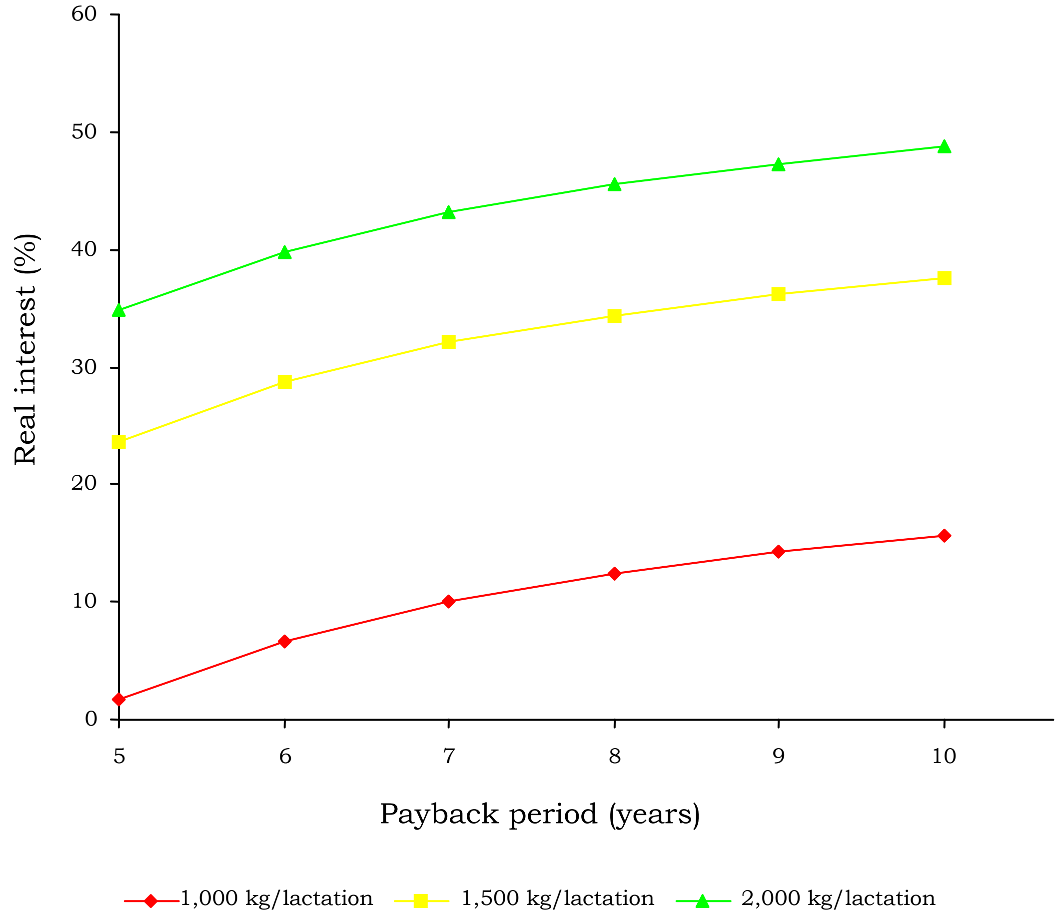

Figure 5. Real interest rate which could be paid by adopting *Cratylia* + sugarcane, based on cow productivity in Nicaragua.

Another important characteristic in Pucallpa is that the production/cow is very low (3 kg/cow per day, Table 1), especially in the dry season when it is practically nill. This characteristic can be due to several factors: (a) low genetic potential for milk production, (b) little availability of nutrients in grasses due to high pasture degradation in low fertility soils, and (c) a very limited market for raw milk.

Regarding the last factor, daily production of fresh milk in the area of Pucallpa is about 2,500 kg and the cattle inventory decreased from 82,000 heads in 1986 to 26,000 at present as a consequence of terrorist activities and cattle rustling. The city of Pucallpa, with a population of 300,000, does not have a milk processing plant. As a result, consumption of milk in Pucallpa is mostly in the form of evaporated milk imported from other cities of the country. This situation has accustomed the population to drink pasteurized milk. As a result, the market for raw milk is very small. Four of the nine producers who collaborate with the Tropileche Consortium thought that if they increased their milk production, they would have problems to market the additional milk because the market was already saturated. The other five producers sell their milk to the School Milk Program, a public-funded project that provides fluid milk to children during school hours.

Another factor that affects the potential to increase the milk market is the substitution of protein sources existing in the region. River products are a good example: the kilogram of DM of fish protein costs US$2.90 in Pucallpa, while the kg of milk protein costs US$8.80. In other words, milk protein is 303% more expensive than fish protein. Furthermore, there are other energy sources, such as cassava and rice, equivalent in dry matter and significantly less expensive than milk. As a result, the market of raw milk in Pucallpa is limited to the upper-class population and its possibilities for growth are very limited, unless a milk processing plant can be established in Pucallpa to satisfy the demand for evaporated milk that hich is now brought from Lima.

Base scenario versus alternative options in Peru. Figure 6 shows milk production costs under different forage alternatives. Unlike the results from Costa Rica and Nicaragua, the most profitable option for Pucallpa under the current situation in Peru is the base scenario found on farms. In other words, the most competitive option is to maintain the herd in native pastures and provide milking cows with a supplement of brewers' yeast during the short 3-month dry season. Brewers' yeast is a viable option because it is abundant and inexpensive (US$0.15/kg DM, 22% CP and 65% digestibility).

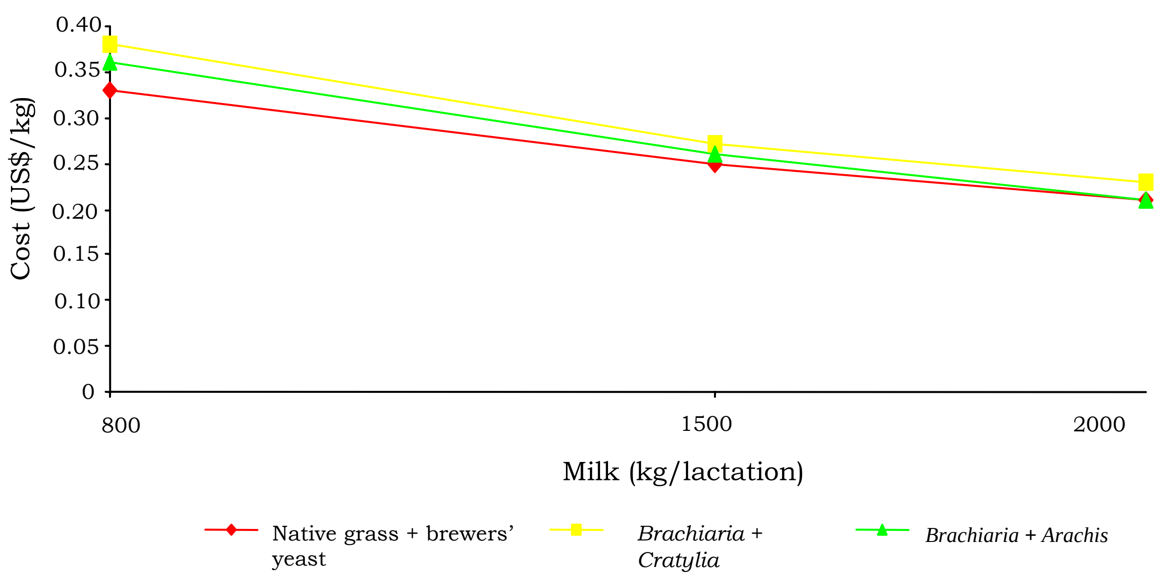

Figure 6. Milk production cost with different forage alternatives in Peru, assuming the same herd size.

With this alternative, the milk production cost was US$0.33/kg while the price received was US$0.32/kg. Therefore, the additional income from the sale of male calves increased farmers' income a little above the minimum wage and paid for variable costs.

This alternative also proved to be the most attractive, with productivities of 1,500 kg/lactation and even up to 2,000 kg/lactation. In no scenario did the forage alternatives evaluated in this study (*Brachiaria* + *Arachis* or *Brachiaria* + *Cratylia*) succeed in reducing milk production costs at levels below that of the native pastures supplemented with brewers' yeast.

Under the assumption that brewers' yeast ceases to be a viable option for supplementation, another option evaluated was maize at US$0.23/kg. For the option of *Brachiaria* with *Arachis* and/or *Cratylia* to form part of the solution, and with milk production levels of 800 kg/lactation, maize price would have to be US$0.38/kg (a 65% increase) so that the cost of producing milk equals the current alternative. Therefore it seems very unlikely that producers will adopt the alternative of *Brachiaria* with *Arachis* and/or *Cratylia* if they have brewers' yeast and/or maize at US$0.23/kg as alternatives. With milking cows producing 1,500 kg/lactation, the price of maize would have to increase 9% to equal the production cost of both alternatives evaluated.

The fundamental reason why none of the improved forage options were economically better than the current management practice of native pastures + brewers' yeast is because of the high capital investment required per milking cow. The low current proportion of milking cows induces a high depreciation rate of improved pastures per cow. In Pucallpa, the percentage of milking cows was 41% while in Costa Rica and Nicaragua this figure was close to 60%. Therefore, to invest in these new improved forage alternatives, it would be necessary to increase the percentage of milking cows in a year to a minimum of 53%, or increase the stocking rate of 0.9 AU/ha to 1.3 AU/ha by introducing more animals. In this new scenario, the evaluated forage options would form part of the solution.

From the financial viewpoint, Figure 7 presents the real interest rates that could be paid if a producer in Pucallpa invests in the establishment of *B. decumbens* associated with *A. pintoi*. Peru had the highest real interest rate of the three countries considered in this study, with 34% (44% nominal minus 10% annual inflation rate). Therefore, even if the investment in these new forage options was economically superior, the high real interest rate available in Peru did not allow producers to adopt these technologies. Therefore, in the financial scenario existing during the study, producers in Pucallpa had no option for intensification, (not even with productivities/cow of 2,000 kg/lactation and with payback periods of 10 years) because it was not possible to pay a real interest rate of 34% (the best scenario possible was 15%).

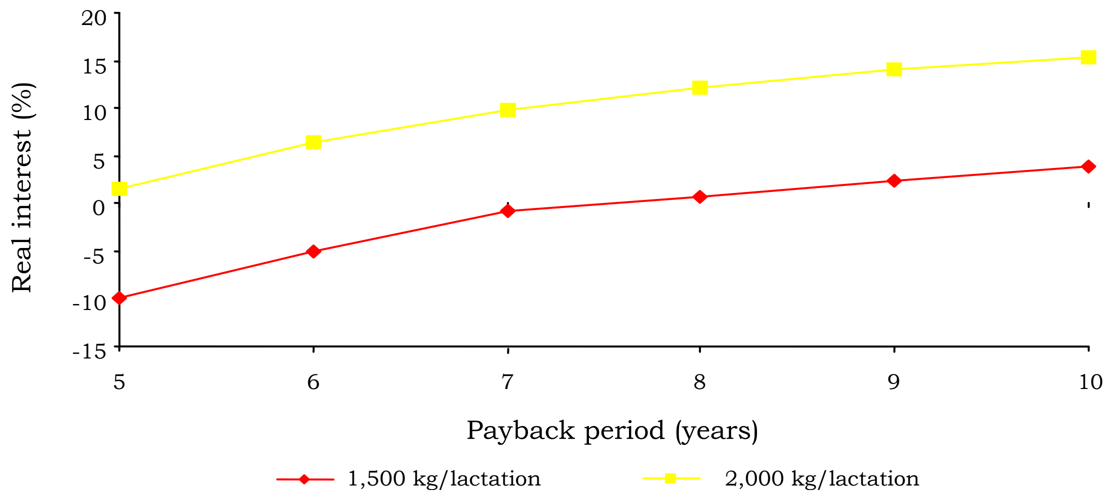

Figure 7. Real interest rate that could be paid in Peru by adopting *Brachiaria* +*Arachis* based on alternative milk yields.

However, the advantage of establishing these forage alternatives in Pucallpa is that both options successfully released significant proportions of areas currently under grazing so they could be destined to other alternative uses such as reforestation and/or conservation (Figure 8). The area released represents 35.4% in the case of *Brachiaria* + *Cratylia* (20.2 ha/farm), and 48.1% in the case of *Brachiaria* + *Arachis* (27.4 ha/farm).

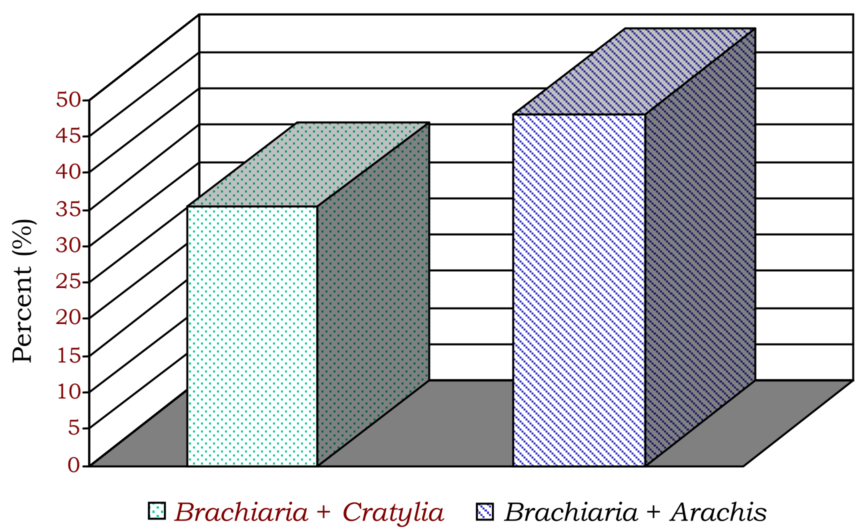

Figure 8. Percentage of pasture area that could be released for alternative uses in Pucallpa, Peru, if improved forage alternatives are adopted, with same herd size.

