Assessment of dry matter yield, nutritional value, and calf weight gain in Mombaza-Kudzu pasture associations

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ABSTRACT
Objective: To evaluate the biomass production, nutritional value and animal production of an association with fabaceae species and grasses with grazing calves.
Design/Methodology/Approach: The study compared Mombaza (*Megathyrsus maximus*) – Kudzu (*Pueraria phaseoloides*) association pasture against a Mombaza in monoculture control. Ten calves, five in each pasture type, were grazed in rotation for seven months. Dry matter yield, proportion of Kudzu in the association, protein, neutral detergent fiber (NDF), acid detergent fiber (ADF), ash, and daily weight gain were evaluated every 36 days.
Results: Dry matter yield did not differ between pasture types, but varied by sampling dates, being higher at the onset of the rainy season (May 20th). The proportion of Kudzu in the association was low, decreasing from 8.42% to 1.71% over the study period. Lignin content increased in the association during the driest month (April). Daily weight gain was 978 g in the monoculture pasture and 678 g/day in the association, with no significant difference.
Study Limitations/Implications: The low persistence of the fabaceae in the association limits the nutritional value of the pasture, consequently, the improvement of grazing animal production.
Findings/Conclusions: During the drought season, both pastures exhibited the highest protein concentration and the greatest weight gain at the beginning of this period. However, the association did not result in greater weight gains due to the low persistence of the fabaceae.

Keywords: *Pueraria phaseoloides*, dry matter yield, protein, grazing, animal production.

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INTRODUCTION

Natural pastures are the main source of feed in tropical areas. The humid tropics support grass growth most of the year due to frequent rains, however, there are drought periods, lasting 3 to 4 months, during which grass production can decrease by up to four times (Pardo *et al.*, 2020). This reduction in forage leads to changes in its nutritional value and a reduced stocking rate (Juárez *et al.*, 2011), necessitating adaptive pasture management (occupation/rest) to control usage and nutritional value. Seasonal forage distribution, nutritional value changes, and stocking rate cause fluctuations in weight gain or milk production. An alternative solution is pasture association of fabaceae species and grasses (Fabaceae-Poaceae). Pardo *et al.* (2020), reported that the *Urochloa humidicola* with *Arachis pintoi* association produced 0.8 t ha^{-1} more dry matter (DM) compared to

Humidicola in monoculture, and the association recorded 19.21 g kg^{-1} more protein than the monoculture. Diverse pastures achieve greater production stability, since forage species reach their phenological stages at different times (Prieto *et al.*, 2015). Fabaceae fix atmospheric nitrogen in the soil, allowing grasses greater access to nutrients, enhancing nutrition and tolerance in drought periods (Schmitz *et al.*, 2023). Fabaceae-grass associations also improve dietary nutritional value due to the high protein content of fabaceae, resulting in increased animal production (Brink *et al.*, 2008).

Few experimental studies with livestock exist in the humid tropics of Mexico, so information on the benefits and persistence of fabaceae within these associations in tropical climates is limited.

Therefore, this study aimed to determine the effect of grazing on biomass production and the nutritional value of fabaceae-grass association by assessing the daily weight gain of grazing calves at different times of the year.

MATERIALS AND METHODS

The study was established in 2019 and was conducted in 2020 at the "Las Margaritas" Experimental Site of the Instituto Nacional de Investigaciones Forestales Agrícolas y Pecuarias (INIFAP), located east in the state of Puebla (19° 45' N, 97° 27' W) at 450 meters above sea level. The soil was loam texture, high in OM (6.5%), in Fe (17.1 mg kg^{-1}), in Zn (0.10 mg kg^{-1}), Mn (7.13mg kg^{-1}) in Cu (0.79 mg kg^{-1}), and in Al (28.4 mg kg^{-1}), low in Mg (53.2 mg kg^{-1}), with apparent density of 1.1 g cm^{-3}, and acidic pH (5.9). The surface of the study was 3.0 ha. Secondary vegetation was removed through slash and burn. The main weed, *Paspalum virgatum*, was eliminated with the herbicide glyphosate (N-(phosphonomethyl) glycine) applying 1kg ha^{-1}. In June 2019, two types of pasture were established: monoculture and associated fabaceae-grass. Each type covered 1.5 ha separated by barbed wire. Grass and fabaceae seeds were sowed on lines drawn 1 m apart using minimum tillage, with 5.0 cm deep blows every 50 cm. The monoculture pasture consisted of *Megathyrsus maximus* var. Mombaza sowed at 7 kg ha^{-1}, while the associated pasture consisted of a mix of Mombaza (6 kg h^{-1}) and Kudzu (*Pueraria phaseoloides*) (3 kg h^{-1}). Seeds were commercially purchased, and no fertilization was applied. Pastures were established in december 2019 and divided into four (0.370 m^2) subplots per type, with electric wire for rotational grazing (12/36 days occupation/rest). The climate data is shown in Figure 1. Ten Zebu × Simmental calves (eight months old) were divided into two groups of five, each assigned to a different pasture. Group 1 averaged 225 kg in weight (182 to 288 kg) and was assigned to the Mombaza-Kudzu association. Group 2 averaged 229 kg (212 to 266 kg) and was assigned to Mombaza monoculture. During January 2020, adaptation grazing was carried out. The study ran from February 14th to September 3rd, 2020, with data collection until October 9th.

