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Article

Productive behavior of a Mombasa-Kudzu association at different times of the year

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Abstract:

The objective was to evaluate the effect of the legume kudzu (*Pueraria phaseoloides*) on the dry matter yield and nutritional value of the pasture and the weight gain of grazing heifers. The study was conducted from Dec-19-2019 to Jul-21-2020 on 4 ha at INIFAP-Pichucalco, Chis., with 2 ha of Mombasa Guinea grass (*Megathyrsus maximus* var. Mombasa) and 2 ha of the Mombasa-kudzu association. Each pasture had six heifers in rotational grazing. The dry matter yield, protein, neutral detergent fiber, lignin, and daily weight gain were evaluated. A completely randomized split-plot design was used for dry matter yield and nutritional value, and a completely randomized design was used for animal weight gain. The lowest dry matter yield was in the dry season with 2,963 kg ha^{-1} for mombasa, and 3,771.5 kg ha^{-1} for mombasa-kudzu. The highest yield was in rainfall with 10,092 kg ha^{-1} for mombasa and 8,977 kg ha^{-1} for the association. Kudzu registered the highest yield in the north winds season with 763.4 kg ha^{-1} and 19.4 % cover. Kudzu registered 1.7 times more protein than mombasa, maintaining its concentration at 146.26 g kg^{-1} DM during the study period mombasa-kudzu registered 31.9 g kg^{-1} DM more protein than mombasa, and higher neutral detergent fiber (44.3 g kg^{-1} DM more) and lignin (8 g kg^{-1} DM more). The highest animal weight gain was registered in the north winds season, in association with 504 g $animal^{-1}$ d^{-1} *vs* 333 g $animal^{-1}$ in monoculture.

Keywords: Animal production, Dry matter yield, Grazing, Dry matter yield, *Megathyrsus maximus*, Nutritional value, *Pueraria phaseoloides*.

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Introduction

Seasonal forage production is the main issue for the efficient utilization of forage grasses by grazing animals. In tropical areas, grasslands are the basis of cattle feed for beef, milk, or calf production; however, they have a marked seasonality of biomass production due to climate variations during the year. Most pasture production occurs during the rainy season, characterized by high temperatures in June through September, after which forage production decreases over the months(1). There are records of up to four times less forage yield reduction in the dry season (mid-March to mid-June) compared to the rainy season(2). This leads to changes in the availability of forage and animal-carrying capacity of the pastures during the year. Another problem with seasonality is that forage plants of the same age may have different nutritional values depending on the time of year, which leads to variations in animal production(3).

Different strategies have been evaluated for managing the seasonal distribution of forage production. One of them is the use of associated pastures, in which the use of legumes associated with grasses is usually considered(4). In soils of low fertility, the evaluation of the dry matter yield (DMY) and protein concentration in a *Brachiaria humidicola* pasture in monoculture and in association with the legume *Arachis pintoi* showed that, during the dry season, both pastures had the lowest yield of the year, but the association registered a higher DMY with 0.8 t ha^{-1} more than the monoculture pasture(1). Also, the humidicola grass in association recorded 19.21 g kg^{-1} of DM more protein than in monoculture. This decrease in the DMY of the associated grassland and the higher protein concentration of the associated grass had been previously reported(5) under the same environmental conditions when studying a humidicola-*Stylosantes guianensis* association. Although forage legumes are well known to have a higher concentration of protein (and minerals) than grasses(6), previous research shows that legumes also benefit when accompanying grasses with nitrogen, which is taken from the atmosphere and fixed to the soil by bacteria found in the root nodules of these species(7).

The decrease in the DMY or the greater stability of production of a grass-legume association results from the genetic diversity of the species that make up the association, since the association of different species exhibits short-term morphological changes, giving the grassland greater stability over time(8,9). As a result of their higher protein content and greater DMY stability, grass-legume associations can improve animal nutrition and production in pasture(10). In this regard, it has been observed that young cattle attain higher values with the grass-legume associations, yielding higher daily weight gains in steers (602 g d^{-1}) than in heifers (573 g) with the grazing of *Andropogon gayanus* associated with *Stylosanthes capitata*(11). The effect of the time of year on weight changes was not measured. Studies on animal production with grazing of associated grass-legume pastures under tropical conditions are still limited. Forage legumes are hypothesized to improve the stability of grassland biomass production and protein availability for livestock. Therefore, the objective of the present study was to evaluate the impact of legumes on the dry matter yield and chemical composition of the pasture, and on the weight gain of grazing animals at different times of the year.

Material and methods

Environmental conditions and evaluated grasslands

The study was conducted at the "Pichucalco" Experimental Site belonging to Instituto Nacional de Investigaciones Foestales, Agrícolas y Pecuarias (INIFAP) and located in Pichucalco, Chiapas. The soil was loam textured, high in organic matter (3.59 %), Fe (83 ppm), Zn (5.05 ppm), Mn (39.4 ppm), and Cu (6.37 ppm), and low in Al (3.93 ppm) and Mg (164 ppm), with a bulk density of 1.2 g cm^{-3} and a slightly acidic pH (6.0). In June through August 2018, over an area of 4 ha, secondary vegetation was eliminated by cutting with machetes and burning of the cut material. In August of the same year, the invasive grass *Paspalum virgatum* was eliminated with a glyphosate herbicide [N-(phosphonomethyl) glycine], applying 1 kg of the active ingredient per hectare. Once the weeds were removed in September, seeds of two types of grass were sown: Mombasa guinea grass in monoculture (*Megathyrsus maximus* var. *mombaza*) and Mombasa guinea grass in association with a legume (*Mombaza-Pueraria phaseoloides*). The planting was carried out with seeds both of the grass and the legume. As it was a hilly terrain, the two pastures were sown with a spiked stick with a separation of 50 cm between strokes (approximately 5 cm deep) on a line drawn with sisal twine, and at 1 m between rows.