Early Adoption of *Arachis pintoi* in the Humid Tropics: The Case of Dual-Purpose Cattle Systems in Caqueta, Colombia

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The region of Caquetá, Colombia, is representative of the environmental and economic situation prevailing in Colombia's Amazon region. Development efforts began in this region in the early 1900s and, since then, have gone through several phases up to the implementation of complex agricultural and cattle production systems that, over time, have been progressively intensified. CIAT, together with Nestlé, has assessed the evolution of livestock systems in Caquetá regarding two topics of interest for both institutions: (1) the adoption of forage technologies and (2) the production and productivity of livestock systems.

The forage legume *Arachis pintoi*, or perennial forage peanut, is the result of a joint research effort of CIAT with collaborating institutions. This material was evaluated during several years and released in 1992 as a forage alternative. The adoption and transfer of new forage technologies are complex and time-consuming processes. The decision to adopt an improved pasture involves a considerable investment of capital not only in pasture establishment, but also in higher livestock requirements because this type of forage technology increases the stocking rate. This is a critical issue for small- and medium-scale farmers, such as those that exist in Caquetá, with little capital and limited access to financial institutions.

The present study focused on analyzing the evolution of the early adoption process of *Arachis pintoi* promoted by CIAT and Nestlé to generate relevant information that would allow possible limitations to adoption to be identified, while facilitating the design of strategies that would accelerate the adoption process.

Materials and Methods

Basic data were collected through surveys in which the universe was the group of dairy farms that supplied milk to the Nestlé plant in Caquetá. Two sampling strategies were used: (a) a random sample whose size was estimated using conventional statistical methods, and (b) an additional sample of 52 farms that were already using the new material, in view of the fact that the adoption of this technology was in an initial phase. Sufficient information was accordingly gathered regarding experiences, difficulties, and prospects of producers testing *Arachis*.

Results

Available data shows that land use patterns in Caquetá are highly dynamic when compared with the results of a study carried out in 1986 by Ramirez and Seré (1990) (Tables 1 and 2). The most relevant aspects of this comparative analysis were that (1) the relative importance of natural grasses of low productivity decreased as the use of improved pastures increased; (2) the greater diversification of the forage germplasm used decreased the relative importance of *B. decumbens* as compared with other types of *Brachiaria*; and (3) unlike 1986, mixed pastures of grasses with legumes were observed as a new forage alternative for Caquetá.

Table 1. Land use dynamics in dual-purpose farms in Caquetá, Colombia, during 1986 and 1997.

Land use	1986 survey		1997 survey	
	Area (ha)	%	Area (ha)	%
Total farm area	131	100	158	100
Total pasture area	95	73	129	82
- Natural	62	47	38	24
- Improved	33	26	91	58
Crop area	4	3	3	2
Fallow area	22	17	10	6
Forest area	9	7	16	10

Uses, knowledge, and expectations about *Arachis pintoi*. Of 226 producers interviewed, most of them (179) had heard about the existence of this new forage alternative in the region. Of this group, 171 had seen the material (76% of all producers). At the time of the interview, 68 of them (30% of total) were using *A. pintoi*. Two types of pastures with *Arachis* were identified: (1) seed banks, with an average area of 1.3 ha/farm and (2) pastures of grasses mixed with *Arachis* with an average area of 9.6 ha/farm. Fifty-seven livestock owners (82%) who were experimenting with *Arachis* used it mixed with grasses. Of a total of 68 early adopters, 21 (31%) had had problems establishing peanut. The main problems were related to low germination rate of the grass (8) and slow establishment of the peanut (7). However, the degree of satisfaction with *Arachis* performance was high and 82% of farmers said they were satisfied with the results obtained so far. The fact that more than half of the adopters (55%) have already used the legume in associated pastures is significant.

Table 2. Change in area of improved pastures in Caquetá (Colombia) during 1986 and 1997.

Species or cultivar	1986	1997	Variation (%)
Brachiaria decumbens	76.0	64.1	-11.9
Brachiaria humidicola	0.6	13.8	13.3
Echinochloa polystachya	3.8	11.9	8.1
Brachiaria brizantha	0.0	4.7	4.7
Arachis in association	0.0	2.7	2.7
Arachis alone	0.0	0.1	0.1
Brachiaria dictyoneura	0.0	1.0	1.0
Axonopus scoparius	6.2	0.7	-5.5
Other *Brachiaria*	0.0	0.3	0.3
Brachiaria ruziziensis	0.0	0.1	0.1
Hyparrhenia rufa (Puntero)	7.9	0.3	-7.6
Panicum maximum (Guinea)	2.1	0.0	-2.1
Brachiaria sp. (Pará)	1.2	0.0	-1.2
Pennisetum purpureum (elephant grass)	2.3	0.0	-2.3
Other forages	0.0	0.3	0.3
Total	100.0	100.0	0.0

Producers who have used *Arachis* have identified its capacity to increase the productivity of the associated grass as an important attribute of this new forage option. About 63% of the producers have detected one or more of the following advantages: increased stocking rate, higher milk yield and increased weight gain, enhanced competitiveness with weeds, and improved palatability for animals. Table 3 summarizes how producers rate *Arachis* based on their experiences.

About 12% of producers who have tested *Arachis* (8 of 68) are not satisfied with the results obtained. Table 4 indicates the causes of this dissatisfaction.

Adoption rate during the study. The adoption rate of *A. pintoi* in Caquetá, during the study period, expressed as the proportion of producers using this material, was close to 9.2% (16 early adopters out of a random sample of 174 producers). Based on this adoption rate, a preliminary estimate of total area planted to *A. pintoi* was about 3,000 ha in the 2,973 dairy farms supplying milk to the Nestle plant. Of this area, 2,626 ha (88%) were associations of *A. pintoi* with grasses and the rest, seed banks of the legume.

Table 3. Ranking of experiences with *Arachis pintoi* by producers in Caquetá, Colombia, in 1997.

Ranking	Producers (no.)	Percent (%)
Excellent	10	26.3
Good	19	50.0
Regular	4	10.5
Bad	1	0.6
Do not know yet	4	1.5
Total	38	100.0

Table 4. Causes of unsatisfaction from producers who have used *Arachis pintoi* in Caqueta, Colombia, in 1997.

Cause of dissatisfaction	Producers (no.)	Percent (%)
Benefits not clearly identified	4	50.0
No progress observed	2	25.0
Not consumed by cattle	1	12.0
Tends to disappear	1	12.0
Total	8	100.0

Of 68 early adopters, 58 (85%) said they were willing to expand planted areas and would increase, over the next 3 years, the area planted to *Arachis* by 11 ha/farm in year 1, by another 10 ha/farm in year 2, and 11 ha more during year 3.

Technical and economic viability of *A. pintoi*-based technology. The technology of grass-legume pastures, using *A. pintoi*, is economically attractive for the Caquetá region. Its profitability, expressed as internal rate of return, is substantially higher than that of traditional technology based on improved grass pastures alone (Table 5).

Table 5. Profitability of *Arachis pintoi* mixed with different *Brachiaria* species in Caquetá, Colombia, during 1996.

Type of pasture	Establishment cost (US$/ha)	Milk yield (kg/cow per day)	Stocking rate (AU/ha)	Internal rate of return (%)
B. decumbens	158	3	1	12.0
B. decumbens + *A pintoi*	282	3.5	1.5	19.3
B. humidicola + *A. pintoi*	337	3.5	2.0	21.8
B. dictyoneura + *A. pintoi*	368	3.5	2.0	21.1

Changing traditional technology to a grass-legume association with *Arachis* substantially increases establishment cost from US$157/ha (*B. decumbens* alone) to US$368/ha (*B. dictyoneura* + *A. pintoi*). In addition to the substantial increase in establishment cost, the increase in stocking rate also implies the need to purchase more cattle.

In view of the current situation of Colombia, where high real interest rates prevail, new, low-cost alternatives must be identified to establish improved forage alternatives.

Although the quality of commercial seed used in Caquetá is high in terms of purity and germination, its local price is high compared with neighboring countries such as Bolivia. The cost/kg of *A. pintoi* in the region ranged from US$20 to US$25/kg during the study, while that of Bolivian seed cost around US$15/kg. Despite the attributes of *A. pintoi*, its cost is substantially higher than that of other forage legumes used in the region, for example *Pueraria phaseoloides* (kudzu), *Centrosema macrocarpum*, and *Desmodium ovalifolium*, whose costs ranged between US$12 and US$15/kg.

The reduced economic activity in Colombia and the farmers' scarce knowledge of this new material affect its rate of adoption. Information on the use, management, and potential of *Arachis* should be diffused broadly to accelerate its adoption rate; seed costs must also be lowered to reduce establishment costs.

The Need for Forage Technologies in the Alto Mayo Region of the Peruvian Amazon

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CIAT (1), FUNDAAM (2), CTAR (3), and MAG-Peru (4)

Researchers from the Fundación del Alto Mayo (FUNDAAM), the Ministry of Agriculture (MAG) of Peru, the Consejo Transitorio Agropecuario Regional (CTAR), and the International Center for Tropical Agriculture (CIAT) conducted a diagnostic field survey to evaluate feeding systems for dual-purpose cattle in the Alto Mayo Region, Department of San Martin, in the Peruvian Amazon.

The study was carried out in four communities (Nuevo Cajamarca, Soritor, Habana, and Rioja), where farmers owned, on average, some 25-30 head of cattle, with 4 to 10 cows being milked at any given time throughout the year. Farm size ranged between 25 and 33 ha, of which 16-18 ha were sown to pastures. The most common species was *Brachiaria decumbens,* followed by *B. brizantha*. The milk produced in the region is mainly marketed through a processing plant that sells milk to the government for a social project providing milk to schoolchildren.

The invasion of weeds and wet-season trampling, which caused soil compaction, were the most frequent pasture management problems. Livestock was affected by parasites and diseases. In addition to livestock production, the farmers also depend on subsistence crops such as irrigated rice and coffee.

The survey indicated that the lack of improved forages was a constraint to enhanced herd productivity in the region. In the four communities surveyed, several farmers had established cut-and-carry forages, mainly elephant grass (*Pennisetum purpureum*) and king grass (*Pennisetum* sp.). These farmers had also installed improved milking and feeding stalls and infrastructure for animal feeding. Because of the low prices paid for raw milk, many producers allocated the milk produced to late-weaned calves rather than to market.

Materials and Methods

The study area was located in the piedmont region of the Peruvian Amazon region, at 1,000 masl. Average annual precipitation was 1,380 mm, with a dry season between May and August. Mean annual temperature was 22 ˚C. The survey covered 52 producers; interviews were informal, but structured around a series of themes. Data were tabulated and analyzed each day after field visits. Interview themes for the following day were modified daily based on findings of the previous day. The research team spent the last day of the intensive 4-day diagnostic survey process to draw conclusions and discuss implications for future needs of research and collaboration.

Results

Cattle numbers were determined on 18 farms in Nuevo Cajamarca and 22 farms in Soritor. On the farms in Nuevo Cajamarca, the mean herd size was 32 animals, ranging between 6 and 70. This number included 15 cows, of which nine were being milked (Table 1). The ratio of cows to herd size and milking cows to dry cows were typical of the study area.

Herd size varied. In Soritor and Nuevo Cajamarca, 30% of the producers interviewed had up to 15 head of cattle (13 on average), 53% had between 16 and 49 (31 on average), and 18% had 50 or more head (62 on average). The ratio of small-, medium-, and large-scale operations appeared be characteristic of the whole area visited. Taking Soritor (where herd size averaged 26 head) as example, producers reported, on average, 8 births (ranging between 2 and 21), 2 accidental or disease-related deaths (ranging between 0 and 10), and five sales during the year immediately before (ranging between 0 and17) (Table 1).

Table 1. Livestock inventory in Nuevo Cajamarca and Soritor (Alto Mayo, Peru).

Cattle inventory	Nuevo Cajamarca		Soritor	
	Average	Range	Average	Range
Total	32	6-70	26	5-65
Categories				
Cows	15	2-60	11	3-27
Milking cows	9	0-30	4	0-17
Bulls	1.4	0-5	1.3	0-3
Births	11	0-30	8	2-21
Deaths	1.5	0-4	2	0-10
Sales	4	0.14	5	0-17

Mean farm size ranged from 25 ha in Rioja and Soritor to 33 ha in Nuevo Cajamarca. Farm size ranged from 4 to 90 ha, with herd sizes proportional to farm size. All farmers had some land in pasture. Assuming an average area in pasture of 16-18 ha among the four communities, the mean proportions of pasture area in relation to the whole farm varied from 56% to 64% (Table 2). Stocking rates ranged from a mean 1.3 head/ha in Habana to 1.8 head/ha in Nuevo Cajamarca.

