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# Yield Performance of Forage Shrubs and Effects on Milk Production and Chemical Composition under the Tropical Climatic Conditions of Peru

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**Abstract:** Forage shrubs have the potential to substantially contribute to pasture and increase the milk production of cows in tropical environments. The yield performance of forage shrubs and its effects on the production and chemical composition of milk in *Bos indicus* and *Bos taurus* crossbred cows in the tropics of Peru were studied. Fifteen cows were divided into *M. alba*, *L. leucocephala*, *M. oleifera*, and *C. argentea* treatments and only one of *B. brizantha* (control). Analysis of variance ($p < 0.05$) and comparison of means with Tukey's test were performed. The highest plant height, stem diameter, fresh forage, and dry matter were observed in *L. leucocephala* and *M. oleifera*. The highest milk production was observed in cows fed *B. brizantha* with *M. alba*, and the highest milk production was in the rainy season. The highest concentration of fat and total solids was observed in milk from cows fed *B. brizantha* with *L. leucocephala*. The highest utility was observed in cows fed *B. brizantha* with *M. alba*; however, the highest operational profitability was observed in the treatment of only *B. brizantha* and *B. brizantha* with *L. leucocephala*. The use of forage shrubs can contribute to cattle feeding, especially in the dry season when there is a shortage of pastures, and possibly contribute to improving the soil and overcoming climate change.

**Keywords:** sustainable livestock; forage shrubs; milk production; profit and profitability; Peruvian tropics

## 1. Introduction

The growth of the human population and the increase in income in underdeveloped countries have stimulated the increase in the demand for animal protein. In 2020, it was estimated that these countries consumed 223 million metric tons of milk, more than in 1993 [1], and by 2050, an increase of 58% in consumption of dairy products is estimated compared to current values [2]. In this sense, livestock activity plays an important role in the economy of producers in Latin America [3], but until now, production indicators have continued to remain unchanged, having negative repercussions on the economy of producers [4]. The negative repercussions are due to the disadvantages that occur in old livestock systems, such as monocultures that provide a reduced quantitative and qualitative offer of grasslands, constant droughts, and the loss of organic matter and soil biodiversity [4,5].

A challenge of sustainable livestock is to improve the existing trend with the implementation of efficient and sustainable systems over time that allow us to cover the nutritional deficit of livestock and reduce the production of greenhouse gases [6,7]. All tropical grasses of the grass family have protein contents of less than 12% that do not gather the nutritional requirements of the animal; however, this can be balanced by supplying forages and shrubs in the diet that have a protein content greater than 15% [8]. A high number of forage woody species have the potential to produce plant biomass that serves as feed for cattle in silvopastoral systems and could help mitigate the effects of climate change and nutritional deficiencies in dry areas [9,10]. Tree forages are used in cattle diets to dilute the starch content in the ration, prevent acidosis, and regulate methane production in the rumen [11]. Feeding ruminants in intensive production systems for dairy production requires the supply of very high levels of energy and protein [12]. Most tree forage species have ecological plasticity because they are found in different soil conditions, precipitation, and temperature [13]. Therefore, its use in the diet of dairy cows in silvopastoral systems could improve the balance and use of the energy contained in it and, consequently, optimize milk production and quality [14].

Cattle raising is one of the main economic activities in the San Martín region (Peru), with the use of natural and introduced grasses, with good initial performance, but which decreases due to inadequate management of overgrazed soils. The development of livestock activity using woody, weedy, and climbing species in association with pastures is an alternative that should be promoted in the different livestock areas, especially in the tropics, due to its great plant biodiversity [15]. Over the years, research has been carried out on efficient and sustainable alternatives, such as the identification of species such as grasses, legumes, and weeds, among others, that have good agricultural potential, production, and nutritional quality [15]. However, these species have a different behavior according to the geographical area and agroclimatic conditions, among other factors [16]. Under this perspective, it was proposed (i) to analyze the yield performance of four forage shrub species for animal feed, (ii) to determine milk production in Gyr with Brown Swiss crossbred cows fed with four forage shrub species, (iii) to analyze the lactic acid, fat, and total solids of milk from Brown Swiss cows fed with four forage shrub species at two times of the year, and (iv) to analyze the economic and profitability indicators.