Two hectares were used for each pasture. The monoculture pasture was sown with 7 kg ha^{-1} of commercial seed. In the associated pasture, the sowing rate of Mombasa was 6 kg ha^{-1} and that of kudzu was 3 kg ha^{-1}; the grass was sown mixed with the legume. In October, there was an ant attack on the seeds of both pastures; the seeds were carried out of the study area, which strongly affected their establishment. Consequently, the pastures were reseeded in November, and the seeds were impregnated with an organophosphate/pyrethroid insecticide powder and received no fertilizers. Both the monoculture and the associated pastures were established in June 2019. Table 1 shows the climate data that prevailed during the study period.

Table 1: Average weather data during the study period at three times of the year

	Season of the year		
	North winds (2019 and 2020)	**Dry (2020)**	**Rains (2020)**
Period covered	Nov-Feb	Mar-May	Jun-Jul
Accumulated rains, mm	580	250	450
Average monthly rains, mm	145	84	225
Maximum temperature, °C	27	34	34
Minimum temperature, °C	19	24	24

Note: Maximum and minimum temperatures are seasonal averages.

In July through September 2019, it was proceeded to the perimeter delimitation of the entire experimental area and the separation of the two types of grasslands with barbed wire, using four wires, thus forming two plots of 2 ha each: one plot for monoculture grassland (mombasa), and one plot for associated grassland (mombasa+kudzu). In October and November, each type of pasture was divided into four paddocks for rotational grazing within each pasture using electric fences with two wires per fence posts spaced 10 m (33 ft) apart from each other.

Animal management

A total of 12 Brahman (*Bos indicus*) calves averaging 9 mo of age were selected and divided into two homogeneous groups of 6 animals; each group was randomly assigned to one of the two plots. Each calf was considered a repeat. Group 1 averaged 206 kg ± 22 kg and was assigned to the mombasa-kudzu association plot, and Group 2 averaged 210 kg ± 25 kg and was assigned to the mombasa monoculture plot. From December 9 to 18, adaptive grazing was carried out. The evaluation began on December 19, 2019, and ended on July 21, 2020. Grazing was rotational and consisted of 14 d of occupation and 42 d of rest, and the animals were weighed at the end of each grazing cycle, i.e., every 42 d. Due to failures of the electronic livestock scale, the first weighing was carried out 48 d after the start of the study.

Response variables

Animal weights were measured at the end of the north winds season (February-March), the dry season (March to May), and the beginning of the rainy season (end of May-June). Samples of the forage available for each treatment were taken every 42 d at the entrance of the animals to each of the paddocks that made up the pastures; that is, at the end of each grazing cycle. In this manner, the available forage, after a 42-d pasture rest, was determined by the m^2 method[12], which consists of cutting the forage within four steel squares of 1.0 m^2 each, randomly assigned in each of the paddocks of the Mombasa pasture in monoculture, as well as in each of the paddocks with the mombasa-kudzu association. Thus, four replicates were used as the harvests (or samples) of both types of grasslands; this meant collecting four replicates per treatment on the dates of December 19, 2019, January 23 and February 28, 2020, for the north winds season; April 4 and May 10 for the dry season, and June 15 and July 21 for the rainy season.

The sampling consisted of harvesting all green biomass or green matter (GBM) within each square with cuts at 15 cm above ground level in both grasslands. When m^2 covered individual kudzu plants, they were harvested at 7 cm above ground level. Additional samples of kudzu were also collected from the associated pasture for their individual evaluation in terms of yield, chemical composition, and their proportion in the associated pasture. The harvested plant material was weighed on a portable electronic scale with a capacity of 10 ± 0.001 kg. To determine the dry matter yield (DMY, kg ha^{-1}) of each paddock, subsamples of 300 g of VM were separated, dried in forced-air ovens at 65 °C for 48 h, and dried at 65 °C for 48 h. Thus, the available dry matter (ADM) yield was calculated based on the dry matter yield of the 300 g of VM as well as on the total green matter yield of 1 m^2. A second subsample of

200 g separated into grass and legume components was utilized to determine the DM yield (kg ha^{-1}) or proportion of legume in the total biomass. The proportion of the legume (%) in the total biomass was obtained by dividing the dry weight of the legume by the dry weight of the total biomass (grass + legume).

Concentrations (g kg^{-1}DM) of protein, neutral detergent fiber (NDF), and lignin were determined only on three sampling dates (December 19, 2019, May 10, and July 21, 2020) representative of each time of year, the samples consisting of leaves and stems. These determinations were quantified from dry samples of 300 g of MV, which were previously ground to a particle size of 1 mm in a Wiley Mill. The protein concentration was determined by the Kjeldhal method[13], by multiplying the N content by the conversion factor 6.25. The NDF was determined using sodium lauryl sulfate at neutral pH[14].