The animals were weighed every 36 days at the end of each grazing cycle, covering both the drought and rainy season. For forage sampling, one of the four subplots of Mombaza in monoculture and one of the Mombaza-Kudzu association were chosen. Sample collection of the available forage in both subplots occurred every 36 days before the entry of the

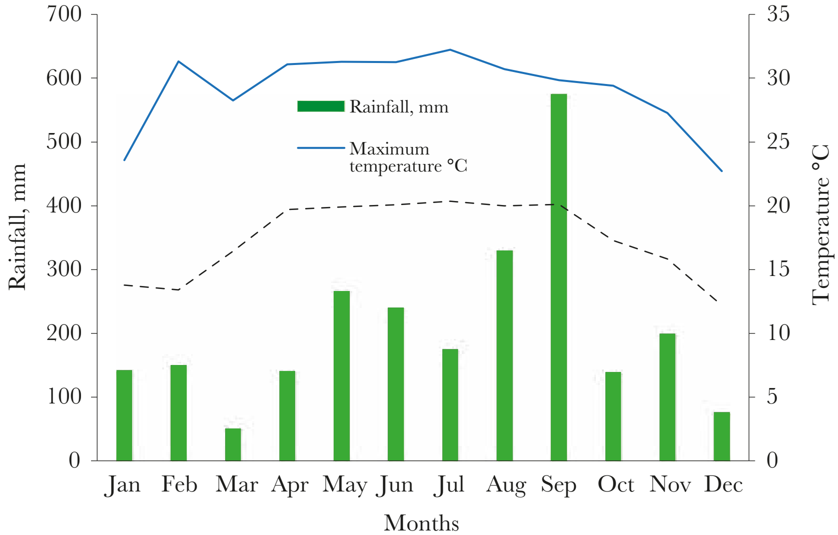

Figure 1. Average climate data during the study period, year 2020.

animals. Samples were collected using a randomly assigned 1 m^2 plot in both pastures, following the method proposed by Toledo & Schultze-Kraft (1982). Four repetitions were conducted from March 9th to October 9th, 2020. Sampling involved harvesting the biomass or fresh matter (FM) within each 1 m^2 plot with cuts made 15 cm above ground level. When the 1 m^2 plot contained individual Kudzu plants, they were harvested 7 cm above ground level. Additionally, in the associated pasture extra samples of Kudzu were taken for individual evaluation in dry matter yield, nutritional value, and its proportion in the pasture. The harvested material was weighed on a portable electronic scale with a capacity of 10 kg ± 1 g. To determine the dry matter yield (DMY, kg ha^{-1}), subsample of 300 g of FM were separated and dried in forced air ovens at 65 °C for 48 h. The DMY was calculated based on the DMY of the 300 g of FM and the total FM of the 1 m^2 plot, extrapolated to one hectare. For the determination of the DMY (kg ha^{-1}) and proportion of the fabaceae in the total biomass, a second subsample of 200 g was used, which was separated into its grass and fabaceae components. The proportion of fabaceae (%) in the total biomass was obtained by dividing its dry weight by the dry weight of the total biomass (grass + fabaceae). The concentrations (in g kg^{-1} of DM) of protein, neutral detergent fiber (NDF), acid detergent fiber (ADF), and lignin from Mombaza and Mombaza-Kudzu, were obtained from representative dates of the drought (April 14th) and rainy season (July 29th). These determinations were from the dry samples of 300 g of FM, ground to a particle size of 1 mm in a Wiley brand mill, according to the AOAC (1990).

Statistical analysis

The analysis of variance for available forage, nutritional value, and daily weight gain of the calves was performed using the SAS GLM program (SAS Institute, 2010). The effect of harvest date, pasture type, and the interaction date by pasture type, was analyzed in completely randomized designs in a divided plot arrangement with four repetitions, considering harvest date as the main plot, and pasture type as the subplot. Means were compared using Tukey test ($p \leq 0.05$). Daily weight gain was analyzed separately in a completely randomized design with five repetitions, considering each animal a repetition, the effect of each type of pasture was analyzed considering the average daily gain.