## 2. Materials and Methods

### *2.1. Site and Experimental Design*

The experiment was carried out in the paddocks of the National Institute of Agrarian Innovation, Fernando Belaunde Sur Highway Km 14—Juan Guerra District, San Martín Province, Peru (6°35′42″ S, 76°18′24″ W; 205 m altitude). The temperature and precipitation are detailed in Figure 1. January to June was the rainy season, and July to December was the dry season. The temperature and precipitation values were taken from SENAMHI (https://www.senamhi.gob.pe/?p=seasons (accessed on 14 May 2022)).

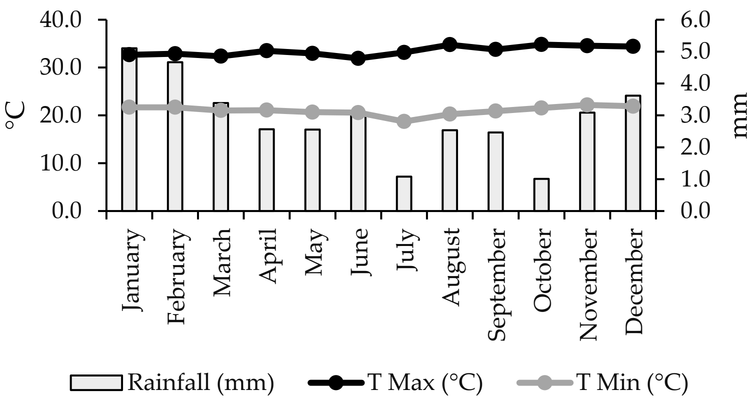


**Figure 1.** Temperature and precipitation during the experimental period.

Each treatment contained only one forage shrub species and the pasture *Brachiaria brizantha* cv. The treatments were as follows: (i) Morera (*Morus alba*), (ii) Leucaena (*Leucaena* *leucocephala*), (iii) Moringa (*Moringa oleifera*), (iv) Cratylia (*Cratylia argentea*), and (v) a no-forage shrub, grass only control (*B. brizantha*). Three replicates were established for each treatment for a total of 15 experimental plots in a randomized blocked experimental design. In each replica plot of *L. leucocephala* and *M. oleifera* containing a woody treatment, a total of 100 woody forages were arranged in three 1 × 2 m plots, and for *M. alba* and *C. argentea* containing a woody forages treatment, a total of 65 woody forages were arranged in three 1.5 × 2 m alleys with pasture grass. Stands of *L. leucocephala*, *M. oleifera*, and *C. argentea*. were established from locally collected seeds and *M. alba* planted from 40 cm stakes 2 years prior to the experiment (Figure 2).