Table 2. Land use at study sites in Alto Mayo, Peru.

Land use	Nuevo Cajamarca n=18		Soritor n=22		Habana n=11		Rioja n=11	
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
Farm size	33	100	25	100	32	100	25	100
Pasture	18	100	16	100	18	100	16	100
B. decumbens	13	89	16	100	14	82	15	100
B. brizantha	1	33	2	42	3	27	0.5	18
Cut & carry	3	100	0.4	40	0.6	64	0	27
King grass	1	66	0	72	0.5	55	0	27
Elephant grass	2	78	0	0	0.14	18	0	0
Coffee	5	55	2.4	55	2	73	1	73
Lowland rice	2	28	3	21	0.6	36	2	73
Forest/fallow	2	55	6	75	11	100	3	73
Stocking rate	1.8	-	1.6	-	1.3	-	1.7	-
Chopper	-	22	-	50	-	45	-	0

In Habana, 82% of the farmers had *B. decumbens* in their pastures, while 100% of the farmers in Rioja and Soritor had pastures sown to this grass, accounting for 72%-93% of total pasture area. In Rioja, 18% of the farmers had also sown *B. brizantha* and in Soritor, 42% (Table 2).

Many farmers had also established cut-and-carry forages: 27% of farmers interviewed in Rioja and 100% of the farmers in Nuevo Cajamarca. Areas sown ranged from small plots in Rioja, Soritor, and Habana (0.5 ha on average) to 3 ha in Nuevo Cajamarca (Table 2). Varieties sown for cut-and-carry feeding were mainly king grass and elephant grass. None of the farmers in Rioja and half of those in Soritor had mechanized forage cutters.

Other main land uses were coffee, irrigated rice, annual crops, and forest or forest fallow. Between 50% and 66% of farmers in each community grew coffee on plots averaging 1 ha (in Rioja) to 5 ha (Nuevo Cajamarca).

From 21% to 73% of the farmers grew lowland rice on plots from 0.6 ha to 3 ha in size. More than half the farmers had land under forest/fallow. Habana was the most forested (11 ha/farm) (Table 2).

Animal health problems were ectoparasites such as ticks and "nuche", a skin burrowing maggot) and diseases such as mastitis and stomatitis. Treatments consisted in farmers administering prophylactic drugs.

Weed control was the pasture management problem that demanded most labor. Farmers in flatter areas suffered from soil compaction caused by pasture trampling in the wet season. Although paddocks were regularly rotated, some farmers rented additional pastureland during the rainy season to decrease pasture degradation. Additional pastureland was seldom leased during the dry season (Table 3).

Table 3. Frequent problems in the Alto Maya region of Peru and percentage of farmers identifying these problems.

Problem	Site			
	Nuevo Cajamarca	Soritor	Habana	Rioja
Livestock pests and diseases	94	95	640	100
Weeds	44	55	18	18
Compaction of pastures	22	18	55	9
Crop pests and diseases	56	23	36	45
Lack of land	23	9	18	36
Non-agricultural aspects/ others[a]	78	33	27	63

a. Low prices paid for products, land tenure, and poor water quality.

Farmers interviewed were consistent in terms of what they wanted to achieve in the future. Around half wanted to increase their areas sown to pastures, and an equal number of farmers wanted to increase and/or improve their herds. Only a few mentioned plans to decrease herd size, but planned to improve herd quality by introducing improved breeds and selection. In Nuevo Cajamarca, 50% of farmers wanted to improve their feeding/milking sheds. From 33% to 66% of farmers wanted to improve their pastures by establishing *B. brizantha* and other new forage species, including legumes (Table 4).

Table 4. Farm improvement plans in the Alto Mayo region of Peru and percentage of farmers interviewed who want changes.

Improvement plans	Site			
	Nuevo Cajamarca	Soritor	Habana	Rioja
Increase the area under pasture	50	40	45	64
Improve sheds/corrals	55	27	18	36
Improve the herd	55	59	45	64
Improve the pasture	66	59	36	55
Other	50	22	36	45

Conclusions

The main conclusions of the activities carried out by this collaborative effort between national institutions and CIAT in the Alto Mayo region of Peru were as follows:

- Local farmers managed a mixture of enterprises, changing proportions over as time determined by market variables.

- Farmers adjusted the amounts of milk sold versus the milk consumed by calves in response to prices paid for milk.

- Farmers had technically sound but expensive solutions to their problems of weeds and cattle diseases.

- A high number of farmers were in process of adopting cut-and-carry forages, improving feeding and milking sheds, and installing forage cutters. The demand for improved forages was therefore relatively high.

- Although the need for dietary protein was acknowledged, the adoption of forage legumes has been hindered by high losses in biomass due to attacks of insects and wild herbivores.

- Very little pasture degradation due to pasture trampling by animals was observed at the time of the survey, although producers mentioned that this was a production constraint in flatter areas.

Research Recommendations

Based on results and conclusions, the group recommended additional research on basic indicators, weeds, cattle pests, improved forages, and soil macro-fauna. Recommendations included the following:

- Basic indicators must be defined and monitored to better understand local dual-purpose systems and to measure future changes. The group proposed the monitoring of a sample group of dual-purpose cattle farms to record data on herd composition, birth and death rates, milk production, liveweight gain, and feeding systems.

- Research on weed control in pastures should be strengthened, especially regarding costs. Further research is needed on the effects of periodic burning, pasture rotations, stocking rates, and pasture species on weed composition and spread. Pasture species that help control weeds and that can be used in livestock/pastures associated management systems should be evaluated.

- Farmers continually invested in treatments to control parasites in animals. The factors favoring the appearance of these pests should be studied.

- FUNDAAM and the Ministry of Agriculture have conducted substantial research on forage improvement. The Ministry recently distributed seed of *C. macrocarpum, P. maximum*, and *B. brizantha* to some 200 farmers for testing and multiplication. The goal was that each farmer would be able to establish a protein bank. Forage species and varieties that not only improve animal and milk outputs, but also help suppress weeds, are resistant to drought, and are tolerant to waterlogging should also be identified. Farmers recognized the potential value of forage legumes, although they are attacked by pests and rodents. The group suggested enhanced farmer participation in the testing of a "cocktail" of forage varieties and species.

The group agreed that there is need to better understand political decisions and the market context relevant to dual-purpose livestock producers. The issues discussed included national research priorities and policies, building of roads, the "Glass of Milk" program for local school students, credit, and national policies concerning milk imports, exports, and subsidies.

Potential Benefits of New Forage Germplasm in Dual-Purpose Cattle Farms in the Dry Tropics of Costa Rica, Honduras, and Nicaragua

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Milk production in Central America and the Caribbean has grown during the 90´s at an annual rate of 4.6%, which evidences the marked dynamism of the sector (Umaña, 1998). However, even with this high growth, the region is a net importer of dairy products. These imports are growing at an annual rate of 13% due to the high demand. The region went from importing 20% of its needs in 1990 to almost 28% in 1996, equivalent to US$104 million/year (Umaña, 1998).

It is estimated that around 85% of the milk produced in the region comes from dual-purpose farms that produce milk and beef with the same herd. This type of production system is mostly found in small and medium farms where pastures are the main feeding source because they are inexpensive and abundant.

Research executed by the International Center for Tropical Agriculture (CIAT) and the International Livestock Research Institute (ILRI), carried out by the Tropileche Consortium in the subhumid areas of Costa Rica, has demonstrated that improved forages contribute to the intensification of milk production on small dairy farms by: (1) increasing milk production and stocking rate; (2) releasing areas not suitable for livestock for use as environmental reserves; and (3) reducing the demand for purchased feed inputs and thus improving the cash flow (Holmann et. al., 1999). In addition, producers outside benchmark sites have been observed to spontaneously adopt new forages, mainly in Costa Rica and Peru and to a lesser extent in Nicaragua and Honduras.

Objectives

This study aims to measure the impact of new forage germplasm on productivity and reduction of production costs, at different on-farm levels of adoption; identify the potential benefits; and determine the region's seed production needs. The study covered dual-purpose farms located in hillside areas where the Tropileche Consortium operates in the dry tropics of Costa Rica, Honduras, and Nicaragua.

Materials and Methods

Data for this study were obtained from direct interviews with 78 producers located in the dry tropics of each country to understand their systems of production, their use of resources, the prices of inputs and products, and the technologies used. In Costa Rica, 21 producers were randomly interviewed in the area of Puntarenas and Esparza in the Central Pacific region. In Honduras, 20 producers were intereviewed in the areas of Olancho, Catacamas, and Juticalpa. In Nicaragua, 37 producers were interviewed in the Muy-Muy and Esquipulas watersheds (Department of Matagalpa), where livestock production is an important activity.

A CIAT-developed linear programming simulation model was used to analyze information. This model, based on electronic sheets, maximizes on-farm income.

Productivity and Land Use

Table 1 shows the averages for livestock inventory, milk production, reproductive parameters, and land use in dual-purpose farms in Costa Rica, Honduras, and Nicaragua during the time of the study.

The largest mean herd size was found in Nicaragua (44 cows and 81 AU) followed by Honduras (42 cows and 78 AU); the smallest mean herd size was found in Costa Rica (23 cows and 36 AU). Milk yield, however, was highest in Costa Rica (6.8 kg/cow per day during the rainy season), followed by Honduras (6.6 kg/cow per day) and Nicaragua (4.2 kg/cow per day).

Reproductive and animal management parameters are similar in the three countries, with the only difference that calf and adult mortality is highest in Nicaragua.

On-farm land use differed among countries. Large parts of the farms were allocated to pastures, ranging from 77% in Honduras to 95% in Nicaragua. The highest proportion of forest was found in Costa Rica (13%) while this area was minimal in Nicaragua (3%). Small areas were allocated to agricultural crops in Costa Rica and Nicaragua (0.6 ha-1.8 ha), being much larger in Honduras (7.6 ha).

The highest percentage of pasture area under low-productivity “naturalized” species (96%) was found in Nicaragua, followed by Costa Rica (84%). The pasture area in Honduras had the highest proportion of improved varieties (69%), which explains to a great extent the high stocking rate found in Honduras (1.44 AU/ha) compared with the other two countries (0.75 AU/ha for Costa Rica and 0.99 AU/ha for Nicaragua).

Table 1. Averages of livestock inventory, milk production, reproductive parameters, and land use in dual-purpose cattle systems in Costa Rica, Honduras, and Nicaragua.

Variable	Costa Rica (n=21)	Honduras (n=20)	Nicaragua (n=37)
Rainy season			
Milking cows (no.)	16	30	33
Dry cows (no.)	7	12	11
Milk production/farm (kg/day)	109	198	139
Milk production/cow (kg/day)	6.81	6.60	4.22
Dry season			
Milking cows (no.)	16	28	23
Dry cows (no.)	7	14	21
Milk production/farm (kg/day)	66	136	77
Milk production/cow (kg/day)	4.12	4.86	3.35
Livestock inventory (no.of animals)			
Heifers	6	36	36
Calves	13	29	22
Bulls	1	1.8	4
Total AU[a]	36.4	78.2	81.0
Reproductive parameters			
Calving rate (%)	71.4	71.4	75.0
Culling rate (%)	17.9	14.8	18.2
Adult mortality (%)	3.7	1.7	4.8
Calf mortality (%)	6.3	6.7	13.6
Duration of lactation (days)	285	286	274
Land use (ha)			
Native pastures	40.5	13.7	78.5
Improved pastures	7.7	30.1	3.2
Agriculture	0.6	7.6	1.8
Forest/rest	7.2	5.6	2.5
Total	56	57	86
Stocking rate (AU/ha)	0.75	1.44	0.99

a. Cows = 1.0, heifers = 0.7, calves = 0.3, and bulls = 1.3.

Prices of Inputs/Outputs and Use of Feeding Supplements

Table 2 contains the prices of inputs and outputs used by dual-purpose farms in each country. The farmgate price of milk paid to producers is different in each country and varies depending on the season of the year. The average weighed price is higher, however, in Honduras (US$0.26/kg), followed by Costa Rica (US$0.22/kg) and Nicaragua (US$0.21/kg). This difference in price could be attributed to the fact hat Honduras has a milk deficit, while Costa Rica and Nicaragua export milk—Costa Rica in the form of long-life UHT milk and Nicaragua in the form of fresh, nonpasteurized cheeses.

Also, during the rainy season the milk price varies from US$0.27/kg, paid by processing plants in Costa Rica, to US$0.18/kg in Honduras. During the dry season, middlemen in Honduras pay the best milk price (US$0.34/kg), whereas middlemen in Nicaragua pay the lowest (US$0.17/kg). The largest buyers of milk were processing plants in Honduras (65%) and Costa Rica (42%), while in Nicaragua middlemen purchased 46% of the milk produced.

The price of beef (as culled cow) was similar in Costa Rica (US$0.62/kg) and Nicaragua (US0.65/kg), while it was higher in Honduras (US$0.80/kg), where the commercial price of animals is significantly higher.