RESULTS AND DISCUSSION

Dry matter yield (DMY)

There was no interaction ($p > 0.05$) between harvest date and pasture type (Table 1). DMY followed a similar chronological pattern in both pastures throughout the study period, with no significant differences ($p > 0.05$). These results differ from those of Carrillo-Hernández *et al.*, (2022) who reported higher yields in Mombaza-*Canavalia brasiliensis* than in Mombaza alone.

The average DMY of both pastures was 2428.23 kg DM ha^{-1} varying from 1040.96 to 3930.93 kg ha^{-1} for the monoculture, and from 775.69 to 3398.5 kg ha^{-1} for the associated pasture. However, harvest date significantly affected ($p \leq 0.001$) the DMY in both pastures (Table 1). On March 9th and April 14th, the lowest DMY was recorded, with average values of 908.3 kg ha^{-1} and 1069 kg ha^{-1}, respectively for both pastures (Table 2). Between May and October, the DMY increased 200%, with no significant differences ($p > 0.05$) between dates, with average values of 2259.5, 2495.1, 3340.8, and 3664.8 kg ha^{-1} compared to May 20th, June 23rd, July 29th, September 3rd, and October 9th. This meant a production of 196 kg of DM ha^{-1} more, in the May-October period, compared to March-April. This increase is associated with higher rainfall, from January-April (121mm) to May-October (317 mm) (Figure 1). These results are consistent with records of peak growth for grasses and forage fabaceae in the summer (Pardo-Aguilar *et al.*, 2020).

The DMY of Kudzu in the association was low, and significantly affected ($p \leq 0.05$) by the sampling date (Table 1). The yield was lower on April 14, with 21.0 kg of DM ha^{-1} less compared to the average of 67.0 kg of DM ha^{-1} for the rest of the evaluated dates (Table 2). The DMY of the fabaceae remained low but persisted in the association. This

Table 1. Mean squares of dry matter yield (DMY) and nutritional value of *Megathyrsus maximus* var. Mombaza in monoculture, and the Mombaza-Kudzu (*Pueraria phaseoloides*) association, at 36 days post-grazing.

Variables measured	Average	Date (D)	Meadow (M)	D x M
DMY, kg ha^{-1}	2428.2	9.656 ***	0.4816 NS	0.1154 NS
Legume, kg ha^{-1}	64.3	0.0007 *	----------	---------
D.F.		6	1	6
Protein, g kg^{-1} DM	80.19	1142.70 **	13.44 NS	102.66 NS
NDF, g kg^{-1} DM	697.42	4442.90 ***	40.70 NS	13.02 NS
ADF, g kg^{-1} DM	458.28	4704.48 **	376.32 NS	406.0 NS
Lignin, g kg^{-1} DM	50.17	51.66 NS	108.60 *	122.24 NS
Ashes, g kg^{-1} DM	109.8	375.20 *	14.30 NS	55.04 NS
D.F.		1	1	1

DF: Degrees of freedom; NDF: Neutral Detergent Fiber; ADF: Acid Detergent Fiber. Statistical differences *** ≤0.001, ** ≤0.01, and * ≤0.05; NS, not significant.

Table 2. Dry matter yield (DMY, kg ha^{-1}) of the different components of the pasture in monoculture and associated on different dates.

Harvest dates	Mombaza in monoculture	Mombaza + Kudzú association	Mombaza of the association	Kudzú of the association	Kudzú ratio (%)
March 09	1041.0 c	775.7 b	710.3 c	65.31 ab	8.42 a
April 14	1181.4 c	957.7 b	957.8 bc	46.83 b	4.75 b
May 20	2201.0 bc	2318.1 ab	2234.0 abc	84.06 a	3.73 bc
June 23	2466.3 abc	2523.8 ab	2449.8 ab	74.19 ab	3.13 bcd
July 29	3543.5 ab	3138.1 a	2240.8 abc	72.64 ab	2.36 cd
Sept 3	3930.9 a	3398.6 a	3341.8 a	56.92 ab	1.72 d
October 9	3282.8 ab	3236.5 a	3186.3 a	50.17 ab	1.71 d
LSD	1588.4	1755.0	1715.9	35.3	1.97

LSD: Least significant difference; Means within the column followed by different letters are statistically different ($p \leq 0.05$).

persistence can be attributed to the irregular defoliation of the animals, which induces the formation of small bare areas that allow light penetration and stimulates the development of branches of their axillary buds (Zegler *et al.*, 2018). Therefore, the proportion of Kudzu in the pasture decreased ($p \leq 0.05$) with the advancement of sampling dates, from 8.42% on March 9th to less than 2% on October 9th (Table 2). This decrease was also due to the increase ($p \leq 0.05$) in DMY of Mombaza grass, recorded from May 20th onward. This indicated that compared to Mombaza, Kudzu showed a lower efficiency in converting soil nutrients and water into dry matter.