Statistical analysis

The analysis of variance applied to determine the available forage and the nutritional value and weight gain of the calves was based on the SAS GLM software[15]. The effects of the harvest date, grassland type, and date × DMY interaction were analyzed in a totally random design in a split-plot arrangement; the large plot was the harvest date, and the small plot was the grassland type. For the study of the chemical composition, a representative date was analyzed for both treatments and for each of the three seasons of the year. Thus, the dates analyzed for the chemical composition were January 19, May 10, and July 21, 2020, in relation to the north winds, dry, and rainy seasons. The means were compared using Tukey's method ($P \leq 0.05$). The calf weight gain was analyzed separately under a completely randomized design with six replicates, in which the effects of treatments (pasture types) on the average daily gain were analyzed. The animals were used as replicates, with a comparison of means with Tukey's test ($P \leq 0.05$).

Results and discussion

The climate conditions varied significantly during the grazing period. The total accumulated rainfall in the north winds season was 330 mm higher than in the dry season and 130 mm higher than in the rainy season. However, the average temperature was higher and similar in the dry and rainy seasons, while the average temperature in the north winds season was 6 °C lower than in the dry and rainy seasons (Table 1).

Available dry matter (ADM) yield

Data are presented for the DMY of mombasa in monoculture, mombasa-kudzu association, and kudzu separately. There was a harvest date × grassland type interaction ($P \leq 0.05$) for the available DMY (Table 2). The chronological pattern of the available DMY was similar in both grassland types throughout the evaluation period.

Table 2: Mean squares per pasture of available dry matter (DMY) yield, associated pasture, legume, and chemical composition of available forage, at regrowth age 42 days after grazing, harvested on seven different dates and in two types of pastures

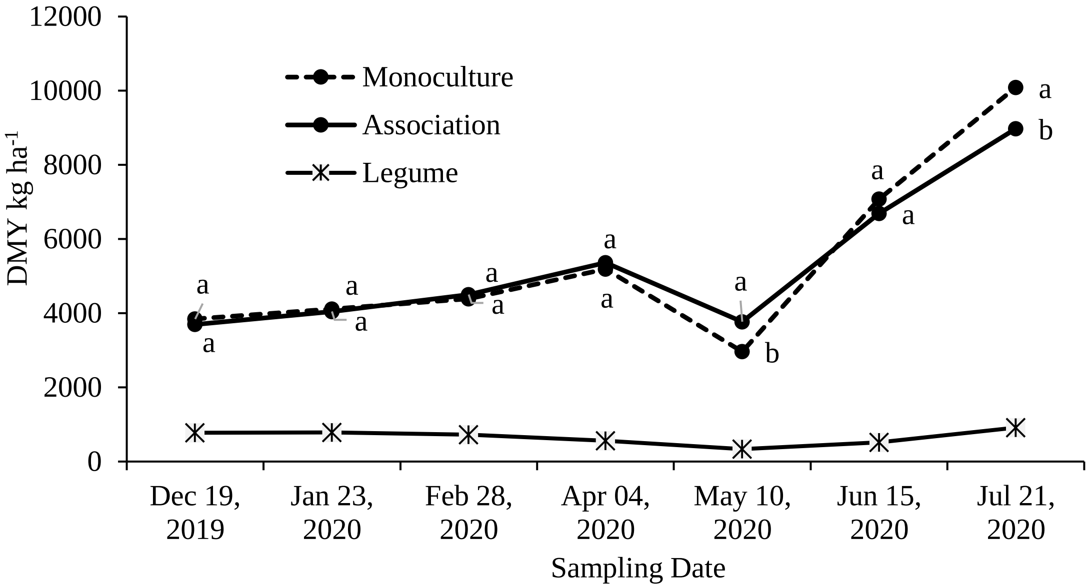
Variables measured	**Mean**	**Date (D)**	**Pasture (P)**	**D x P**
DMY, kg ha^{-1}	5337.07	383 x 10^5 NS	107 x 10^3***	685 x 10^3*
Legume, kg ha^{-1}	660.12	156 x 10^3***	----------	----------
DF		6	1	6
Protein, g kg^{-1} DM	98.75	2975.9***	4585.6***	635.4**
NDF, g kg^{-1} DM	716.42	43.44 NS	8831.2***	805.72*
Lignin, g kg^{-1} DM	52.87	610.33***	11.20 NS	162.00 NS
DF				

NDF= neutral detergent fiber. DF= degrees of freedom. *, **, *** Significance level at 0.05, 0.01, and 0.001, respectively. NS= not significant.

From December 19 to April 4 and at harvest on June 15, there were no differences ($P>0.05$) in DMY availability between both types of pasture (Figure 1), with average DM yields of 3,769, 4,079, 4,444, and 5,279 kg ha^{-1}, with respect to the dates Dec 19,2019, Jan 23, 2020, Feb 28, 20--20 and Apr 04, 2020, and with a yield of 6,885 kg ha^{-1} for the June 15 date.