The use and cost of labor also differs markedly among countries, ranging from US$2.30/work day in Nicaragua to US$9.30/work day in Costa Rica (including all social benefits). These differences in labor cost affect efficiency, this effect being greatest in Costa Rica (17.3 cows/person) with the smallest herd size and lowest in Nicaragua (13.2 cows/person) with larger herd sizes.

Similarly, commercial land value also contrasts, ranging from US$612/ha in Nicaragua to US$3,676/ha in Costa Rica. The high land value in Costa Rica can be attributed to the high level of public infrastructure, the proximity to urban markets, and the country's long social and economic stability.

The amount of feed supplements used/cow per year in Costa Rica is greater than those ones reported by the other countries (Table 3), which is consistent with the higher milk yields and efficiency of labor reported in Costa Rica.

Table 2. Prices of inputs and products on dual-purpose cattle farms in Costa Rica, Honduras and Nicaragua.

Variable	Costa Rica (n=21)	Honduras (n=20)	Nicaragua (n=37)
Milk			
Weighted price (US$/kg)	0.22	0.26	0.21
Rainy season			
Processing plant	0.27	0.18	0.21
Middlemen	0.17	0.21	0.17
Farmgate	0.20	NA*	0.18
Dry season			
Processing plant	0.27	0.31	0.24
Middlemen	0.17	0.34	0.27
Farmgate	0.21	NA	0.28
Producers (%) sell milk to			
Processing plant	42	65	11
Middlemen	29	35	46
Other producers	29	0	38
Meat (US$/kg culled cow)	0.62	0.80	0.65
Use of labor			
Permanent (no. of people/farm)	1.52	2.95	3.36
Temporary (no. of work days/farm per year)	4	31	27
Labor cost (US$/day)[a]	9.3	3.6	2.3
Efficiency (no. of cows/person)	17.3	15.2	13.2
Land value (US$/ha)	3,676	2,078	612
Animals (US$/animal)			
Cow	540	750	485
Heifer	500	415	330
Weaned calf	160	140	110
Bull	600	800	550
Input prices (US$/kg)			
Chicken manure	0.04	NA	0.065
Molasses	0.08	0.09	0.08
Commercial feed concentrate	0.19	0.21	0.19
Salt	0.13	0.12	0.12
Minerals	0.94	0.86	0.95

a Includes social benefits estimated at 44% for Costa Rica and 17% for Honduras and Nicaragua.
* NA = Not available.

Table 3. Amount of feed supplements used on dual-purpose cattle farms in Costa Rica, Honduras, and Nicaragua.

Feed supplement	Consumption (kg/cow per year)		
	Costa Rica (n=21)	Honduras (n=20)	Nicaragua (n=37)
Chicken manure	496.7	NA*	410.6
Commercial feed concentrate	508.6	292.0	NA
Rice polishing	137.3	NA	NA
Molasses	41.3	87.3	70.5
Salt	38.1	7.8	24.1
Minerals	19.0	20.9	12.4

* NA = Not available.

Analysis of Potential Benefits of New Forage Germplasm

This study aims to estimate the potential benefits of new forage germplasm, with different levels of adoption on-farm and at the regional level in the dry tropical hillside areas where the the Tropileche Consortium operates. The alternatives analyzed were *Brachiaria brizantha*, *B. decumbens*, and *B. dictyoneura*, as well as the legumes *Cratylia argentea* and *Arachis pintoi,* and sugarcane as energy source.

Table 4 presents the nutritional parameters and biomass production of all forage alternatives evaluated in this study using the simulation model. Animal management parameters were taken from farm averages in each country so that they represented the current conditions of management and resource use (Tables 1 to 3).

The situation prevailing during the study was evaluated for each region within each country and this, in turn, was compared against three levels of adoption. Similarly, the following parameters were estimated to compare the different scenarios:

- Additional investment in the new germplasm (per farm and per cow in the herd)
- Net income (per hectare and per cow) after discounting fixed and variable costs amd use of family labor valued as minimum wage cost
- Milk productivity/ha

- Livestock area that can be released as a result of the different levels of adoption (in number of hectares and as percentage of farm area allocated to livestock production)

- Production cost/kg milk as the maximum expression of competitiveness

Table 4. Forage parameters used to run the simulation model at different benchmark sites of the Tropileche Consortium.

Parameters	Forages				
	Jaragua	*Brachiaria*	*Arachis*	*Cratylia*	Sugarcane
Crop duration (years)	10	10	10	15	10
Rainy season					
Edible biomass production (DM, t/ha)	3.2	4.5	1	2	1.6
Crude protein, CP (%)	8	10	20	18	2
CP degradability (%)	50	60	70	60	20
IVDMD (%)	45	60	50	50	60
Dry season					
Edible biomass production (DM, kg/ha)[a]	640	900	0	4,000	0
CP (%)	3	4	20	18	2
CP degradability (%)	50	60	70	60	20
IVDMD (%)	30	35	50	50	60
Losses due to trampling (%)					
Rainy season	25	25	25	0	0
Dry season	20	20	20	0	0
Residual biomass from rainy to dry season (DM, kg/ha)[b]	800	1,125	250	2,000	16,000

[a] Equivalent to 20% of biomass production during rainy season for grasses and 100% for *Cratylia*.
[b] Equivalent to 25% of biomass production during rainy season for grasses and 100% for *Cratylia* and sugarcane.

Situation prevailing during study period. The average farm was assessed as to management practices and use of resources based on the results of each individual country survey (Tables 1 to 3).

Level 1. This level consisted in the adoption of new germplasm to substitute purchased feeds used to supplement the herd, especially during the dry season (Table 3). The same herd size (the same number of milking cows) and milk production/cow were assumed for this scenario. This adoption level requires the lowest level of investment and new forage alternatives will be established in small areas. With this level of adoption no areas are released for other alternative uses because its sole objective is to partially substitute purchased feed supplements.

Level 2. This level implied the adoption of new alternatives to not only satisfy substitute feeds purchased to supplement the herd, but also to release areas currently allocated to livestock production for other alternative uses. As in Level 1, the same herd size and milk production/cow were assumed; this level required a slightly higher investment than Level 1 and could be considered the most rational option for producers already in Level 1.

Level 3. This level of adoption consisted in the establishment of new forage germplasm in the entire farm area allocated to livestock production. This level of adoption assumed the same milk production/cow but allowed the expansion in herd size. Therefore this level required the highest level of investment because it not only required that larger areas be established with improved forages, but also that additional animals be purchased to maximize land use. This level could be the option for producers already in Level 2.

Results and Discussion

On-farm analysis of benefits. Tables 5, 6, and 7 present the results of simulation runs of the linear programming model to analyze the situation at that time versus potential benefits of three levels of adoption of new forage germplasm in dual-purpose farms in Costa Rica, Honduras, and Nicaragua. The situation of the dual-purpose farms surveyed was different in each of the three countries. Nicaragua presented the lowest milk productivity/ha because practically all the farms surveyed were covered by naturalized Jaragua pastures (Table 7). The opposite situation was observed in Honduras where milk productivity/ha was highest because the farmrs surveyed had significant areas under improved pastures (>60%), as well as important areas under cut-and-carry systems, for example sugarcane and forage sorghum (Table 6). The situation observed in Costa Rica was intermediate, with most of the pasture area covered by naturalized pastures and a low level of adoption of improved forages (<10% of the area under livestock production). In all countries most farms supplemented herds with purchased feeds, especially during the dry season. The amount invested in supplement feeds/cow per year was highest in Honduras (US$96), lowest in Nicaragua (US$32), and intermediate in Costa Rica (US$71).

Table 5. Use of a simulation model to compare the situation of dual-purpose cattle farms in the dry tropics of Costa Rica versus the adoption of new forage germplasm to eliminate the purchase of feeds and to improve production efficiency.

Parameter	Prevailing situation	Level 1[a]	Level 2[b]	Level 3[c]
Adult cows (no.)	23	23	23	48
Land use (ha)				
Native pasture	40.5	38.5	0	0
Sugarcane	0.3	0.7	1.0	4.9
Cratylia argentea	0	1.6	1.7	3.6
Brachiaria spp. alone	7.2	7.2	26.5	0
Bracharia spp. + *Arachis pintoi*	0	0	0	39.5
Total area (ha)	48	48	29.2	48
Additional investment for new germplasm (US$)				
Per farm	NA*	872	5,730	15,960
Per cow	NA	38	249	333
Stocking rate (AU/ha)	0.75	0.75	1.23	1.56
Use of purchased feed (kg/cow per year)				
Chicken manure	491	0	0	0
Feed concentrates	270	0	0	0
Total cost (US$/cow per year)	71	0	0	0
Net annual income				
Per hectare	16	43	98	119
Per cow	34	89	124	119
Per farm	782	2,047	2,852	5,712
Milk production (kg/ha)	666	666	1,095	1,390
Use of labor (no. of cows/person)	17.3	15.9	18.5	17.6
Area released				
No. of hectares	NA	0	18.8	NA
Percent of livestock area	NA	0	39.2	NA
Milk production cost (US$/kg)	0.21	0.18	0.16	0.16

a. Level 1 = Substitution of purchased feed.
b. Level 2 = Substitution of purchased feed + release of area.
c. Level 3 = Establishment of new forages on the farm.
* NA = Not available.

Table 6. Use of a simulation model to compare the situation of dual-purpose systems in the dry tropics of Honduras versus the adoption of new forage germplasm to eliminate the purchase of feeds and to improve production efficiency.

Parameter	Prevailing situation	Level 1[a]	Level 2[b]	Level 3[c]
Adult cows (no.)	42	42	42	46
Land use (ha)				
Native pasture	13.7	10.4	0	0
Sugarcane	3.2	3.4	3.7	4.1
Cratylia argentea	0	3.0	2.9	3.2
Brachiaria spp. alone	27.1	27.1	33.3	36.7
Bracharia spp. + *Arachis pintoi*	0	0	0	0
Total area	44	44	39.9	44
Additional investment in new germplasm (US$)				
Per farm	NA*	850	1,830	2,580
Per cow	NA	20	44	56
Stocking rate (AU/ha)	1.44	1.44	1.59	1.58
Use of purchased feed (kg/cow per year)				
Molasses	88	0	0	0
Feed concentrates	418	0	0	0
Total cost (US$/cow per year)	96	0	0	0
Net annual income				
Per hectare	160	249	276	277
Per cow	167	261	264	265
Per farm	7,014	10,962	11,088	12,190
Milk production (kg/ha)	1,386	1,386	1,530	1,530
Use of labor (no. of cows/person)	15.3	14.8	15.2	15.1
Area released				
No. of hectares	NA	0	4.1	NA
Percent of livestock area	NA	0	9.3	NA
Milk production cost (US$/kg)	0.16	0.12	0.11	0.11

a. Level 1 = Substitution of purchased feed.
b. Level 2 = Substitution of purchased feed + release of area.
c. Level 3 = Establishment of new forages on the farm.
* NA = Not available.

Table 7. Use of a simulation model to compare the situation of dual-purpose systems in the dry tropics of Nicaragua versus the adoption of new forage germplasm to eliminate the purchase of feeds and to improve production efficiency.

Parameter	Prevailing situation	Level 1[a]	Level 2[b]	Level 3[c]
Adult cows (no.)	44	44	44	86
Land use (ha)				
Native pastures	80	77.7	0	0
Sugarcane	0	0.6	4.4	9.2
Cratylia argentea	0	1.7	2.5	5.2
Brachiaria spp.	0	0	37.3	0
Bracharia spp. + *Arachis pintoi*	0	0	0	65.6
Total area	80	80	44.2	80
Additional investment in new germplasm (US$)				
Per farm	NA*	695	7,410	22,070
Per cow	NA	16	168	256
Stocking rate (AU/ha)	0.99	0.99	1.80	1.95
Use of purchased feed (kg/cow per year)				
Chicken manure	410	0	0	0
Molasses	70	0	0	0
Total cost (US$/cow per year)	32	0	0	0
Net annual income (US$)				
Per hectare	21	38	91	93
Per cow	38	69	91	87
Per farm	1,672	3,036	4,044	7,482
Milk production (kg/ha)	493	493	892	964
Use of labor (no. of cows/person)	13.2	12.9	14.7	14.9
Area released				
No. of hectares	NA	0	35.8	NA
Percent of livestock area	NA	0	44.8	NA
Milk production cost (US$/kg)	0.18	0.16	0.14	0.14

a. Level 1 = Substitution of purchased feed.
b. Level 2 = Substitution of purchased feed + release of area.
c. Level 3 = Establishment of new forages on the farm.
* NA = Not available.

The production cost/kg milk was lowest in Honduras (US$0.16), intermediate in Nicaragua (US$0.18) and highest in Costa Rica (US$0.21). Differences in production costs obeyed labor cost, which was more expensive in Costa Rica (US$9.30/work day) and less expensive in Nicaragua (US$2.30/work day), but also the herd size and/or stocking rate, which was 1.44 AU/ha in Honduras and 0.75 AU/ha in Costa Rica.