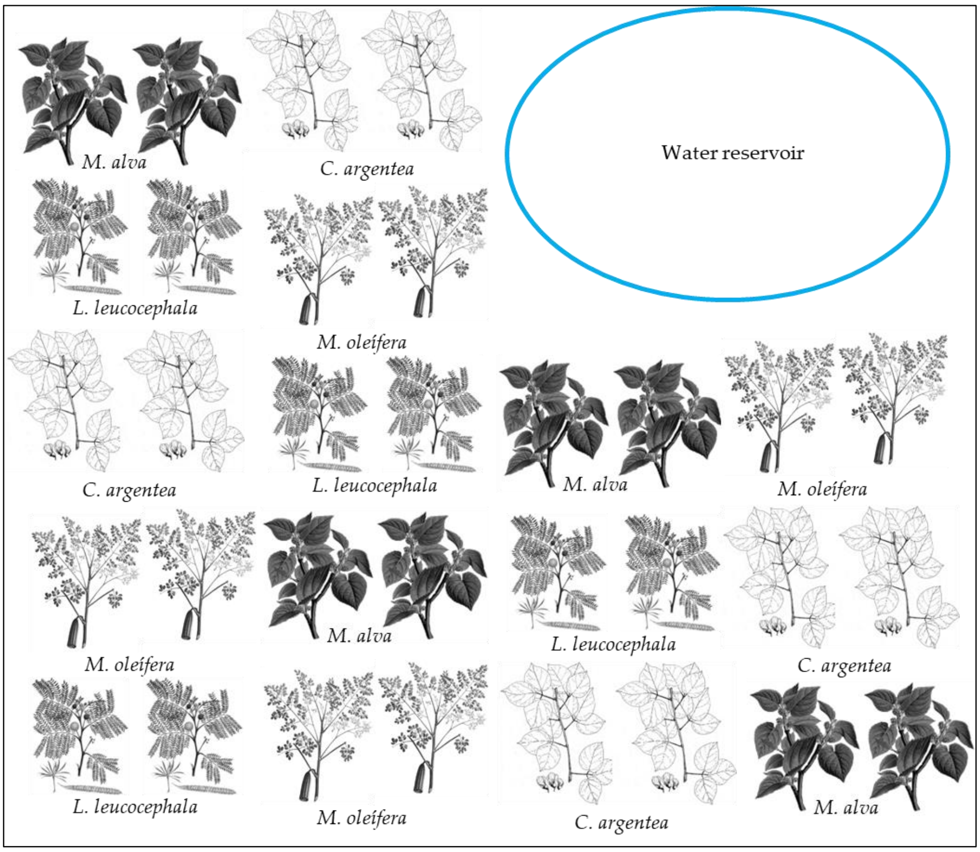


**Figure 2.** Distribution of forage shrub species treatments.

Fifteen Gyr with Brown Swiss crossbred cows that were visually estimated to have the same size, age, and body condition were selected for the experiment. The cows were initially placed in a training corral where they had a 30-day period of acclimatization [17]. The cows were housed according to treatment, the forage shrubs were cut and offered twice a day (6:00 a.m. and 16:00 p.m.), and water was supplied ad libitum. The experiment began on January 2018 and concluded on December 2018.

### *2.2. Forage Measurements and Milk Production*

Plant height was measured from the base of the stem to the top of the forage shrubs with a winch, and stem diameter was measured using a forestry millimeter tape. For the fresh matter, 10 plants per treatment were randomly selected, and only the edible matter (leaves and succulent stems) was weighed. For the dry matter, 250 g were weighed and brought to 60 °C in an oven until a constant weight was obtained [18].

Milk production was recorded for each treatment. Milking was performed at 2:00 a.m. and 12:00 p.m. In the milk register, the breed, age, parents, and date of birth of each individual were described. For the analysis of total solids, fat, and acidity, individual samples were taken from each treatment and determined according to the AOAC [19]. The profitability was determined by following the method of Cacep et al. [20]. All procedures respected international standards for animal experimentation and animal welfare (Peruvian National Law No. 30407: "Animal Protection and Welfare").

### 2.3. Data Analysis

The data was processed in a completely randomized design, and data were checked for normality with Shapiro–Wilk and variance with Levene's test. Analysis of variance ($p < 0.05$) and comparison of means with Tukey's test were performed. All statistical tests were carried out in IBM® SPSS vs. 26.

## 3. Results

### 3.1. Productive Performance of Forage Shrub Species

The plant height, stem diameter, fresh forage, and dry matter significantly varied across treatments ($p < 0.05$) (Table 1). For plant height, *L. leucocephala* and *M. oleifera* were similar in height, but they were superior to *C. argentea* and *M. alba*. The stem diameter varied according to forage shrub species; *M. oleifera* showed a greater diameter compared to the other species. *L. leucocephala* and *M. alba* were statistically similar in stem diameter but higher than *M. oleifera*. Fresh forage production varied significantly according to forage shrub species ($p < 0.05$). *L. leucocephala* produced approximately 5.1 t/ha more than *C. argentea* and *M. alba* and approximately 2.0 t/ha more than *M. oleifera* (Table 1). A similar effect was observed in dry matter production; *L. leucocephala* showed superiority in dry matter production compared to the other forage shrub species ($p < 0.05$).