Differences in DMY between the two types of pasture occurred in the dry season (May 10 harvest), and in the rainy season (July 21 harvest). During the dry season, the mombasa-kudzu association was the pasture with the highest MSY, with a value of 3,771 *vs* 2,963 kg of DM ha^{-1} of the grassland consisting of Mombasa (Figure 1). When comparing an associated *Brachiaria humidicola-Arachis pintoi pasture vs B. humidicola* in monoculture, it was observed that the associated pasture was more stable because it registered a higher DMY than the monoculture pasture in the dry season of the year in very acid soils (pH of 4.6) of low fertility(1).

Figure 1: Dry matter yield (DMY) of a Mombasa pasture in monoculture, Mombasa in association with kudzu, and kudzu separately, at the regrowth age of 42 days after grazing at different sampling dates



[ab] Different letters within a date indicate significant differences ($P \leq 0.05$).

A greater production stability of the associated pastures during periods of difficult plant growth had also been observed in other studies(16,17). This production stability of the association was explained above(9): The diversity of species in a pasture has been proven to regulate its productivity and stability by inducing complementary effects. On the other hand, the fixation of nitrogen to the soil by the legume may have been used by the grass resulting in a higher DMY in association with kudzu than in monoculture(18). During the rainy season, particularly in the July 21 harvest, the DMY were reversed; the monoculture pasture then registered the highest yield, with 1,115 kg ha^{-1} more than the yield recorded in the associated pasture (Figure 1). Similar results were reported before(5), when 1,200 kg ha^{-1} more of DM production was registered in a *Brachiaria humidicola* pasture in monoculture than in the *B. humidicola-Stylosanthes guianensis* association during the rainy season.

When observing the behavior of DMY between harvest dates, changes were recorded throughout the study period for the two types of grasslands (Table 3). In the first stage, there was stability in the DMY of both types of pasture from Dec19, 2019 to Apr 04, 2020, i.e., no differences (P>0.05) in DMY were observed between harvest dates in this period. Subsequently, this pattern of available DMY included a decline from April to May (dry season of the year), which coincided with a decrease of more than 300 mm of accumulated rainfall in both grassland types. The DMY of the monoculture pasture decreased by 2,232 kg ha^{-1} from April 4 to May 10 (42-d period), while in this same period the associated pasture registered a smaller decrease, of 1,593 kg ha^{-1} (42-d period). This meant an DMY reduction rate of 53 kg ha^{-1} d^{-1} for the monoculture pasture, and only 38 kg for the associated pasture.

This higher DMY of the association in the dry season was also found by another study(19), in which higher yields were observed in the dry season when grass and legume mixtures were utilized. At the end of the dry season, particularly from May 10, 2020 to July 21, 2020 (rainy season), the monoculture pasture registered the greatest increase in DMY, of 7,129 kg ha^{-1}, with the lowest increase for the associated pasture in this same period, of 5,206 kg ha^{-1}. This increase coincided with an increase of 200 mm in cumulative rainfall, compared to the cumulative rainfall of the dry season.

Table 3: Available forage (DM) in two types of pasture, available legume forage in the pasture associated with protein, neutral detergent fiber (NDF), and lignin of the available forage on seven harvesting dates

Type of pasture	Sampling date	Available forage (kg DM ha^{-1})	Legume (kgDM ha^{-1})	Chemical composition (g kg^{-1} DM)		
				Protein	NDF	Lignin
Monoculture Mombasa	Dec-19-2019	3843.3 ^{c}		80.4 ^{b}	704.3 ^{a}	60.8 ^{a}
	Jan-23-2020	4111.3 ^{cde}		------	------	------
	Feb-28-2020	4385.5 ^{cd}		------	------	------
	Apr-04-2020	5195.0 ^{c}		------	------	------
	May-10-2020	2963.0 ^{e}		96.7 ^{a}	691.8 ^{a}	41.2 ^{b}
	Jun-15-2020	7076.5 ^{b}		------	------	------
	Jul-21-2020	10092.0 ^{a}		71.2 ^{c}	686.7 ^{a}	43.7 ^{b}
	Mean	5380.8		82.7	694.2	48.6
Mombasa associated with kudzu	Dec-19-2019	3695.8 ^{d}	773.8 (21) ^{a}	121.8 ^{b}	722.3 ^{a}	67.8 ^{a}
	Jan-23-2020	4047.3 ^{d}	788.2 (20) ^{a}	------	------	------
	Feb-28-2020	4503.0 ^{dc}	728.3 (17) ^{ab}	------	------	------
	Apr-04-2020	5364.3 ^{c}	561.1 (11) ^{bc}	------	------	------
	May-10-2020	3771.5 ^{d}	335.1 (9) ^{d}	142.7 ^{a}	744.6 ^{a}	49.4 ^{b}
	Jun-15-2020	6694.3 ^{b}	519.0 (8) ^{dc}	------	------	------
	Jul-21-2020	8977.0 ^{a}	915.2 (11) ^{a}	79.53 ^{c}	748.73 ^{a}	54.16
	Mean	5293.2	660.10	114.7	738.5	57.1

Numbers in parentheses indicate the proportion of the legume in the associated pasture, calculated based on the harvested samples and measured as a percentage.

^{abcd} Averages with different letters within a column by pasture type are statistically different ($P \leq 0.05$).