Nutritional value

The nutritional value did not show an interaction between the sampling date and the type of pasture ($p>0.05$) in the evaluated variables. However, it was affected by the time of year (sampling date), except for lignin ($p>0.05$; Table 1) which did not vary between sampling dates, averaging 50.17 g/kg of DM (Table 3).

The protein concentration was higher on April 14th (drought season), with 15.52 g kg^{-1} of DM more than on July 29th (rainy season).

Table 3. Nutritive value (g kg^{-1} of DM) of *Megathyrsus maximus* var. Mombaza in monoculture and the Mombaza-Kudzu (*Pueraria phaseoloides*) association on representative climate dates in 2020.

Variable	Averages of two seasons of the year			Dry Season (April 14)			Rainy Season (July 29)		
	April / 04	July / 09	LSD	Mombaza	Mombaza + Kudzú	LSD	Mombaza	Mombaza + Kudzú	LSD
Protein	9.95 a	0.43 b	1.6	5.96 a	93.0 a	2.5	2.30 a	8.56 a	4.3
NDF	78.18 b	16.66 a	5.9	75.30 a	81.07 a	3.2	15.86 a	17.46 a	1.4
ADF	38.48 b	78.08 a	5.1	27.07 a	49.90 a	3.5	78.30 a	77.86 a	2.5
Lignin	8.10 a	2.25 a	1.3	1.90 b	4.30 a	1.3	2.43 a	2.06 a	1.2
Ashes	15.43 a	04.25 b	3.0	18.66 a	12.20 a	6.4	03.20 a	05.30 a	1.1

LSD: Least significant difference; NDF: Neutral Detergent Fiber; ADF: Acid Detergent Fiber; Means in the same row with different letters are different ($p \leq 0.05$).

The higher protein concentration in the drought season is explained by the low DMY, causing less dilution within the plant (Reyes *et al.*, 2015). Conversely, the highest concentration ($p \leq 0.05$) of NDF and ADF was recorded in the rainy season. This indicates that the DMY was made up mainly of stems, which are the support organs of the plant and have a higher concentration of fiber. The increase in DMY during the rainy season in forage species has been attributed to the decrease leaf:stem ratio and leaf senescence (Calzada-Marín *et al.*, 2019), which may also explain the reduction in nutritional value during this time of year. Higher nutritional values have also been recorded in the drought season in other tropical species (Portillo-López *et al.*, 2021).

The higher concentration of total ashes (115.43 *vs.* 104.25 g kg^{-1} of DM in rainy season), representing the plant's minerals (calcium, potassium, phosphorus, magnesium, and copper), in the drought season could be due to soil minerals (which have no nutritional value for animals), since the dusty conditions of the drought season increase this contamination. This ash concentration (124.7 g kg^{-1} DM) is similar to that reported by Schmitz *et al.* (2023) in Mombaza associated with *Arachis pintoi*, although it is lower (134.01 g kg^{-1} DM) than that reported by Enwete *et al.* (2023). On the contrary, the lower concentration of ash in the rainy season can be attributed to the greater growth of the plant, which results in a higher dilution, similar to what occurs with the concentration of protein.

The protein concentration in the Mombaza-Kudzu association was not higher ($p>0.05$) than Mombaza in monoculture (Table 1), even though Kudzu recorded an average value of the two seasons, of 206.72 g kg^{-1} of DM (Table 4). This was because the proportion of Kudzu in association was not sufficient to improve the protein concentration of the pasture.

Daily Weight Gain (DWG)

There was no interaction ($p \leq 0.05$) between weighing date and pasture type of the DWG. A trend towards greater gains was observed on the second weighing date, from March 9th to April 14th, where DWG in the Mombaza monoculture pasture was 300 g day^{-1} higher than that recorded in Mombaza-Kudzu association (Figure 2). However, the difference was not significant ($p>0.05$) due to the high variation of the data (c.v.=28.0%). Therefore, DWG between pasture types did not differ ($p>0.05$), with an average gain of 485.6 g day^{-1} across both pastures during the study period.

Similar results were reported by Schmitz *et al.* (2023) who did not observe differences in DWG between a Mombaza pasture and a Mombaza-Arachis pasture, attributing it to

Table 4. Nutritive value, in g kg^{-1} of Kudzu (*Pueraria phaseoloides*) dry matter on two dates of the year with contrasting climates.