**Table 1.** Productive performance of four forage shrubs in dry and rainy season [1].

| Item | Plant Height (cm) | Stem Diameter (cm) | Fresh Forage (t/ha) | Dry Matter (t/ha) |
|---|---|---|---|---|
| Forage shrub | | | | |
| *L. leucocephala* | $223.67 \pm 31.8_{a}$ | $3.79 \pm 1.3_{ab}$ | $8.84 \pm 2.8_{a}$ | $2.67 \pm 0.8_{a}$ |
| *M. oleifera* | $235.83 \pm 21.9_{a}$ | $5.27 \pm 2.0_{a}$ | $6.85 \pm 2.1_{ab}$ | $1.54 \pm 0.7_{b}$ |
| *C. argentea* | $141.83 \pm 25.3_{b}$ | $2.50 \pm 0.8_{b}$ | $4.31 \pm 1.9_{bc}$ | $1.37 \pm 0.6_{b}$ |
| *M. alba* | $144.83 \pm 31.4_{b}$ | $3.87 \pm 2.4_{ab}$ | $3.24 \pm 2.7_{c}$ | $0.97 \pm 0.8_{b}$ |
| *p*-value | 0.0002 | 0.0004 | 0.0001 | 0.0002 |
| Dry | | | | |
| *L. leucocephala* | $209.0 \pm 41.9_{a}$ | $2.79 \pm 0.7_{ab}$ | $6.83 \pm 2.5_{a}$ | $2.21 \pm 0.9_{a}$ |
| *M. oleifera* | $229.3 \pm 24.9_{a}$ | $3.41 \pm 0.3_{a}$ | $5.48 \pm 1.4_{ab}$ | $1.23 \pm 1.0_{ab}$ |
| *C. argentea* | $121.7 \pm 7.4_{b}$ | $1.84 \pm 0.4_{b}$ | $2.83 \pm 0.8_{bc}$ | $0.98 \pm 0.3_{ab}$ |
| *M. alba* | $119.8 \pm 21.5_{b}$ | $1.74 \pm 0.2_{b}$ | $0.77 \pm 0.4_{c}$ | $0.20 \pm 0.1_{b}$ |
| *p*-value | 0.002 | 0.003 | 0.005 | 0.050 |
| Rainy | | | | |
| *L. leucocephala* | $238.3 \pm 10.9_{a}$ | $4.80 \pm 0.9_{bc}$ | $10.84 \pm 0.9_{a}$ | $3.14 \pm 0.3_{a}$ |
| *M. oleifera* | $242.3 \pm 21.2_{a}$ | $7.13 \pm 0.3_{a}$ | $8.21 \pm 1.8_{ab}$ | $1.84 \pm 0.2_{b}$ |
| *C. argentea* | $162.0 \pm 18.0_{b}$ | $3.16 \pm 0.5_{c}$ | $5.78 \pm 1.4_{b}$ | $1.75 \pm 0.5_{b}$ |
| *M. alba* | $170.3 \pm 7.1_{b}$ | $6.00 \pm 1.2_{ab}$ | $5.71 \pm 0.2_{b}$ | $1.73 \pm 0.1_{b}$ |
| *p*-value | <0.0001 | 0.002 | 0.002 | 0.001 |
| Season | | | | |
| Dry | $169.83 \pm 56.9_{b}$ | $2.45 \pm 0.8_{b}$ | $3.98 \pm 2.8_{b}$ | $1.16 \pm 0.9_{b}$ |
| Rainy | $203.25 \pm 51.0_{a}$ | $5.27 \pm 1.7_{a}$ | $7.64 \pm 2.4_{a}$ | $2.12 \pm 0.7_{a}$ |
| *p*-value | 0.0012 | 0.0001 | 0.0001 | 0.0004 |

[1] Mean ± Standard deviation. Different subscripts indicate significant differences between treatments at $p < 0.05$ with Tukey's test.