Kudzu, present in the associated pasture, maintained a low DMY —which implied a low proportion of this legume in the pasture— through the various harvesting dates (Table 3). During the months with minimum temperatures and favorable environmental humidity (Dec19, 2019 to Feb 28, 2020), kudzu registered the highest DMY, averaging 763.4 kg ha^{-1}, which amounted to 19.4 % of the pasture's yield. This proportion declined considerably during the dry period of the year, from February 28 to May 10, when the DMY decreased to 335 kg ha^{-1} (9%). Subsequently, at the end of the study (July) and during the rainy season, the kudzu DMY increased to 915 kg ha^{-1} but maintained its proportion in the pasture at 11.0 % due to the high increase in biomass of the pasture (mombasa + kudzu), which went from 3,771.5 kg ha^{-1} in the dry period to 8,977 kg DM ha^{-1} at the end of the study (in the rainy season). Similar results in terms of legume yield have been reported in the past[20], with a three-fold increase in kudzu from the dry season to the rainy season. However, the mombasa grass (plant C4), expressed its potential to convert photoassimilates into biomass more efficiently under favorable conditions of humidity, compared to kudzu (C3).

Chemical composition

There was a harvest date x pasture type interaction for protein and NDF concentration, but not for lignin concentration (Table 2). In the case of protein, the interaction originated in the rainy season (Jul 21, 2020), when the two types of pastures exhibited no differences in protein concentration, both of them averaging 75 g kg^{-1} of DM. conversely, in the north winds season (Dec 19, 2019) as well as the dry season (May 10, 2020), the protein concentration was higher in the associated pasture, registering 41 and 40 g kg^{-1} of DM plus protein than the monoculture pasture, in those periods, respectively (Figure 2). The mombasa-kudzu pasture registered a higher protein concentration, as a result of kudzu having 1.7 times more protein than mombasa grass, whereby this legume maintained a high protein concentration throughout the study, with an average of 146.2 g kg^{-1} of DM (Table 4).

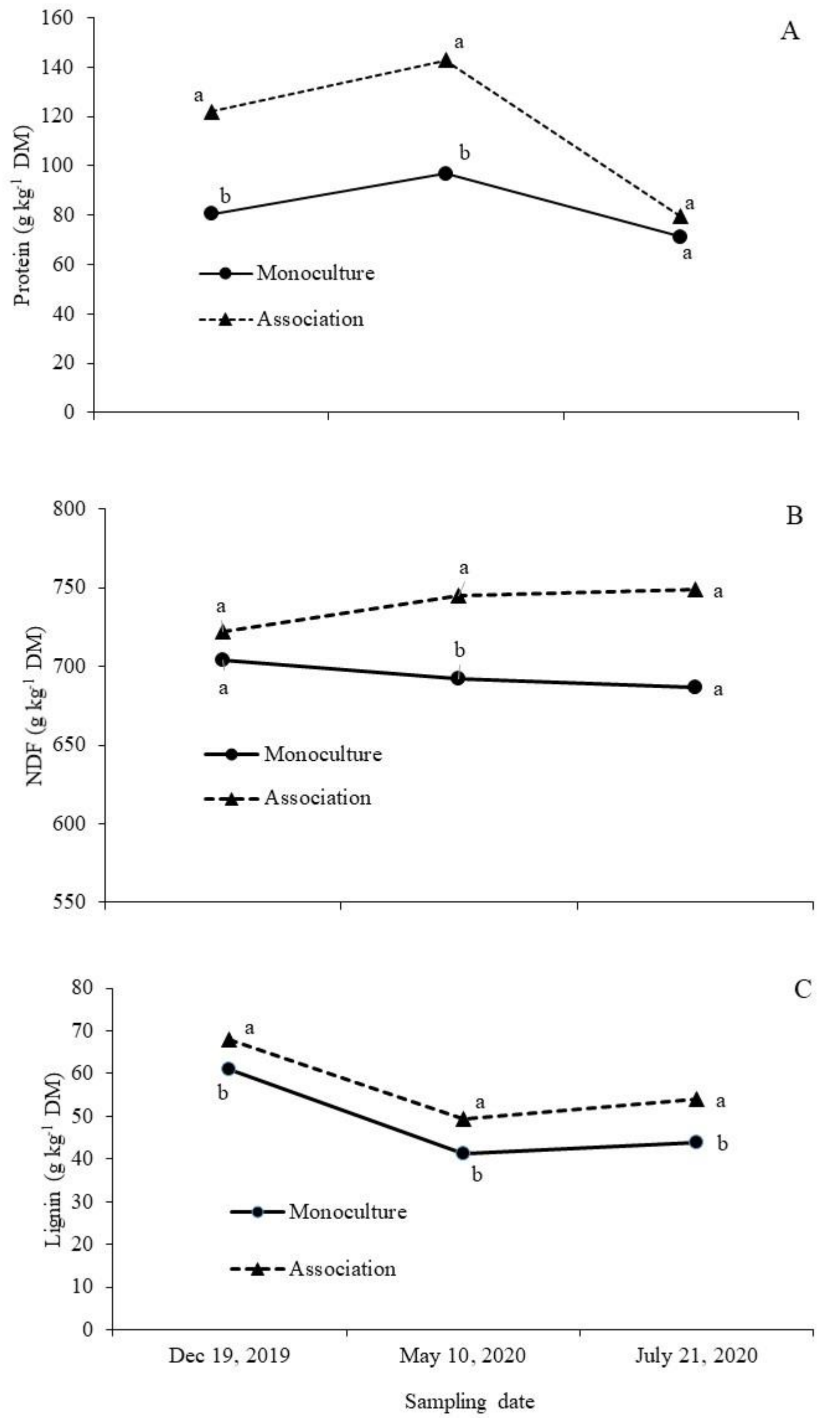
Between harvest dates, variations in the protein concentration differed between the monoculture and associated pastures (Table 3). Both pastures registered the highest concentrations in the dry season (May 10, 2020), and the lowest in the rainy season (July 21, 2020). In the monoculture pasture, average values of 16 and 25 g kg^{-1} DM of protein were higher in the dry season than in the north winds and rainy seasons, respectively. The decrease in protein in the two types of pastures in the rainy period of the year may have resulted from the higher plant growth induced by the higher rainfall, which caused a dilution of protein with the increase in grassland biomass. This phenomenon of protein dilution has been explained in tropical pastures[21] and consists in a decrease of the concentration of protein per unit of dry matter accumulated in the plant during its growth.