Level 1. This level of adoption aimed to establish minimal areas of improved germplasm to replace the use of purchased feeds for the herd, especially during the dry season. The forage option that achieved this goal most economically was the establishment of *Cratylia argentea* as protein source together with sugarcane as energy source.

In the case of Costa Rica, the establishment of 0.7 ha of sugarcane with 1.6 ha of *Cratylia* represented an investment of US$872 for a herd of 23 cows. This area produced enough nutrients and biomass to completely eliminate the need to purchase 491 kg of chicken manure and 270 kg of feed concentrate usually required per cow each year. This investment was equivalent to US$38/cow, and generated savings in cash flow of US$71/cow per year, allowing an increase in annual net income/cow of US$55 (from US$34 to US$89) and a reduction in production cost/kg milk of US$0.03 (from US$0.21 to US$0.18).

The potential benefit of the new technology was even greater in Honduras than in Costa Rica because the annual cost of purchased feeds in Honduras was the highest of the three countries. Therefore, with a small investment of US$850/farm to establish 3.4 ha of sugarcane and 3 ha of *Cratylia*, the purchase of 88 kg of molasses and 418 kg of feed concentrate/cow per year could be eliminated (Table 6). In addition, this level of adoption reduced production cost/kg milk by US$0.04 (from US$0.16 to US$0.12) and increased the net income/cow per year by US$94 (from US$167 to US$261).

The economic impact of this level of technology in Nicaragua was similar to that observed in Honduras. In this case, small areas (0.6 ha of sugarcane + 1.7 ha of *Cratylia*) were needed to replace the use of purchased feeds that amounted to 410 kg of chicken manure and 70 kg of molasses per cow/year, with a very modest investment of US$695/farm (Table 7). The investment to achieve this level of adoption reduced production cost/kg milk by US$0.02 (from US$0.18 to US$0.16), which increased net income/cow per year by US$31 (from US$38 to US$69).

Level 2. This level of adoption aimed not only to substitute purchased feeds by establishing new forage options, but also to release areas currently allocated to livestock production for other alternative uses. To meet this objective, the simulation model incorporated not only the forage alternatives used in Level 1, but also the adoption of improved grasses such as *Brachiaria* spp.

In the case of Costa Rica, this level of adoption required, in addition to the investment of Level 1 and the 7.2 ha of improved grasses already existing, that another 19.3 ha of *Brachiaria* spp. be established. This investment cost US$5,730/farm (US$249/cow) and allowed up to 18.8 ha of land, equivalent to 39.2% of the area allocated to livestock production, to be released for alternative uses. As a result, the stocking rate was increased from 0.75 AU/ha to 1.23 AU/ha. The adoption of improved forages reduced milk production costs even more than in Level 1 and increased net income (Table 5).

The additional investment to reach this level of adoption in Honduras was lower than that required in Costa Rica: US$1,830/farm (US$44/cow) because the farms surveyed reported, on average, the existence of 27.1 ha of improved grasses. Thus, to achieve the objectives of this level of adoption, an investment similar to that of Level 1 was required, and producers also had to invest in the establishment of an additional 6.2 ha of *Brachiaria* spp.

Because the stocking rate in Honduras was relatively high (approximately 1.44 AU/ha) as a result of the adoption of improved grasses and cut-and-carry forages, the area that could be released without affecting herd size and production/farm was low compared with Costa Rica and Nicaragua. The area that could have been released in Honduras was about 4.1 ha, which represented 9.3% of the total farm area allocated to livestock production (Table 6). This level of adoption led to additional reduction in production cost/kg milk (US$0.11/kg) and an increase in net income/cow per year.

Level 2 required a higher level of investment in Nicaragua than in Costa Rica and Nicaragua because the areas to be established with improved forages were larger in view of the precarious situation of farms at that time. To achieve Level 2 of adoption, an investment of US$7,410/farm, equivalent to US$168/cow, was necessary to establish 4.4 ha of sugarcane, 2.2 ha of *Cratylia,* and 37.3 ha of *Brachiaria* spp. (Table 7). This investment increased the stocking rate from 1 AU/ha to 1.80 AU/ha, and released about 35.8 ha of land for other alternative uses (44.8% of area allocated to livestock production). With this level of adoption, it was possible to reduce even more the milk production costs and increase net income/cow per year.

Level 3. This level attempts to show the potential of adopting new forage germplasm in the entire farm area allocated to livestock production. This level of adoption required the largest amount of capital investment because not only were improved forages established in larger areas, but also more animals had to be purchased a result of increased stocking rate. This level of adoption can be regarded as the most intensive of the three levels considered in this study, both in terms of productivity/ha and in terms of capital and labor use. The simulation model included the legume *Arachis pintoi* associated with grasses of *Brachiaria* spp.

In Costa Rica this level of adoption required the additional establishment of 3.6 ha of *Cratylia* and 4.9 ha of sugarcane, in relation to levels 1 and 2, as well as the establishment of *A. pintoi* associated with *Brachiaria* in all pasture area (39.5 ha). The investment was US$15,960/farm, equivalent to US$333/cow, which allowed a significant increase in stocking rate (1.56 AU/ha) as well as the herd size (from 23 to 48 cows). This increase in herd size generated other benefits, such as increased milk productivity/ha during the survey: from 666 kg at Level 1 to 1,095 kg milk/ha at Level 2 and 1,390 kg milk/ha at Level 3.

Atlhough the annual net income/cow and per hectare varies little regarding Level 2 (increased from US$98/ha to US$119/ha but decreased from US$124/cow to US$119/cow), the net income/farm increased markedly because of the effect of stocking rate and expansion of herd size, practically duplicating the annual net income of producers from US$2,852/farm with Level 2 to US$5,712 with Level 3.

As in Costa Rica, this level of adoption in Honduras required an additional increase in the area planted to *Cratylia* (3.2 ha) and sugarcane (4.1 ha), as well as the establishment of *A. pintoi* associated with *Brachiaria* (36.7 ha) in the total area under pastures. The investment to achieve this level of adoption totaled US$2,580/farm and was significantly lower than that required in Costa Rica because the farms surveyed in Honduras already had more than 60% of the pasture area established with improved grasses, including important areas of cut-and-carry forages (3.2 ha or more per farm). This level of adoption allowed farmers in Honduras to increase herd size by 9.5%, from 42 to 46 cows, thus increasing net income (US$12,190/farm) as compared with the other levels of adoption (Table 6).

The case of Nicaragua was similar to that of Costa Rica and Honduras because this level requires an additional increase in the area planted to *Cratylia* (for example, from 2.5 ha to 5.2 ha) and to sugarcane (for example, from 4.4 ha to 9.2 ha), as well as the establishment of *A. pintoi* associated with *Brachiaria* spp. in the totality of the area under pastures (65.6 ha). The investment to achieve this level of adoption in Nicaragua was the highest of the three countries studied (US$22,070/farm) because the farms surveyed in Nicaragua were completely covered with naturalized pastures. This investment in Nicaragua allowed producers to double the current stocking rate from 0.99 AU/ha to 1.95 AU/ha and increase herd size from 44 to 86 cows, thus increasing net income to US$7,482/farm per year, which is significantly higher than that obtained at Level 2 (US$4,044/farm per year). As a result, even though the investment to reach this level of adoption is high, so is the potential benefit regarding the other two countries.

As in Costa Rica and Honduras, milk production cost and net income/ cow and per hectare in Nicaragua at Level 3 were similar to those of Level 2; however, net income/farm increased by 85% because of the increase in herd size.

Regional Benefit Analysis

Table 8 presents the area under pasture, the number of livestock producers, and the livestock population located in the dry tropics of each region where the germplasm validated by the Tropileche Consortium could be successfully replicated. Table 9 shows the potential benefits of new forage germplasm for each level of adoption, assuming these are effectively adopted in accordance with the data reported in Table 8.

Table 8. Characteristics of dual-purpose farms in the dry tropics of Costa Rica, Honduras, and Nicaragua and adoption potential of new forage germplasm (Tropileche Consortium).

Characteristic	Costa Rica[a]	Honduras[b]	Nicaragua[c]
Area in pasture (ha)	528,254	364,852	819,590
Producers (no.)	18,768	18,722	21,447
Cattle population (no. of cows)	167,323	133,642	320,380

SOURCES: a = SEPSA, 1990; b = Dirección General de Estadísticas y Censos, 1998; c = MAG, 1999.

Level 1. This level of adoption had the largest impact on the situation of farmers because large increases in net income/cow per year were obtained (from US$31 to US$94) with small investments per cow (between US$16 and US$38). Cash flow increased with the substitution of purchased feed supplements with improved germplasm.

The investment required in each region ranged from US$2.7 million in Honduras to US$6.4 million in Costa Rica. This investment was represented by the establishment of new areas under improved forages, and estimated on the basis of the cost of each forage alternative (Table 9).

The analysis of benefits, in terms of annual net income in cash for farmers in the region, increased from US$9.9 million to US$12.6 million, which surpassed the one-time investment required every 10 years. The payback period necessary to return the investment with the marginal income was lower or equal to 6 months in all countries. In other words, the initial investment could be paid back in the following 6 months, once the improved forages had been established, before the onset of the dry season, when feed supplements would be needed.

Table 9. Potential benefits of new forage germplasm at three levels of adoption in dual-purpose cattle farms in the dry tropics of Costa Rica, Honduras, and Nicaragua.

Country	Level of adoption[a]		
	1	2	3
Costa Rica			
Investment/cow	38	249	333
Increase in income/cow per year[b]	71	90	85
Investment at regional level (US$ millions)	6.4	41.7	55.7
Increase in regional income/year (US$ millions)[b]	11.9	15.1	29.6
Years to pay investment	0.5	2.8	1.9
Honduras			
Investment/cow	20	44	56
Increase in income/cow per year[b]	94	97	98
Investment at regional level (US$ millions)	2.7	5.9	8.2
Increase in regional income/year (US$ millions)[b]	12.6	12.9	14.3
Years to pay investment	0.2	0.5	0.6
Nicaragua			
Investment/cow	16	168	256
Increase in income/cow per year[b]	31	53	49
Investment at regional level (US$ millions)	5.1	53.8	82.0
Increase in regional income/year (US$ millions)[b]	9.9	17.0	30.7
Years to pay investment	0.5	3.2	2.7

a Level 1 implied the adoption of new forage alternatives with the minimum area needed to eliminate the use of purchased feeds to maintain the same milk production and herd size. Level 2 implied the adoption of new alternatives to satisfy level 1 and to also release the largest area under pasture for other alternative uses. Level 3 implied the adoption of improved forages on the entire farm to achieve the highest production potential both on-farm and at the regional level.

b Marginal increase regarding the average situation of farms surveyed in each country.

Level 2. This level, as analyzed before, should be the next phase once Level 1 has been achieved because it demands a higher investment of capital, and is therefore not easy to adopt initially.

The capital required for this level of adoption in different regions and countries ranged between US$6 and US$54 million, equivalent to an investment of US$44/cow in Honduras and US$249/cow in Nicaragua. Furthermore, the payback period varied from 6 months to 3.2 years because the levels of investment were highest, except in Honduras where there was already a significant adoption of improved forages.

Level 3. This level was the most difficult because it demanded the highest investment. Achieving an impact at the regional level required from US$8 million in Honduras to US$82 million in Nicaragua; however, the benefit, in terms of additional income for producers in the dry tropics in each country, ranged between US$14.3 million/year in Honduras and US$30.7 million/year in Nicaragua. Thus, based on this cash flow, the payback period needed to recover the initial investment varied from 0.6 years in Honduras to 2.7 years in Nicaragua.

Seed Requirements for Technology at the Regional Level

Table 10 presents seed production needs required for the establishment of each forage alternative, according to the level of adoption at the regional level in each country (Table 8), assuming an annual rate of adoption of 10% of the available area for each alternative.

Level 1. About 9 t of *C. argentea* seed are required per country per year. Seed production/ha of *Cratylia* is approximately 160 kg/ha (Argel and Lascano, 1998) and the demand for seed is about 8 kg/ha (Table 11). Because availability of *Cratylia* seed is a limitation, to satisfy the demand it will be necessary to establish 58 ha of seed multiplication plots in Costa Rica, 48 ha in Honduras, and 62 ha in Nicaragua.

The demand of sugarcane propagation material is similar to that of *Cratylia*. It is estimated that 1 ha of sugarcane produces 60 t of planting material for multiplication and that approximately 14 t are needed to establish 1 ha (Table 12). Therefore to satisfy planting needs, 68 ha of seed multiplication plot must be established in Costa Rica, 15 ha in Honduras, and 102 ha in Nicaragua.

Level 2. The amount of seed required to achieve this level of adoption at the regional level is greater because the area to plant is larger, especially of *Brachiaria* spp. However, grass seed is not a constraint because of the existence of local seed companies.

Table 10. Annual seed requirements of each forage species needed to achieve each level of adoption, estimating an annual impact on 10% of the livestock population, in Costa Rica, Honduras, and Nicaragua.