In the dry season, the forage shrubs *L. leucocephala* and *M. oleifera* were taller than *C. argentea* and *M. alba* ($p < 0.05$). Plant diameter varied according to the forage shrub ($p < 0.05$), with *M. oleifera* showing superiority to *L. leucocephala*, *C. argentea*, and *M. alba*.

The production of fresh forage and dry matter was higher for *L. leucocephala*, and production was lower for *M. alba* (Table 1).

In the rainy season, the plant height, stem diameter, fresh forage, and dry matter varied between forage shrub species. *L. leucocephala* and *M. oleifera* showed similar growth but were superior to *C. argentea* and *M. alba*. *M. oleifera* had a higher diameter, and *C. argentea* had a smaller diameter. L. leucocephala doubled the production of fresh forage and dry matter compared to *M. alba* and *C. argentea* (Table 1). Finally, in the rainy season, higher productions of fresh forage and dry matter per hectare were observed ($p < 0.05$).

### 3.2. Milk Production

The average values of milk production according to treatment and by season are shown in Figure 3. The treatment of *B. brizanta* with *M. alba* achieved higher milk production compared to the cows that were fed *B. brizanta* and *B. brizanta* with *C. argentea* ($p < 0.05$). The cows with the lowest milk production were those that were fed only with *B. brizantha* and *B. brizantha* with *C. argentea*. The cows with the highest milk production were those that were fed *B. brizantha* with *M. alba* (Figure 3A). The highest milk production was observed in the rainy season compared to the dry season ($p < 0.05$, Figure 3B).

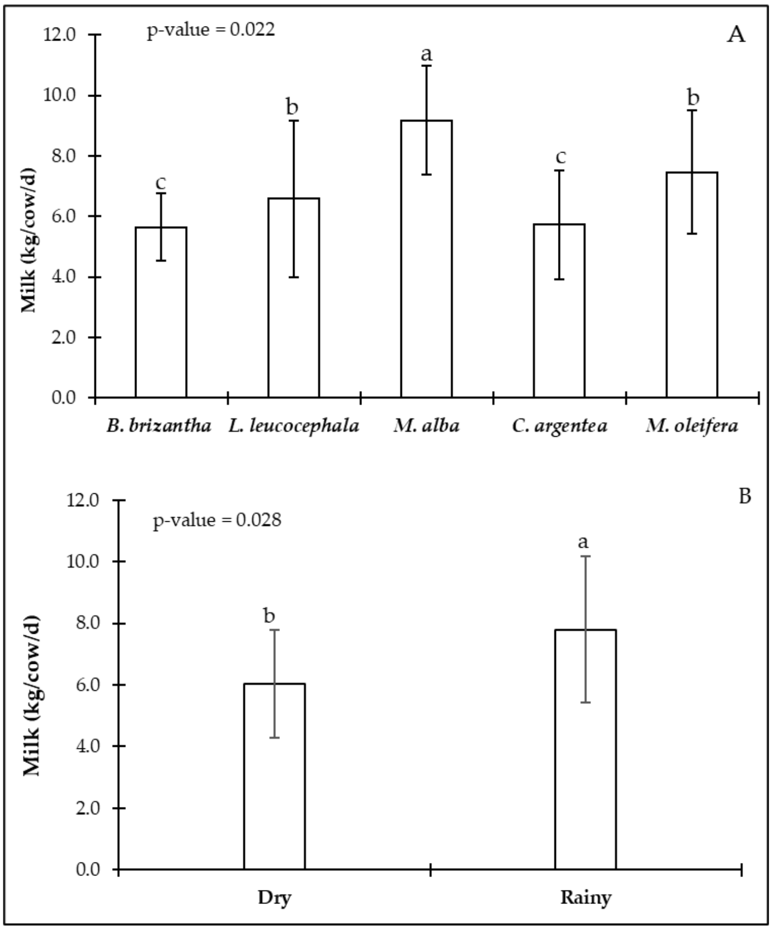


**Figure 3.** Milk production of cows (Mean ± Standard deviation) fed with forage shrubs in dry and rainy seasons. A: Production of cow's milk according to treatment. B: Production of cow's milk according to the season. a, b, c, in each subfigure indicate significant differences between treatments at $p < 0.05$ with Tukey's test.