The harvest date x pasture type interaction for NDF (Table 2) was recorded in the dry season (May 10, 2020), as the associated pasture then had a higher concentration and there were no differences between the two pastures in the two remaining seasons of the year. In the dry season, the associated pasture registered 52.8 g kg^{-1} of DM more NDF than the monoculture pasture. In the north and rainy seasons, there were no differences in NDF concentration between the two types of pasture, with average values of 713.3 and 717.3 g kg^{-1} of DM for Dec19, 2019 and Jul 21, 2020, respectively (Figure 2). Between harvest dates or times of the year, the mombasa pasture both in monoculture and associated with kudzu, exhibited no change in its NDF concentration (Table 3). Throughout the study period, the DM averaged 694.5 g kg^{-1} in the monoculture pasture, and the NDF, 738.5 g in the associated pasture.

Given the absence of harvest date × grassland type interaction for lignin concentration (Table 2), the highest concentrations throughout the study period were recorded in mombasa-kudzu grassland (Figure 2). This associated pasture recorded 7.0, 8.2 and 10 g kg^{-1} of DM more lignin than the monoculture pasture for the north, dry and rainy seasons, respectively. The higher lignin concentration in the associated pasture is the result of the high lignin concentration recorded in kudzu, registering an average value of 89.5 g kg^{-1} DM for the three seasons of the year (Table 4). These high lignin values are in agreement with another study(22) where the nutritional value of kudzu was evaluated at different ages for animal consumption, with the result that, at 40 d of age, kudzu registered average concentrations of 90 g kg^{-1} of DM, with a lower concentration of lignin before 40 d of age.

Variations in lignin concentration between sampling dates were observed in both grassland types. In both monoculture and association pastures, lignin concentration was higher in the north winds and was similar in the dry and rainy seasons (Table 3). This higher concentration in the northeast was due to the favorable availability of water in the soil, which probably led to an increase in the number of stems of the plants, but with slow growth due to the minimum temperatures during this period. Slow-growing stems accelerate the process of lignification of vegetative organs(23). The monoculture pasture recorded 18.3 g kg^{-1} of DM more lignin in the north winds compared to the average value (42.4 g) of the dry and rainy seasons. In addition, the associated grassland recorded 16 g more lignin in the north winds season than the average (51.7 g) recorded in the dry and rainy seasons.

Figure 2: Concentration of protein, neutral detergent fiber (NDF), and lignin of a mombasa pasture in monoculture, and of the mombasa + kudzu association, at the regrowth age of 42 days after grazing in three sampling dates, representative of the north winds season (Dec 19, 2019), dry (May 10, 2020) and rainy (Jul 21, 2020) seasons



Different letters within a date indicate statistically different differences ($P \leq 0.05$).

Table 4: Crude protein, neutral detergent fiber (NDF), and lignin of the association kudzu at 42 days of regrowth on three different harvest dates

Sampling dates		Protein	NDF g kg^{-1} DM	Lignin
December 19, 2019		152.4 [a]	667.7 [ab]	89.4 [a]
May 10, 2020		144.9 [b]	663.5 [b]	88.6 [a]
July 21, 2020		141.4 [b]	679.7 [a]	90.4 [a]
Mean		146.2	670.3	89.5
	DF	**Mean squares**		
Harvesting date	2	93.65**	210.68*	2.44 NS