Season	Protein	NDF	ADF	Lignin	Ashes
Dry (april 14)	208.99 a	536.58 a	399.41 a	105. 85 a	63.30 a
Rainy (july 29)	204.46 a	554.13 a	421.74 a	102.81 a	66.58 a
LSD	22.8	26.5	28.7	16.8	4.4

LSD: Least significant difference; NDF: Neutral Detergent Fiber; ADF: Acid Detergent Fiber; Means in the same row with different letters are different ($p \leq 0.05$).

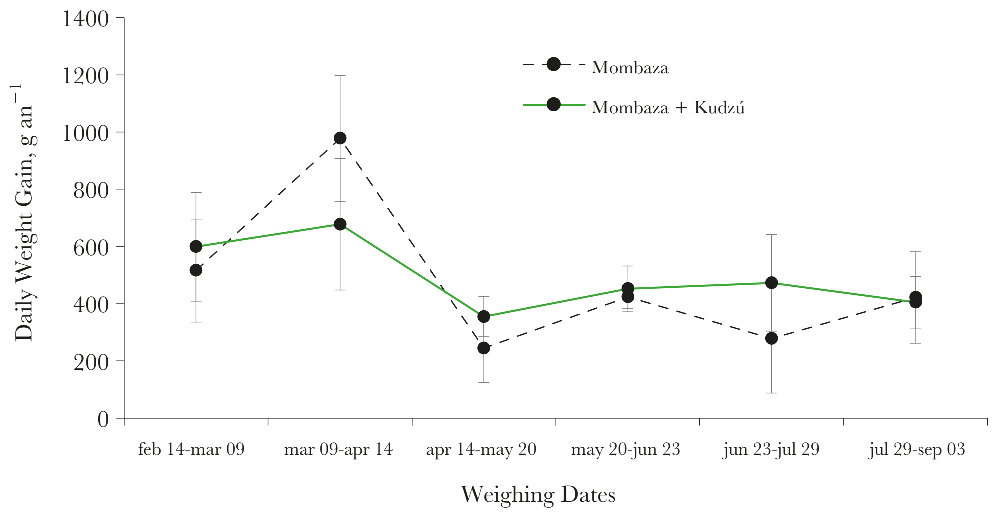

Figure 2. Daily weight gain (DWG) of calves in pastures with monoculture Mombaza and Kudzu-Mombaza association on four grazing dates.

the animal's low preference for the fabaceae species. The DWG was affected by the date of the year ($p \leq 0.05$), particularly from March 9th to April 14th, when there was greater DWG in both pastures (Table 5). During this period the animals recorded 600 g more per day with moniculture Mombaza, compared to the average gain (377 g d^{-1}) for the rest of the evaluation dates (March 9th to April 14th and September 3rd), while in the Mombaza-Kudzu association was 221 g more per day, compared to the average (457 g d^{-1}) for the rest of the dates studied.

This higher DWG from March to April (drought season) was associated with the highest protein concentration and the lowest fiber concentration of the available forage (Table 3). The lowest DWG in rains (July 29th) corresponds with Rueda *et al.* (2020), who observed that in the rainy months, grasses increase their NDF, a protein insoluble in neutral detergent, and decrease metabolizable energy, which limits the weight gain of calves.

Table 5. Daily weight gain of calves in pastures with *Megathyrsus maximus* var. Mombaza in monoculture and in Mombaza-Kudzu (*Pueraria phaseoloides*) pastures in 2020.

Evaluation period	Mombaza (g an^{-1} d^{-1})	Mombaza + Kudzú (g an^{-1} d^{-1})
February 14 – March 09	517 b	600 ab
March 09 – April 14	978 a	678 a
April 14 – May 20	245 b	356 b
May 20 – June 23	424 b	453 ab
June 23 – July 29	278 b	472 ab
July 29 – September 03	422 b	405 ab
LSD	322.1	307.1

LSD: Least Significant Differences; Means within the column with different letters are statistically different ($p \leq 0.05$).

CONCLUSIONS

Kudzu demonstrates less association capacity than Mombaza as its proportion in the pasture decreased over time. Therefore, there were no differences in nutritional value or daily weight gain of the animal between the Mombaza and Mombaza-Kudzu pastures, due to the low availability of the fabaceae. However, the higher protein concentration at the beginning of the drought period induced higher DWG in both pastures, additionally, both pastures responded similarly to the distribution of rains, registering 2.9 times more DMY during the rainy period than in the first months of evaluation with less precipitation.

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