Type of germplasm and level of adoption[a]	Costa Rica		Honduras		Nicaragua	
	Area to plant (ha)	Seed required (t/year)	Area to plant (ha)	Seed required (t/year)	Area to plant (ha)	Seed required (t/year)
Level 1						
Brachiaria spp.	0	0	0	0	0	0
Cratylia argentea	1,164	9.3	955	7.6	1,240	9.9
Arachis pintoi[b]	0	0	0	0	0	0
Sugarcane	291	4,074	64	896	437	6,118
Level 2						
Brachiaria spp.	14,040	56.2	1,970	7.9	27,160	108.6
Cratylia argentea	1,237	9.9	950	7.6	1,820	14.6
Arachis pintoi[b]	0	0	0	0	0	0
Sugarcane	509	7,129	160	2,240	3,204	44,850
Level 3						
Brachiaria spp.	11,260	45.0	2,790	11.2	24,440	97.8
Cratylia argentea	1,260	10.1	930	7.4	1,940	15.5
Arachis pintoi[b]	13,770	110.2	0	0	24,440	195.5
Sugarcane	1,605	22,450	261	3,654	3,430	48,000

[a] Level 1implied the adoption of new forage alternatives with the minimum area needed to eliminate the use of purchased feeds to maintain the same milk production and herd size. Level 2 implied the adoption of new alternatives to satisfy Level 1 and to also release the greatest amount possible of area under pasture for other alternative uses. Level 3 implied the adoption of improved forages in the entire farm area to reach the highest production potential both on farm and at the regional level.

[b] It is assumed that *Arachis pintoi* is established in association with an improved grass.

To meet the seed needs of *C. argentea*, this level of adoption required the establishment of 62 ha of additional seed multiplication plots in Costa Rica, 48 ha in Honduras, and 92 ha in Nicaragua. To meet the seed requirements of sugarcane, 119 ha of seed multiplication plots must be established in Costa Rica, 38 ha in Honduras, and 748 ha in Nicaragua.

Level 3. This level of adoption required amounts of seed similar to Level 2, but it also required high amounts of seed of *A. pintoi* to establish associations with *Brachiaria.* As in the case of grass seed, the availability of *Arachis* seed did not represent a constraint because there were sufficient quantities in the regional market.

To meet the requirements of *Cratylia* seed for this level of adoption, an additional 64 ha of seed multiplications plots must be established in Costa

Rica, 47 ha in Honduras, and 97 ha in Nicaragua, whereas for sugarcane 374 ha are needed in Costa Rica, 61 ha in Honduras, and 800 ha in Nicaragua.

Strategy to Promote the Adoption of New Technologies

The requirements to reach a level of adoption similar to Level 1 are relatively easy to achieve given the large benefits that can be obtained in terms of reduced production costs and increased cash flow due to the substitution of purchased inputs with improved germplasm. Use of family labor, frequently underutilized or with a very low opportunity cost, especially in Nicaragua and Honduras, is more efficient.

The strategy to ensure successful adoption of Level 1 and subsequent advance toward other levels of adoption consists in establishing strategic alliances with organized farmers groups and/or extension agencies. These alliances allow the:

- Identification of producers interested in establishing seed multiplication plots on their farms so that they become facilitators for the local expansion of new areas in each region, and

- Creation of a followup mechanism to find markets for the seed produced, by identifying early adopters.

Conclusions

The potential benefits that result from the progressive adoption of new forage options based on grasses and legumes validated by the Tropileche Consortium include the following:

- Level 1 of adoption (new germplam based on *Cratylia* and sugarcane to substitute feed supplements for herds) allows producers in all three countries to completely eliminate the need to purchase feed supplements for the herd, especially during the dry season. This effect has a large impact on the cash flow of producers because milk production cost can be reduced by 14% in Costa Rica, by 25% in Honduras, and by 11% in Nicaragua.

- Level 2 of adoption (areas of *Cratylia* and sugarcane similar to Level 1, plus variable areas of *Brachiaria* in each country) not only offers the benefits obtained with Level 1, but also allows the producer to maintain the same milk production and herd size in a smaller area, thus releasing areas to be allocated to other alternative uses. The released areas vary from 9% in the case of Honduras to 39% in Costa Rica and 45% in

Nicaragua. In addition, this level of adoption reduces milk production cost as compared to Level 1 by an additional 11% in Costa Rica, 8% in Honduras, and 12% in Nicaragua.

- Level 3 of adoption (areas of *Cratylia* and sugarcane larger than in Levels 1 and 2, plus pastures of *Brachiaria* +*Arachis* in association) presents the most intensive productivity and requires the highest level of capital investment. The highest milk productivity/ha is achieved with this level of adoption—1,390 kg/ha in Costa Rica, 1,530 kg/ha in Honduras, and 964 kg/ha in Nicaragua—as well as the highest stocking rate—1.56 AU/ha in Costa Rica, 1.58 AU/ha in Honduras, and 1.95 AU/ha in Nicaragua.

- The potential impact that can be achieved by adopting these technologies at the regional level is significant. The required amount of investment to achieve Level 1 in Costa Rica was US$6.4 million; in Honduras, US$2.7 million; and in Nicaragua, US$5.1 million. Because of the reduced production cost, it was possible to obtain an additional annual net income in all regions studied: US$11.9 million in Costa Rica, US$12.6 million in Honduras, and US$9.9 million in Nicaragua. Thus, the potential benefit is quite large regarding the investment, and could be paid back in less than 1 year (Table 9).

- The investment required at the regional level to reach Level 2 of adoption amounted to US$41.7 million in Costa Rica, US$5.9 million in Honduras, and US$53.8 million in Nicaragua. The marginal income per year expected by the reduction in production cost amounted to US$15.1 million in Costa Rica, US$12.9 million in Honduras, and US$17.0 million in Nicaragua.

- The resources required to obtain Level 3 of adoption were estimated at US$55.7 million in Costa Rica, US$8.2 million in Honduras, and US$82 million in Nicaragua, and the additional annual income that can be obtained by reduction in production cost and higher milk sales represented US$29.6 million in Costa Rica, US$14.3 million in Honduras, and US$30.7 million in Nicaragua.

- To promote the adoption of these technologies at the regional level, a strategy must be designed to establish alliances with organized farmers groups and/or extension agencies, as well as a mechanism to supply seed to producers, especially of *C. argentea* and sugarcane. The availability of seed of *Brachiaria* and *A. pintoi* does not represent a constraint.

- This study suggests that large economic incentives exist to design a regional strategy in each country to promote the adoption of technologies at Level 1 to improve the income of small milk producers and increase the competitiveness of dual-purpose production systems through the use of new improved forage germplasm based on grasses and legumes.

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Analysis of the Milk Market of Small-Scale Artisan Cheese Factories in Watersheds of Honduras and Nicaragua Involved in Livestock Production

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Processing plants collect 20% of the milk produced in Honduras and Nicaragua that is turned into pasteurized milk and other dairy products. The price paid for milk during the study period was approximately US$0.30/kg in both countries, but this price was obtained by less than 5% of dairy farms in both countries because these plants require that milk be cooled to improve its hygienic quality and that farms be located in easily accessible sites with good roads (Argel, 1999a; 1999b).

The "informal" market collects the remaining 80% of the milk produced in both countries, mainly in the form of cheese (Argel, 1999a; 1999b). This market is mainly constituted by small-scale artisan cheese factories—mostly located in milk-producing areas—that do not pasteurize milk. These factories transform milk into popular fresh cheeses with shelf lives shorter than 10 days (De Franco et al., 1995). In Honduras alone, there were about 600 artisan cheese factories at the time of the study (Argel, 1999a). As a result, the artisan cheese industry in both countries is the principal buyer of milk produced by small and medium producers who do not fulfill the requirements of milk processing plants of the known "formal" sector.

Seasonality in Production

The price paid to producers by artisan cheese factories depends on the supply of milk, which has a marked seasonality: it is abundant during the rainy season and scarce during the dry season. This situation leads to serious difficulties in allocating surplus milk produced during the rainy season because both countries lack an efficient industrialization and marketing system. The seasonality in production causes milk prices to fluctuate, with differences of up to 50% between seasons (De Franco et al., 1995; Cajina, 1994).

In addition to this problem of seasonality, most milk collected by artisan cheese factories during the rainy season is of poor quality with bacterial counts close to 1,000,000/cc. The pasteurization process does not correct this problem for raw milks with bacterial counts higher than 500,000 bacteria/cc because pasteurization only guarantees the elimination of pathogenic bacteria, and many others remain alive thus affecting cheese quality (De Franco et al., 1996).

Therefore it is not possible to make cheese of acceptable quality with this type of milk, a situation determined by the sanitary conditions during milking and the handling of milk until it reaches the cheese factories. Most milk producers in Honduras and Nicaragua do not have milking sheds or clean, running water. Milking is carried out in open corrals, by hand, using open buckets and surrounded by sludge. Milk cans are washed with any type of common detergent and chlorine is not always used to disinfect them (De Franco et al., 1996).

The milk produced under these conditions during the dry season is of higher quality because there is no excess humidity in the corrals, the udders of cows are cleaner, and the transportation time to the rural cheese factories is shortened because roads are in better conditions (García, 1996).

As a result of these changes in supply and quality, it is more attractive to produce higher volumes of milk during the dry season because it benefits the producer, who receives a higher price, as well as the artisan cheese factories, that receive milk of better quality.

Objective

This study aimed to analyze the milk market of small-scale artisan cheese factories located in the livestock production areas of Honduras and Nicaragua where the Tropileche Consortium operates. The study aimed to answer the following questions:

- Is there a market for additional milk production? If so, how much milk can be absorbed by artisan cheese factories each season?

- Is there a market for milk of higher hygienic quality and, if so, would the farmgate price be higher? What price would the cheese factories be willing to pay?

Materials and Methods

The data for this study was obtained through surveys carried out during March 2000 to 10 small-scale artisan cheese factories in Honduras and 13 in Nicaragua. These cheese factories were located in the area of influence of the Tropileche Consortium: Olancho, Catacamas, and Juticalpa in Honduras, and in Esquipulas and Muy-Muy in Nicaragua. Secondary information from both countries was used to complement survey data.

Results and Discussion

Collection of milk and prices paid. The average milk collected was about 6 times more in Honduras than in Nicaragua in both rainy (6,200 kg/day vs. 1,100 kg/day) and dry season (3,600 kg/day vs. 520 kg/day) (Tables 1 and 2). Milk collected during the rainy season was 73% more than that collected during the dry season in Honduras and 111% more in Nicaragua. This factor disrupts any market and has significant impact on the price of milk that artisan cheese factories are willing to pay. Therefore, the milk price during the rainy season compared with that paid during the dry season was 27% lower in Honduras and 38% lower in Nicaragua. In addition, the milk price paid by cheese factories for raw material of a similar quality was 33% higher in Honduras than in Nicaragua during the rainy season (US$0.24/kg vs. US$0.18/kg) and 14% higher during the dry season (US$0.33/kg vs. US$0.29/kg).

Types of cheeses and yields. Four types of cheese are produced in both countries by artisan factories. They also sell cream as a by-product because most cheeses are made with skimmed milk. The sale of cream represents a net profit in both countries and each type of cheese has a different price. Therefore, the marketing strategy was similar, being segmented to four different types of cheese (tastes) associated with the purchasing power of consumers.

Although all cheese types produced are fresh and have short shelf lifes, the difference between them is the amount of moisture they contain. To produce a cheese with low moisture content, a larger amount of fluid milk is required and, as a result, its price is higher (for example, dry cheese in Honduras and pure cheese in Nicaragua). This situation is demonstrated by the amount of fluid milk necessary to produce 1 kg of cheese, which, in turn, is directly related to sale price. The higher the moisture content of the cheese, the shorter its shelf life. Therefore, low-cost cheeses are also those with the shortest shelf life because they contain more whey.

The amount of milk necessary to produce each type of cheese varies according to the season of the year. During the rainy season, milk production/cow is higher but its solid contents is lower and, as a result, more milk is required to produce the same amount of cheese. For example, in Honduras the artisan factories required 7% more milk during the rainy season to produce 1 kg of “dry” cheese and up to 15% more milk to produce 1 kg of string cheese or “quesillo”. In Nicaragua, artisan factories required 14% more milk during the rainy season to produce “pure” cheese and up to 19% more milk to produce 1 kg of cream cheese. This reduction in yield efficiency during the rainy season forces artisan factories to pay a lower milk price to producers.

Table 1. Characteristics of milk and cheese production and marketing of 10 small-scale rural artisan cheese factories during the rainy and dry seasons in the watersheds of Olancho, Catacamas, and Juticalpa (Honduras) dedicated to livestock production.

Characteristic	Dry season	Rainy season
Gathering of milk (L/day)	3,600	6,230
Purchase price (US$/L)	0.33	0.24
Types of cheese produced and sale price (US$/kg)		
"Dry" cheese	3.60	2.40
Fresh cheese	2.70	1.80
Cream cheese	2.40	1.94
String cheese (*quesillo*)	2.09	1.30
Cream	2.40	1.80
Amount of milk required to produce each type of cheese (L/kg)		
"Dry" cheese	9.48	10.14
Fresh cheese	6.00	6.76
Cream cheese	5.73	6.39
String cheese (*quesillo*)	5.62	6.45
Cream	14.7	16.9
Percentage of cheese processors willing to purchase more milk	55.5	0
Percentage of processors who considered that the milk was of good quality		
Yes	10	10
No	90	90
Higher price people were willing to pay for better quality milk		
US$/L	0.361	0.266
Percent of processors	9.4	11.2

Potential market and milk quality. The potential growth of the cheese market was large and unsatisfied. The artisan cheese factories surveyed in Honduras could purchase up to 55% more milk during the dry season, but there was no milk on offer. In Nicaragua the potential was even greater because artisan factories were willing to purchase up to 76% more milk than that collected during the time of the study.