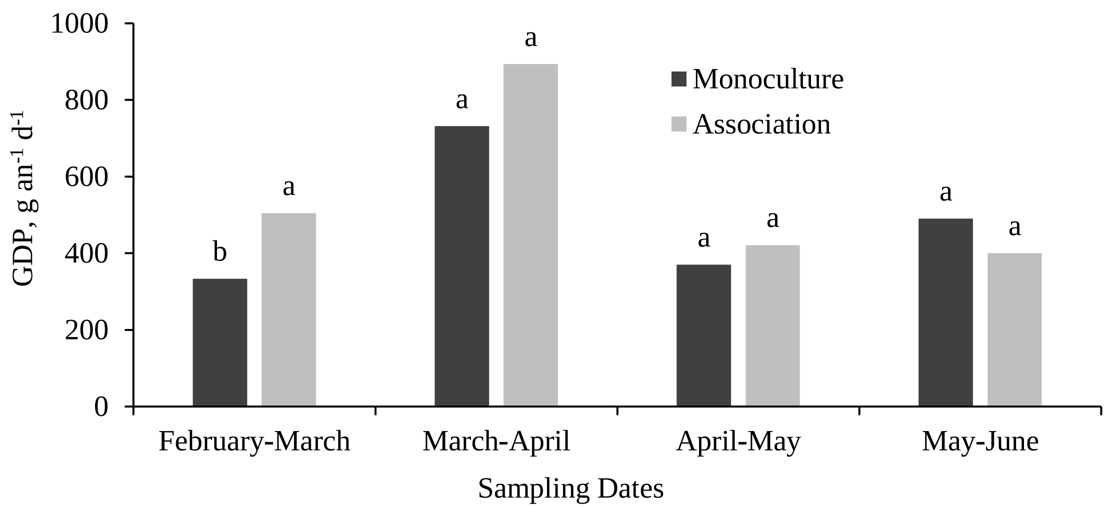
DF= degrees of freedom.

[ab] Averages with different letters within a column are different (*P*≤0.05); *, **, *** Significance level at 0.05, 0.01, and 0.001, respectively. NS= not significant.

Daily animal weight gain (DWG)

Changes in nutritional value and available forage yield as the seasons progressed were reflected in the DWG of grazing calves (Figure 3). In the February-March grazing cycle, the DWG differed (*P*≤0.05) between the two types of pasture, with gains of 333 and 504 g animal^{-1} d^{-1} for the monoculture and association pastures, respectively. In the following grazing cycle, in the months of March to April, there were no differences in weight gain (*P*>0.05), but the average of both pastures was high, with 813 g animal^{-1} d^{-1} In the two subsequent cycles, April-May and May-June, DWG declined by 416 and 367 g, respectively, and averaged over the two pasture types. From March to early May, the two pastures registered an increase in the protein concentration and a reduction in the lignin concentration (Table 3). This increase in the values of chemical composition may have been due to the increase in temperature and the favorable availability of soil moisture, especially in March and April, since, in these areas, the soils still maintain sufficient moisture until April, which may have induced an increase in the resprouting or the sprouting of new young plants with higher nutritional value. In the May-June cycle, despite the high increase in forage production brought about by the increased rainfall (200 mm more than in the previous cycle, Table 1), the calves maintained a low DWG (445 g animal^{-1} d^{-1}). This was related to a decrease in protein concentration (Figure 3), and an increase in NDF (Table 4). With these changes in the chemical composition of the pasture, it can be deduced that the higher forage production that occurred in this last grazing cycle consisted mainly of stems, that is, in a decrease in the leaf/stem ratio, as has been observed in other studies[24,25]. But also, it could be a consequence of the impoverishment in the proportion of the legume in the pasture over time. Only in the first grazing cycle (north winds season), the mombasa-kudzu pasture registered the highest DWG of calves, with a value of 171 g d^{-1} above that of the calves that grazed the mombasa monoculture pasture. This was due to the higher kudzu DMY registered in February (728.4 kg ha^{-1}) compared to April (561 kg) or May (335 kg). In the remaining cycles, there were no differences in DWG between the two types of pasture (Figure 3). The average total gain per animal for the associated pasture was 80.26 kg *vs* 70.08 kg for the monoculture pasture; however, this difference was not significant (P>0.05).

Figure 3: Daily weight gain (DWG) of calves grazing Mombasa in monoculture pastures and in association with kudzu on four grazing dates



Conclusions and implications

The mombasa-kudzu association showed greater stability in the production of dry matter throughout the experimental period and a higher protein concentration than the Mombasa pasture in monoculture during the north winds and dry seasons, unlike during the rainy season. The concentration of neutral detergent fiber was similar in the north winds and the rainy seasons between the two types of pastures, and the concentration of lignin was higher in the association in all three seasons. The favorable results of the associated pasture in terms of yield and protein concentration were reflected in the higher daily weight gain of the animals at the end of the north winds season (February-March).

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grazing animal production in associated grass-legume pastures in the Mexican tropics”), from which the present research arose.

Literature cited:

1. Pardo-Aguilar N, Bolaños-Aguilar ED, Lagunes-Espinoza LC, Enríquez-Quiroz JF, Fragoso-Islas A. Efecto de una asociación pasto-leguminosa en el rendimiento de materia seca y concentración de proteína de la pradera fertilizada con fósforo. Agro Product 2020;13(7):53-60.

2. Reyes-Purata A, Bolaños-Aguilar ED, Hernández-Sánchez D, Aranda-Ibañez EM, Izquierdo-Reyes F. Producción de materia seca y concentración de proteína en 21 genotipos del pasto *Brachiaria humidicola*. Rev Univ y Cienc 2009;25(3):213-224.

3. Mayberry DA, Hatcher S, Cowley F. New skills, networks and challenges: the changing face of animal production science in Australia. Anim Prod Sci 2021;(61):201-207.