### 3.3. Milk Components

Milk lactic acid levels varied between treatments ($p < 0.05$), and the average values are detailed in Table 2. Milk from cows fed *B. brizantha* with *M. oleifera* and *B. brizantha* with *L. leucocephala* presented higher levels of acidity. Milk fat concentration was higher in cows fed *B. brizantha* with *L. leucocephala*, and the lowest concentration was recorded in milk from cows fed *B. brizantha* with *C. argentea*. The lowest concentration of solids was recorded in the milk of cows fed *B. brizantha* with *C. argentea* compared to the other treatments. However, lactic acid, fat, and total solids were not affected when analyzed in the dry season compared to the rainy season ($p > 0.05$).

**Table 2.** Milk components of cows fed four forage shrubs in dry and rainy season [1].

| Item | Lactic Acid (%) | Fat (g/100g) | Total Solids (g/100) |
|---|---|---|---|
| Forage shrub | | | |
| *B. brizantha* | $0.14 \pm 0.003_{c}$ | $3.39 \pm 0.03_{c}$ | $11.62 \pm 0.04_{c}$ |
| *L. leucocephala* | $0.16 \pm 0.003_{ab}$ | $4.83 \pm 0.05_{a}$ | $14.02 \pm 0.03_{a}$ |
| *M. alba* | $0.13 \pm 0.01_{d}$ | $3.06 \pm 0.03_{d}$ | $11.49 \pm 0.33_{c}$ |
| *C. argentea* | $0.15 \pm 0.004_{bc}$ | $1.56 \pm 0.03_{e}$ | $10.41 \pm 0.21_{d}$ |
| *M. oleifera* | $0.18 \pm 0.01_{a}$ | $4.03 \pm 0.04_{b}$ | $12.57 \pm 0.36_{b}$ |
| *p*-value | <0.0001 | <0.0001 | <0.0001 |
| Season | | | |
| Dry | $0.15 \pm 0.02_{a}$ | $3.37 \pm 1.13_{a}$ | $12.07 \pm 1.23_{a}$ |
| Rainy | $0.15 \pm 0.01_{a}$ | $3.38 \pm 1.16_{a}$ | $11.97 \pm 1.36_{a}$ |
| *p*-value | 0.781 | 0.988 | 0.871 |

[1] Mean ± Standard deviation. Different subscripts indicate significant differences between treatments at $p < 0.05$ with Tukey's test.

### 3.4. Economic and Profitability Indicators

The higher utility was observed in the treatment of cows fed *B. brizantha* with *M. alba*, followed by the treatment of *B. brizantha* with *L. leucocephala*, and the least useful treatment was *B. brizantha* with *C. argentea*. However, the highest operational profitability was observed in the treatment of only *B. brizantha* and *B. brizantha* with *L. leucocephala*, and in these two treatments, a higher benefit/cost ratio was also observed compared to the other treatments (Table 3).

**Table 3.** Economic and profitability indicators.

| Concept | *B. brizantha* | *L. leucocephala* | *M. alba* | *C. argentea* | *M. oleifera* |
|---|---|---|---|---|---|
| Production (305 d) | 1720.7 | 2008.4 | 2800.9 | 1745.6 | 2277.3 |
| (+) Sales (USD) [1] | 637.3 | 743.9 | 1037.4 | 646.5 | 843.5 |
| (−) Costs (USD) | 424.9 | 502.1 | 760.7 | 484.9 | 625.6 |
| (=) Operating profit | 212.4 | 241.8 | 276.6 | 161.6 | 217.9 |
| Operating profitability [2] | 0.33 | 0.33 | 0.27 | 0.25 | 0.26 |
| Benefit/Cost ratio [3] | 1.5 | 1.5 | 1.4 | 1.3 | 1.3 |

[1] Whole milk sales (kg) × 0.37 USD, [2] Operating profit/sales, [3] Present value income/present value expenses.