Table 2. Characteristics of milk and cheese production and marketing of 13 small-scale rural artisan cheese factories, during the rainy and dry seasons, in the watersheds of Esquipulas and Muy-Muy (Nicaragua) dedicated to livestock production.

Characteristics	Dry season	Rainy season
Collection of milk (L/day)	523	1,103
Purchase price (US$/L)	0.29	0.18
Types of cheese produced and sale price (US$/kg)		
"Pure" cheese	2.49	1.78
"Media Sangre" cheese	2.13	1.60
Cottage cheese	1.78	1.24
Cream cheese	1.78	1.24
Cream	1.60	0.89
Amount of milk required to produce each type of cheese (L/kg)		
"Pure" cheese	7.71	8.82
"Media Sangre" cheese	6.61	7.71
Cottage cheese	5.51	6.61
Cream cheese	5.51	6.61
Cream	11.03	13.23
Percentage of cheese processors willing to purchase more milk	75.7	0
Percentage of cheese processors who considered that the milk was of good quality		
Yes	80	70
No	20	30
Higher price people were willing to pay for better quality milk		
US$/L	0.29	0.211
Percent of processors	0	17.0

This situation is not the same during the rainy season, when the potential for growth is null in both countries because of the excess offer of milk in the market. As a result, the artisan factories in both countries would only be willing to purchase more milk during the dry season, which has significant implications for the type of technologies that should be promoted among producers in both regions.

In Honduras, 90% of artisan factories surveyed considered that the milk collected during the rainy season had low hygienic quality, but this figure decreased to only 10% during the dry season. Therefore there was a direct relationship between low hygienic quality of milk and rainy season, which agrees with De Franco et al. (1996). In Nicaragua, 30% of artisan factories considered that the milk produced during the rainy season was of low hygienic quality, which is still significant even though lower than in Honduras.

Artisan cheese factories in Honduras and Nicaragua that considered that the milk collected was of low hygienic quality would be willing to pay a higher price if the quality of the milk improved. In Honduras this price would be 9.4% higher during the dry season and 11.2% higher during the rainy season. In Nicaragua the artisan cheese factories would be willing to pay 17% more, but only during the rainy season.

Needs of small-scale artisan cheese factories. Table 3 presents the needs and expectations of artisan cheese factories in both countries. The main need was the improvement of factory infrastructure by acquiring more equipment (for example, creameries, cold rooms, devices to determine hygienic quality). Future prospects of the cheese industry in both countries are promising.

The improvement of milk quality was ranked as second priority in Honduras, while the search for new markets was ranked second in Nicaragua (Table 3). Nicaragua began to export fresh cheeses to El Salvador and Honduras in 1990 for a gross value of US$128,000. Since then, exports have been on the rise, reaching 8,400 t of cheese in 1998 for a gross value of US$14 million (MAGFOR, 2000). All factors considered indicate that this trend will continue in coming years.

Table 3. Needs of rural artisan cheese factories in Honduras and Nicaragua (% of cheese factories).

Need	Honduras (%)	Nicaragua (%)
More equipment to expand infrastructure[a]	80	62
Improved hygienic quality of milk[b]	60	15
Technical assistance to produce new types of cheese	50	15
Improved quality of cheeses[c]	40	23
Expansion of existing markets and search for new markets	10	46

[a] Acquisition of creameries, cold rooms, stainless steel tubs, and/or burners.
[b] Technical assistance to improve hygienic conditions at milking and reduce transportation time of milk from farm to cheese factory.
[c] Includes improving hygienic conditions of the artisan cheese factory and packaging of product.

The third need identified in Honduras was the lack of technical assistance to produce new types of cheeses and thus diversify the market, and not so much the search for new markets for the same types of cheeses. In Nicaragua, the need was to improve the quality of cheeses produced by artisan factories.

Technological Implications

The results of this survey have two types of technological implications for the Tropileche Consortium: animal feeding and genetic improvement of animals.

Regarding animal feeding, these results suggest that an aggressive program to promote the shrub legume *Cratylia argentea* and sugarcane as supplements of cattle herds during the dry season would have a much higher impact than the promotion of grasses or legumes during the rainy season. This technological change would reduce the need to purchase feed concentrates to supplement the herd, thus improving the cash flow of producers and increasing milk fat content.

The protein contained in milk is the main input to produce cheese. In other words, milk with higher protein content yields more cheese. It is estimated that for each 0.1% increase in protein content, cheese yield is increased by 4% (Sozzi, 1999).

Therefore, the other technological implication of improving yield efficiency of cheese making is by using milk with higher protein content, and this is mainly achieved by genetic improvement of animals at the farm level by crossbreeding with cows that produce milk with higher protein content. The type of livestock commonly found in Honduras and Nicaragua is Zebu (Brahman). The protein content of *Bos indicus* breeds such as Brahman, Guzerath, and Nelore is 3.10%, with little variability among them. In *Bos taurus* breeds variability is greater, ranging from 3.15% for Holstein cows, to 3.50% for Brown Swiss cows, to 3.80% for Jersey cows (Ruiz, 1999). As a result, a genetic improvement strategy that incorporates Jersey or Brown Swiss genes into the local Zebu gene pool would allow producers to offer artisan cheese factories milk with higher protein content, provided that a transparent payment system that values milk protein exists.

Conclusions

Study results and the implications of this analysis led to the following conclusions:

- The main buyer of the milk produced by small and medium producers in Honduras and Nicaragua is the small-scale artisan cheese industry.

- The production of milk in watersheds in the dry tropics where the Tropileche Consortium operates is seasonal. Production during the rainy season is practically twice that of the dry season, causing over-supply during the rainy season and scarcity of milk during the dry season. The milk shortage during the dry season in both countries leads to an unsatisfied market potential. Of artisan factories in Honduras, 55.5% would be willing to buy more milk during the dry season, and of those in Nicaragua, 75.7%, but this supply is not available because of the lack of adoption of technologies for animal feeding based on low-cost improved forages.

- The above situation suggests that an aggressive program to promote the use of shrub legume *C. argentea* with sugarcane to supplement the milking herd during the dry season would have greater impact than the promotion of grasses and legumes for the rainy season. This technological change would reduce the need to purchase feed concentrates to supplement the herd, thus improving the cash flow of producers and increasing milk fat content.

- Artisan cheese factories in both countries, but especially in Honduras, require higher quality milk, particularly during the rainy season. In Honduras these factories would be willing to pay 9.4% more during the dry season and 11.2% more during the rainy season. In Nicaragua the artisan factories would be willing to pay 17% more, but only during the rainy season.

- The main need of artisan cheese factories was the improvement of infrastructure by purchasing more equipment. Future prospects for the industry seem promising in both countries. The second most important need in Honduras was to produce and purchase milk of higher hygienic quality, while in Nicaragua the second most important need was the search for new markets. The third most important need in Honduras was the lack of technical assistance to produce new types of cheese to diversify the market, while in Nicaragua it was the improvement of the quality of cheese produced.

- The amount of milk necessary to produce each type of cheese varied depending on the season of the year. During the rainy season, milk production/cow was higher but contained less total solids and, as a result, more milk was required to yield the same amount of cheese as during the dry season.

A genetic improvement strategy that incorporates Jersey or Brown Swiss genes into the local Zebu gene pool will allow producers to offer artisan cheese factories milk with higher protein content, provided that a transparent payment system that values milk protein exists.

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Activity 3.2 Dissemination of research results

Highlights

- The dissemination of results is an integral part of the research and development process and is essential in the adoption of new technologies.

Tropileche Newsletter

Federico Holmann
CIAT-ILRI, Colombia, and national institutions in Peru, Costa Rica, Nicaragua, and Honduras

The Tropileche Consortium has published 10 issues of the Tropileche newsletter. Publication dates are March and October. This newsletter aims to inform our partners about the activities of the Consortium, on-going research trials, research results at the different benchmark sites, and any other news that could prove useful for our readers. The printed newsletter is distributed to those interested and can also be consulted on Internet at the Tropileche web site: http:/www.ciat.cgiar.org/tropileche/start.htm.

Database on Dual-Purpose Cattle Production Systems

Anderson Medina and Federico Holmann
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In October 1996 the Tropileche Consortium developed a database that contains the results of research conducted on dual-purpose cattle systems in tropical Latin America since 1960. Topics covered are nutrition and feeding, forages (grasses and legumes), genetic improvement of animals and reproduction, animal health, economics, and extension, transfer, and adoption of technology.

The database currently contains about 2,260 references, all with basic descriptors; about 70% also include an abstract. This database was developed in Micro CD/ISIS and follows the guidelines of FAO's AGRIS-CARIS information system. The database can be accessed on Internet at the Tropileche web site (http:/www.ciat.cgiar.org/tropileche/start.htm). Over the last two years, an average of 139 users consulted the database each month.

Tropileche on Internet

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The Tropileche Consortium has developed its own web site, which contains the newsletters produced and the database on research results generated in tropical Latin America. Users can access the web site at http:/www.ciat.cgiar.org/tropileche/start.htm, by clicking on the icon "Soils and Systems" or through the "Information and Documentation Unit".

The web site also offers a list of researchers in dual-purpose cattle production systems in Latin America and the Caribbean, with contact addresses. All those interested can access the database and read about the Consortium's activities. Users may also request information, and communicate and interact with other colleagues.

Videotape Production

Federico Holmann[1], Carlos Lascano[1], Pedro Argel[1], and R. Goyenaga[2]
CIAT, Colombia (1), and MAG, Costa Rica (2)

As part of Tropileche's strategy to diffuse information about technology adoption by farmers, the Consortium, with the collaboration of the Communications Department of the Ministry of Agriculture of Costa Rica, produced an 11-minute videotape on the evolution of a dual-purpose farm, owned by Antonio López, in the dry tropics of the Central Pacific region of Costa Rica.

Antonio is a small farmer and one of the Consortium's collaborators who has adopted many of the technologies promoted by the Consortium through Costa Rica's Ministry of Agriculture and Livestock Production (MAG). Antonio is currently producing more milk on less area, he has doubled the family income, and has released areas from livestock production which are now protecting the farm's water sources.

This videotape will be used to show other producers in Costa Rica and elsewhere in Latin America how one small farmer succeeded in intensifying production with new forage technologies, based on improved grasses and legumes, with the technical assistance of MAG and seed donated by the Tropileche Consortium.

Production of Brochures for Extension Agents

As part of a strategy to disseminate information on the new technologies being adopted by producers, the Tropileche Consortium, in collaboration with the Communications Department of Costa Rica's Ministry of Agriculture and Livestock Production, published two brochures for agricultural extension agents. These brochures aimed to explain, in simple terms, the knowledge acquiered about the establishment and management of the shrub legume *Cratylia argentea* and the grass *Brachiaria brizantha* CIAT 26110 cv. Toledo, and their impact on livestock productivity. Summaries of these publications follow.

Cratylia argentea: A Shrub Legume for Livestock Production in the Tropics

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CIAT, Colombia (1), and ECAG (2) and MAG (3), Costa Rica

Cratylia argentea (synonyms = *C. floribunda, Dioclea floribunda*) is a shrub legume that are evaluated and selected by the MAG, ECAG, UCR, and CIAT for its adaptability to prolonged dry seasons and acid soils in Costa Rica.

Description

Cratylia argentea is a shrub that grows naturally in Brazil. Its distribution ranges, in a north-south direction, from the State of Pará to the States of Mato Grosso and Goiás and, in an east-west direction, from the State of Ceará to Peru. The shrub is between 1.5 and 3.0 m high when it grows in the open, but becomes a climbing liana when associated with larger plants.

Adaptation

Cratylia argentea grows naturally at altitudes between 0 and 930 masl, although most individuals are found between 300 and 800 masl. In Costa Rica, this legume adapts well to a broad range of climates and soils, particularly to subhumid climates and to acid Ultisols, which are poor soils with high aluminum content. Even so, the plant responds to fertile soils, and the highest yields have been reported from fertile sites in the humid tropics. Nevertheless, the shrub does not tolerate poorly drained sites or heavy soils that are frequently saturated in rainy seasons. The shrub has an outstanding capacity to regrow and shows high foliar retention during dry seasons. A major reason is the development of vigorous roots that can be as long as 2 m. Thus, between 30% and 40% of the total DM yield can be produced during that critical period of the year—the dry season.

Pests and Diseases

So far, neither pests nor diseases of economic importance have been reported in *C. argentea.* At some sites, isolated cases of plant death have been observed during establishment. The causal agents were “jobotos” or dung beetles (*Melolonthidae* sp.) in the soil, crickets, and leaf-cutting ants. For adult plants, isolated cases of death have also been reported from sites with heavy soils and frequent rains. Roots of infected plants have been found to carry fungi of the genera *Pythium* and *Fusarium*, although these were not proven to be the direct cause of mortality. In other similar cases of plant death, nematodes were found near the stem crown. Pod blight, caused by the fungal genera *Phoma* and *Cladosporium*, has been observed when flowering and fruiting occur under rainy conditions with high relative humidity.