4. García A, Hernández A, Quero A, Guerrero J, Ayala W, Zaragoza J, Trejo C. Persistencia de *Dactylis glomerata* L. solo y asociado con *Lolium perenne* L. y *Trifolium repens* L. Rev Mex Cienc Agríc 2017;7(4):885-889.

5. Domínguez-Pérez D, Bolaños-Aguilar ED, Lagunes-Espinoza LC, Salgado-García S, Ramos-Juárez J, Guerrero-Rodríguez JD. Rendimiento de materia seca y concentración de fósforo de una asociación *Brachiaria humidicola-Stylosanthes guianensis*. Rev Mex Cienc Agríc 2017;8(8):1705-1717.

6. Lüscher A, Mueller-Harver I, Soussana JF, Rees RM, Peyraud JL. Potential of legume-based grassland-livestock systems in Europe: a review. Grass Forage Sci 2014;(69):206-228.

7. Yates RJ, Harrison RJ, Loi A, Steel EJ, Edwards TS, Nutt BJ, Porqueddu C, Gresta F, Howieson JG. Sourcing *Rhizobium leguminosarum* biovar viciae strains from Mediterranean centers of origin to optimize nitrogen fixation in forage legumes grown on acid soils. Grass Forage Sci 2021;76(1):33-43.

8. Zuppinger-Dingley D, Schmid B, Petermann JS, Yadav V, De Deyn GB, Flynn DFB. Selection for niche differentiation in plant communities increases biodiversity effects. Nature 2014;515(7525):108-111.

9. Prieto I, Violle C, Barre P, Durand JL, Ghesquiere M, Litrico I. Complementary effects of species and genetic diversity on productivity and stability of sown grasslands. Nat Plants 2015;(10):1038.

10. Olivera Y, Machado R, Ramírez F, Castañeda L. Evaluación del establecimiento de una colección de accesiones de *Brachiaria brizantha* asociadas con *Stylosanthes guianensis* CIAT-184. Pastos y Forrajes 2012;(35):153-164.

11. Ramírez-Restrepo CA, Vera RR. Bodyweight performance estimated carcass traits and methane emissions of beef-cattle categories grazing *Andropogon gayanus*, *Melinis minutiflora* and *Stylosanthes capitata* mixed swards and *Brachiaria humidicola* pasture. Anim Prod Sci 2019;(59):729-740.

12. Toledo JM, Schutze-Kraft R. Metodología para evaluación agronómica de pastos tropicales. Toledo JM (Ed.). Manual para la evaluación agronómica. Cali, Colombia. CIAT; 1982:91-110.

13. Horwitz W, Latimer GW. Official methods of analysis of AOAC International. 18th edition, Association of official Analytical Chemistry International. Gaithersburg, Maryland, USA; 2005.

14. Van Soest PJ. Nutritional ecology of the ruminant; LTTIECA and London: Comstock Publishing Associates, Cornell University Press; 1994.

15. SAS Institute. User's Guide: Statistics, version 9.3. SAS Inst. Inc. Cary, N. C. USA; 2010

16. Sleugh B, Moore KJ, George R, Brummer EC. Binary legume-grass mixture improve forage yield, quality and seasonal distribution. Agron J 2000;92(1):24-29.

17. Tilman D, Reich PB, Knops JMH. Biodiversity and ecosystem stability in a decade-long grassland experiment. Nature 2006;(441):629-632.

18. Rasmussen J, Soegaard K, Pirhofer-Walzl EJ. N2-fixation and residual N effect of four legumes species and four companion grass species. Eur J Agron 2012;36(1):66-74.

19. Portillo LPA, Meneses HB, Lagos BE, Duter EN, Castro RE. Valor nutritivo de mezclas forrajeras en épocas seca y de lluvias en Nariño, Colombia. Agron Mesoam 2021;32(2):556-572.

20. García-Ferrer L, Bolaños-Aguilar ED, Ramos-Juárez J, Osorio-Arce M, Lagunes-Espinoza LC. Rendimiento y valor nutritivo de leguminosas forrajeras en dos épocas del año y cuatro edades de rebrote. Rev Mex Cienc Pecu 2015;6(4):453-468.

21. Juárez-Hernández J, Bolaños-Aguilar ED, Vargas-Villamil LM, Medina S, Martínez-Hernández PA. Curvas de la dilución de la proteína en genotipos del pasto *Brachiaria humidicola* (Rendle) Schweick. Rev Cub Cienc Agríc 2011;45(3):321-331.

22. Akoutey AM, Kpodekon T, Bannelier C, Gidenne T. Nutritive value of sun-dried *Pueraria phaseoloides* for rabbits under tropical conditions. World Rabbit Sci 2012;(20):209-213.

23. Borrás L, Maddonni GA, Otegui ME. Leaf senescence in maize hybrids:plant population, row spacing and kernel set effects. Field Crops Res 2003;(82):13-26.

24. Bolaños-Aguilar ED, Émile JC. Efecto de la distancia entre surcos y densidad de siembra en el rendimiento y calidad del forraje de sorgo. Rev Mex Cienc Pecu 2013;4(2):161-176.

25. Wade RN, Seed P, McLaren E, Wood E, Christin PA, Thompson K, Rees M, Osborne CP. The morphogenesis of fast growth in plants. New Phytologist 2020;228(4):1306-1315.