## 4. Discussion

The height of *M. oleifera* and *L. leucocephala* were higher than the values of *C. argentea* and *M. alva*. These forage shrubs species (*M. oleifera* and *L. leucocephala*) exceeded 200 cm in height at 12 months of age [21,22]. The height of *L. leucocephala* was higher than that obtained by Anguiano et al. [23], who obtained a value of 138.28 cm under conditions of Colima, Mexico, with high planting densities under coconut woody forages at the height of 59 m above sea level. The diameter varied according to the forage shrub species, and a range from 1 cm to 6 cm was observed. Studies report stem diameters of 0.92 cm for *M. oleifera* and 0.62 cm for *L. leucocephala* at 14 weeks of age [24]. These dasometric indicators in forage shrub species are influenced by environmental parameters such as temperature. The height and diameter of the *L. leucocephala* forage shrub decreased at temperatures below 20 °C [25].

The production of fresh forage and dry matter varied according to the forage shrub species and season. Higher values of fresh forage were obtained in the rainy season compared to the dry season. The highest values were reported for *L. leucocephala* compared to the other species. Our records of fresh forage based on *M. oleifera* are lower than those obtained by Navas [26], who obtained fresh forage production of 12.08 t/ha. However, forage production can vary depending on humidity, temperature, and wind speed, as well as the type of fertilization, variety, density, and cutting height [27,28].

*L. leucocephala* produced more dry matter (2.67 t/ha) than the other forage shrub species. The values obtained in this investigation were lower than the 8.28 t/ha reported by Benítez-Bahena et al. [29] for *L. leucocephala* plus *B. brizantha* at a planting density of 2500 plants/ha. *M. oleifera* produced 1.54 t/ha of dry matter; however, this value is lower than that obtained by ref. [30], who obtained dry matter values of *M. oleifera* of 7.3 t/ha.

The analysis of plant height, stem diameter, fresh forage, and dry matter in the dry season varied between forage shrub species. *L. leucocephala* and *M. oleifera* were the two species that showed superiority over *C. argentea* and *M. alba*. Due to the limited forage production or inadequate handling of gramineous pastures, the sowing of alternative species such as *L. leucocephala* and *M. oleifera* would become alternatives to supply the lack of food for cattle. For a high biomass production of *L. leucocephala*, it is necessary to prune regularly, producing palatable, digestible, and nutritious foliage for ruminants and increasing feed intake and rumen fermentation [31]. The forage shrub *L. leucocephala* was used in the dry season [32]. It is dried to the foliage of *L. leucocephala* and used as hay to feed dairy cows in the dry season when there is a shortage of grass [33]. On the other hand, in the rainy season, *L. leucocephala* and *M. oleifera* also showed superiority in plant height, stem diameter, fresh forage, and dry matter compared to *C. argentea* and *M. alba*. Rengsirikul et al. [34] reported 139 cm plant height, 1.10 cm stem diameter, 3.75 t/ha of fresh forage, and 1.68 t/ha of dry matter in *L. leucocephala* plantations at two years of age. The establishment of *L. leucocephala* in tropical pastures is a good source of food for livestock, allowing greater availability of food and competing with weeds, which are problems in livestock systems. In the tropics and the rapid growth of the stem diameter of *L. leucocephala* is an advantage for producers who would cut these legumes at an early stage of development to use them as cattle feed [34,35].

Livestock productivity in the tropics is greatly affected in the dry season by low forage availability and quality [36]. In this study, in the analyses according to season, we found higher fresh forage and dry matter in the rainy compared to dry seasons. *C. argentea* is a legume that shows a potential source of supplementation in the dry season, especially in acidic soils and prolonged dry seasons [37]. Here, we evaluate *L. leucocephala*, *M. oleifera*, *C. argentea,* and *M. alba,* which demonstrate good dry matter production in both seasons.