Planting

Cratylia argentea propagates easily through seed, whereas vegetative propagation through stakes has, so far, not been successful. Because seeds are soft they do not need scarifying, but they need to be sown close to the soil's surface, that is, no more than 2 cm deep. Deep sowing causes seed rot, retards seedling emergence, and produces plants with less developed root systems. Sowing may be direct into the field with minimum tillage or after conventional land preparation with plow and harrow. Seeds may also be sown in bags for later transplanting to the field. Depending on soil fertility, fertilization is, ideally, with phosphorus (100 to 150 kg/ha of triple superphosphate).

Cratylia argentea seeds respond to inoculation with the strains of the cowpea type of *Rhizobium*, which are very common in tropical soils. Recent experiments show that the legume responds well to effective nodule formation by *Rhizobium* strains CIAT 3561 and 3564, particularly in acid soils with high aluminum content.

Cratylia argentea grows slowly, at least during the first 2 months after sowing, even though its seedlings are more vigorous than those of other shrubby legumes.

Seed Production and Quality

Flowering in *C. argentea* is abundant but poorly synchronized and starts at the end of the rainy season in the lowland tropics. Plants can flower the first year they are established, but seed yields are low. Flowering lasts 3 months and pollinating insects are commonly seen around the flowers. First fruits are mature about one and a half months after pollination, and fruiting continues through the next 2 or 3 months. Harvesting seed is therefore a continuous process, carried out manually, once a week, throughout most of the dry season (February and March).

Seed yield depends on genotype, plant age, cutting management, and prevailing environmental conditions during flowering and fruiting. In Atenas, Costa Rica, 3-year-old plants, cut at 30 cm height, and fertilized with phosphorus at the beginning of the rains, yield, on the average, 50 to 70 g of pure seed/plant (CIAT, 1999). However, the date of the uniformity cut affects first flowering and, as a result, the potential seed yield. Plants cut toward the end of the rainy season or within the dry season tend to flower little, forming few fruits.

Cratylia argentea seed does not have marked physical (due to hardness of seed coat) or physiological dormancy, and can lose its viability relatively quickly if it is stored under the temperature and humidity conditions prevailing in the lowland tropics.

Nutritive Value

The usable forage of 3-month-old *C. argentea* (leaves + thin and tender stems) has a CP content of 23%, but this figure varies from 19% to 26% according to the plant's age. Similarly, the *in vitro* dry matter digestibility of *C. argentea* ranges between 40% and 55%, which is higher than that of other shrub legumes adapted to acid soils, such as *Codariocalyx giroides* (30%) and *Flemingia macrophylla* (20%). The high percentage of CP and the low content of condensed tannins found in *C. argentea* make this legume an excellent source of nitrogen for the ruminant (Wilson and Lascano, 1997).

Use and Management

Cratylia argentea has shown that it is an excellent protein supplement in diets for dairy cows grazing poor quality grasses during the dry season. The highest response has been from cows with medium and high dairy potential and fed the legume as fresh and chopped or as ensiled, together with high-energy sources such as sugarcane. For example, for Jersey cows, as much as 66% of commercial concentrate can be replaced by *C. argentea*, either fresh or ensiled, without significant loss in milk production. The ensiled diet tends toward higher fat than does the fresh-legume diet (Romero and Gonzalez, 2000). Similar results have been reported for dual-purpose cows, which were offered a daily diet of 12 kg of chopped sugarcane, 6 kg of chopped or ensiled *C. argentea*, and 0.6 kg of rice polishings (Table 1) (Lobo and Acuña, 2000). Of the three supplements, fresh *C. argentea* was the most economical, because of its lower costs and the cows' significantly higher milk production.

Cratylia argentea can also be used in direct grazing ("browsing"), with the legume either established as a protein bank or planted in bands within the paddocks. Experiment results showed that grazing cows having access to a bank of *C. argentea* consumed more mature foliage and less immature forage. A major advantage of this legume, therefore, is that, in direct grazing systems, its use by ruminants can be deferred to the dry season. No other management practices need be followed.

Table 1. Average milk production of dual-purpose cows given supplements of either chicken manure or of the legume *Cratylia argentea*, offered either fresh or ensiled, during the dry season on a farm in Esparza, Costa Rica.

Diet[a]	Milk (kg/cow per day)	Fat (%)	Cost of supplement/cow per day (US$)	Cost:benefit ratio
Ensiled *Cratylia*	5.1	3.6	0.164	1.6
Fresh *Cratylia*	5.5	3.4	0.109	2.4
Chicken manure	5.3	3.0	0.217	1.1

a. Chicken manure, sugarcane, and rice polishing were each offered at 3 kg/cow per day. Fresh *C. argentea* contained 20.0% CP and 1.8 Mcal of ME, while the ensiled legume had 16.5% CP and 1.9 Mcal ME. The pH for ensiled *Cratylia* was 4.5 and digestibility was 36%.

In evaluations where cuts were made every 8 weeks during the rainy season and every 12 weeks during the dry season, *C. argentea* responded very well. Adult plants that were more than 1 year old had the highest yield and quality of forage when cut at 90 cm and after the respective 60 days' regrowth (Lobo et al., unpublished data). Total yield can range between 2 and 4 t DM/cut, although this depends on sowing density and the plant's age. A sowing density of 1.0 × 0.5 m gave the highest yield/ha when planting *C. argentea* as protein bank. The legume's good response to cutting shows the high potential that it has for "cut-and-carry" systems.

Limitations

Cratylia argentea does not adapt well to climates found above 1200 masl—at least, the most advanced ecotypes being evaluated (CIAT 18516 and CIAT 18668) do not. This legume establishes slowly, but more quickly than do other shrub legumes. The forage yields are also low during the first year of establishment.

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Brachiaria brizantha CIAT 26110: Cultivar Toledo

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In October 2000, the Costa Rican Ministry of Agriculture and Livestock Production (MAG, its Spanish acronym) released for farmers´ use the new cultivar Toledo (*Brachiaria brizantha* CIAT 26110). This material was officially released during a field day in which 250 farmers, professionals, and seed producers of the region participated. Research that led to the development of this new cultivar began in 1988 with the introduction of experimental seed from the International Center for Tropical Agriculture (CIAT) in Colombia. Research was coordinated by the Tropileche Consortium in Costa Rica, with the participation of MAG, the Escuela Centroamericana de Ganadería (ECAG), the Tropical Center for Agricultural Research and Training (CATIE, its Spanish acronym), the University of Costa Rica, and CIAT.

Origin and Morphology

The accession *Brachiaria brizantha* CIAT 26110 was collected in Burundi, on 15 May 1985 by G Keller-Grein of CIAT in collaboration with technicians from the Institut des Sciences Agronomiques du Burundi (ISABU). The collection site was at 2°53' S and 26°20' W, at 1,510 masl, and an average annual rainfall of 1,710 mm. The site was located between on Km 36 between Bubanza and Bukinanyama in the State of Cibitoke. In October of the same year, this accession was registered as CIAT 26110 in the germplasm bank held at CIAT. The accession was introduced into Costa Rica in 1988 for evaluation with other *Brachiaria* species at Los Diamantes experiment station in Guápiles, according to the cooperative agreement between MAG, CATIE, ECAG, and CIAT´s former Tropical Forages Program.

Cultivar Toledo was derived directly from the *B. brizantha* accession CIAT 26110. It is a perennial grass that develops in form of tillers, and can grow as high as 1.6 m. It produces vigorous stalks that root at the nodes if these should come into close contact with the soil through, for example, trampling by animals or mechanical compaction, thus favoring soil cover and lateral displacement of the grass. Leaves are lanceolate, with little pubescence, and can be 60 cm long and 2.5 cm wide. The inflorescence is a panicle, 40 to 50 cm long. It usually carries four racemes, ranging from 8 to 12 cm in length and each carrying a single row of spikelets. One stalk can produce several inflorescences, each growing from a different node, although the largest is always at the terminal.

Adaptation and Dry Matter Yields

Cultivar Toledo adapts to a broad range of climates and soils, and grows well, not only in subhumid tropical sites with a 5-to-6-month dry season but also in humid tropical sites with an average annual rainfall of 4,300 mm. This characteristic was observed in the agronomic trials carried out at 11 sites in Colombia by the Colombian *Brachiaria* Evaluation Network. Although the grass grows well in low-fertility, acid soils, it performs better at sites where soils are of medium to good fertility. It tolerates sandy soils and poorly drained sites, although growth is reduced if the soil is waterlogged for more than 30 days. It also tolerates the dry season well, maintaining a higher proportion of green leaves than other *B. brizantha* cultivars such as Diamantes 1 (Marandú) and La Libertad. The higher greenery is probably a result of the high leaf tissue content of nonstructural carbohydrates (197 mg/kg of DM) and few minerals (8% of ash) in cultivar Toledo. This cultivar also grows well under shade and, in Costa Rica, at mid-altitudes (1500 masl) where temperatures average 18°C.

Biomass production of cultivar Toledo was high in Inceptisols in Costa Rica and Panama, located at sites with contrasting climate, both during the rainy and dry season. Average production of cultivar Toledo across 11 contrasting sites in Colombia, with cuts every 8 weeks, was about 3.88 t of DM/ha for the dry season and 5.1 t of DM/ha for the rainy season. These yields were higher than those of other *Brachiaria* accessions evaluated at the same sites and under similar management conditions.

Planting

Cultivar Toledo is easily established by means of its seed, which are of good quality and give rise to vigorous seedlings. It can also be propagated vegetatively but, for best results, splits should be used.

Seeds can be broadcast or sown in furrows that are spaced at 0.6 m. The land may be conventionally prepared with plow and harrow, or the cover vegetation is controlled with nonselective herbicides according to zero tillage practices. The amount of seed to use depends on its quality (purity and germination rate) and on the sowing method. For example, sowing in plowed and harrowed furrows requires smaller quantities of seed, compared with sowing by broadcast on land receiving zero or minimal tillage. The final quantity of seed used can range between 3 and 4 kg/ha for seed classified at 60% (e.g., 80% purity and 75% germination rate).

The high vigor of seedlings of cultivar Toledo and their initial aggressive growth allows this cultivar to compete adequately with weeds during establishment. Consequently, the collective experiences of farmers already growing this cultivar in Costa Rica is that the grass can be first grazed 3 to 4 months after sowing.

Nutritive Value and Animal Production

Evaluations carried out at ECAG in Atenas showed that CP contents of leaves are 13.5%, 10.1%, and 8.7% for the regrowth ages of 25, 35, and 45 days, respectively. The *in vitro* dry matter digestibility values for the same ages were, respectively, 67.8%, 64.2%, and 60.3% . These results suggest that cultivar Toledo has similar or slightly better forage qualities than do other *B. brizantha* cultivars.

Observations made on farms in Costa Rica and information provided by cattle producers indicate that cultivar Toledo can support a stocking rate between 2.5 and 3.0 AU/ha during the rainy season, with a frequency of grazing every 21-30 days. One dual-purpose farm reported that daily milk production tended to be similar to that observed for pastures of other *Brachiaria* species in association with the forage peanut (*Arachis pintoi*). Initial reports from Colombia indicate that the daily milk production of a Holstein cow is significantly less on cultivar Toledo (8.0 L/cow) than on *B. decumbens* cv. Pasto Peludo or *B. brizantha* cv. Diamantes 1 (8.8 and 8.9 L/cow, respectively).

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Use and Management

So far, cultivar Toledo has been used only for grazing cattle, although horses have been seen to consume tender leaves. Although little is known about the most adequate occupation and rest periods, considering its rapid recovery, an adequate rest period could be between 21 and 28 days. In addition, this cultivar's high forage production allows stocking rates higher than 2.5 AU/ha, at least during the rainy season.

Because of its growth habit in form of tillers, this cultivar associates well with stoloniferous legumes such as *Arachis pintoi*, resulting in better soil cover and improved forage quality. These observations are still being evaluated in Costa Rica. Although cv. Toledo is adequate for grazing, because of its size and vigorous growth, it could be successfully used in "cut-and-carry" forage systems.

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Published in October 1996; March and October 1997; March and October 1998; March and October 1999; March and October 2000; and March 2001.

LIST OF PROJECT PROPOSALS DEVELOPED

Title	Amount requested (US$)	Duration (years)	Donor
Evaluation of options to develop the dairy sector of tropical Latin America	480,000	3	Fontagro
Integrating the conservation of biodiversity and smallholder livestock systems in sub-humid tropical landscapes	540,000	3	CRUSA & SLP
Improving dual-purpose livestock production systems in Nicaragua	1, 940,000	3	Norway
Improving the productivity of smallholder dairy farms in Central America and the Caribbean	1,470,000	3	IDB
Improving dual-purpose livestock production systems based on improved legumes in the coastal areas of Ecuador	189,000	3	PROMSA/ World Bank
Developing new forage technologies for smallholder dairies in the Alto Mayo region of the Peruvian Amazon	50,000	2	Peru

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