Milk production varied according to the feed source the cows received. We observed higher milk production in cows fed with *M. alba,* lower production with *C. argentea*, and higher production in the rainy season. Our findings were lower (5.72 kg/cow per day, cows fed *B. brizantha* with *C. argentea*) than those found by Romero and Gonzáles [38], who reported milk yields of 10.9 kg/cow per day in Jersey cows fed Fresh *C argentea.* In addition, cows fed *M. oleifera* with *B. brizantha* produced 7.47 kg/cow per day, whose values exceed those of Reyes et al. [39], who recorded 5.07 kg/cow per day fed *B. brizantha* with *M. oleifera*. The forage of *M. oleifera* contains high amounts of protein, which is reflected in the milk production of cows [40,41]. In crossbred *Bos taurus* with *Bos indicus* cows, they obtained 14.1 L/cow per day when fed *L. leucocephala* [42]. Lamela et al. [43] used *M. alba* and *L. leucocephala* to improve milk production in *Bos taurus* and *Bos indicus* crossbred cows and obtained an average of 10 L/cow per day. *M. alba* and *M. oleifera* have higher nutritional value compared to *L. leucocephala*; in particular, supplement protein degraded within the rumen [44]. Our findings on milk production are acceptable and are above the average values for Latin America in cows fed in grazing systems (milk production ranges from 2 to 5 kg/cow per day) [45,46]. We found a variation in milk components according to the food source of the cows. Higher acidity was recorded in milk from cows fed *M. oleifera* and *L. leucocephala*. According to the NTP 202.001 of Peru, the minimum specification of acidity as lactic acid is 0.13 g/100 g, and the maximum is 0.17 g/100 g of milk [47]. The content of fat and total solids in this research was shown to be higher in cows fed *B. brizantha* with *L. leucocephala* compared to the other groups. Regarding the three milk components evaluated, similar results were found in previous studies with similar experimental conditions [38,48,49]. In milk from Jersey cows fed fresh *C. argentea*, 3.69% fat and 12.47% total solids were observed [38]. In Jersey crossbred cows with Central American Milking Creole grazed in silvopastoral systems of *Erythrina poeppigiana* associated with *Cynodon niemfuensis*, *Brachiaria rusisiensis*, *Axonopus compresus,* and *Paspalum conjugatum* pastures, and supplemented with sorghum, milk fat production was 42.2 g/kg, and total solids was 129 g/kg [48]. In Brown Swiss-Zebu crossbred cows grazed in intensive systems of *L. leucocephala* with *Cynodon nlemfuensis*, the concentration of fat in the rainy season was 3.3% and in dry was 3.7%, and total solids were 11.3% in rainy and 11.8% in dry [49].

The economic and profitability indicators of this research provide evidence of the economic benefits associated with the use of four forage shrub species (*B. brizantha* with *L. leucocephala*, *B. brizantha* with *M. alba*, *B. brizantha* with *C. argentea.* and *B. brizantha* with *M. oleifera*). The tendency to adopt and implement alternative protein banks and silvopastoral systems with forage shrub species in tropical regions of Latin America is increasing due to the economic benefits they generate in livestock due to the increase in the availability and quality of forage throughout the year [50,51]. However, in the Northern Peruvian Amazon, adoption of these systems has been slow despite low-cost food sources. Cow feeding provides additional benefits that are often unseen and unrecorded.

## 5. Conclusions

The highest plant height, stem diameter, fresh forage, and dry matter were observed in *L. leucocephala* and *M. oleifera*. The highest milk production was observed in cows fed *B. brizantha* with *M. alba*, and the highest milk production was in the rainy season. Lactic acid was higher in milk from cows fed *B. brizantha* with *M. oleifera,* but a higher concentration of fat and total solids was observed in milk from cows fed *B. brizantha* with *L. leucocephala*. The highest utility was observed in cows fed *B. brizantha* with *M. alba*; however, the highest operational profitability was observed in the treatment of only *B. brizantha* and *B. brizantha* with *L. leucocephala*.

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