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Yield and quality of Guinea grass cv. Mombasa according to plant spacing and season of the year

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ABSTRACT

Objective: The purpose was to evaluate the yield, the chemical composition and the *in vitro* digestibility of Guinea grass (*Megathyrsus maximus*, Jacq.) cv. Mombasa according to plant spacing and season of the year.

Design/methodology/approach: The Mombasa grass was stablished at spacing between plants of: 25×25, 50×25, 70×25 and 100×25 cm between rows and plants, respectively, and with broadcasting (traditional planting); cutting was conducted in cool, dry and rainy seasons. A factorial split-plot design in randomized blocks was used, with four replications.

Results: The dry matter yield (DMY) of Mombasa grass was equal ($p>0.05$) in cool and rainy seasons and lower ($p<0.05$) in dry season (27.2, 27.5 and 12.7 kg ha^{-1} d^{-1}, respectively). The crude protein (CP) increased with greater plant spacing ($p<0.05$). The fodder of the dry season showed a higher ($p<0.05$) CP content than cool or rainy seasons (10.5, 9.7 and 8.7%). The content of all fiber fractions, except lignin, did not differ between plant spacing ($p>0.05$).

Study limitations/implications: The season of the year affects the quality of tropical grasses. On the other hand, there is no information about the effect of plant spacing on the quality of Mombasa grass.

Findings/conclusions: The highest DMY was in the cool season at 75×25 cm and 100×25 cm. The fodder harvested in the dry season showed lower fiber content in cell walls and higher *in vitro* digestibility ($p\leq0.05$), but lower DMY. To ensure proper yield and quality, it is recommended to establish the Guinea grass cv. Mombasa at greater plant spacing, such as 75×25 cm or 100×25 cm.

Keywords: digestibility, *Megathyrsus maximus*, morphology, tropical grasses, seed yield.

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INTRODUCTION

Grasses of the genus *Megathyrsus* are extremely important fodder species for bovine livestock production in the Mexican humid tropics (Hernández *et al.*, 2020). The Guinea grass (*Megathyrsus maximus*) cv. Mombasa (Poaceae) presents yields of 650 kg ha^{-1} of dry matter in the dry season and 1,696 kg ha^{-1} in the rainy season (Ramírez *et al.*, 2010). The fodder presents 11.6% of crude protein (CP), 68.6% of soluble neutral detergent fiber (NDF) and 41.1% of soluble acid detergent fiber (ADF) (Molina *et al.*, 2015), and degradability of the dry matter of 47% (Almaraz-Buendía *et al.*, 2019). However, factors such as the season of the year and the population density of plants affect the yield and nutritional quality of the grasses (Freitas *et al.*, 2012; Pereira *et al.*, 2012). In a study it was observed that the Guinea grass presented better chemical composition in the early rainfall season, followed by the winter season, and the worst chemical composition in the dry and late rainfall season (Juárez *et al.*, 2009); for their part, Muñoz-González *et al.* (2016) reported that the chemical composition was better in the dry season. Although the density of plants has an effect on the biomass production of Guinea grass (Freitas *et al.*, 2012; Pereira *et al.*, 2012), there is no evidence of its effect on the quality of the fodder (Freitas *et al.*, 2012). Manipulating the plant density by varying the distance between rows can be an option to improve the yield and quality of the Guinea grass.

In Mexico, information about the effect of plant spacing and season of the year on the yield and nutritional quality of Guinea grass is non-existent. Therefore, this study evaluated the effect of plant spacing and season of cutting on the biomass yield and nutritional quality of Guinea grass cv. Mombasa harvested at 30 d of regrowth.

MATERIALS AND METHODS

Study area

The study was carried out under rainfed conditions in lands of La Posta Zootecnica at Universidad del Papaloapan Campus Loma Bonita, Oaxaca, Mexico (18° 06' 35" LN and 95° 52' 47" LW at 25 masl). The climate is warm, sub-humid with summer rains (Aw). The mean annual precipitation is 1,845 mm and the average temperature is 24 °C (INEGI, 2016). Soil in the plot is crumbly sandy texture with pH of 3.68 (strongly acidic) and 1.03% of organic matter. The climate data found in each period of evaluation are presented in Figure 1.

Grassland establishment

The fodder samples were taken from a Guinea cv. Mombasa grassland established in August 2015. Seed of the Guinea grass [*Megathyrsus maximus* (Jacq.) B.K. Simon & S.W.L. Jacobs] cv. Mombasa was used to establish the grassland. Fertilization was done only at the

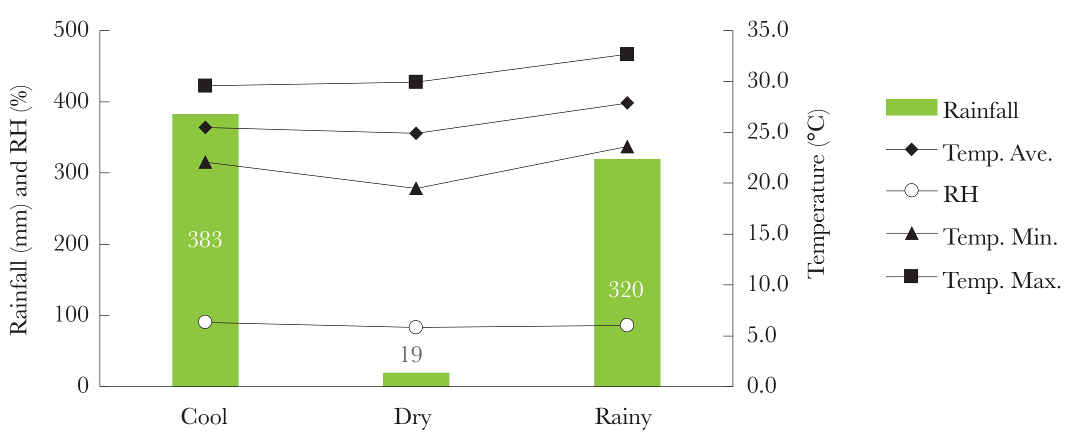

Figure 1. Climate data obtained from the meteorological station of the Military Air Force No. 8, located in Loma Bonita, Oaxaca. Periods: Oct-Nov/2015, Feb-Mar/2016, Jun-Jul/2016.

beginning with the N:P:K 50-50-50 formula. Sowing was done manually: by broadcasting (traditional) on flat terrain, at 5.5 kg ha^{-1} of seed, and in rows at spacing of 25, 50, 75 and 100 cm between rows, seeking 25 cm of distance between plants.

Experimental plots

The grassland was divided into 20 experimental plots to apply the treatments. Each treatment had four experimental units of 12 m^2 each. Two uniformity cuts were made in the grassland: September 1st and October 9th.

Treatments and experimental design

The treatments consisted of four distances between plants: 25×25 cm, 50×25 cm, 75×25 cm and 100×25 cm of separation between rows and plants, respectively, and broadcasting (traditional sowing). To measure the effect of the season of the year three fodder cuts were made at different dates: 17/11/2015, cool season; 21/03/2016, dry season; 21/07/2016, rainy season. All the cuts were made at 30 d of regrowth and at 5 cm above ground. A factorial experimental design was adjusted into divided plots, in completely randomized blocks; plant spacing constituted the main plot and season of the year the sub-plot, with four replications per treatment.

Variables evaluated

Yield variables. To determine the dry matter content (DM, %) and to calculate the DM yield (DMY) in each plot and in each season of the year, all of the grass present was cut at 1 m^2 and the weight in green was recorded. Then, the samples were taken to a drying furnace at 65 °C for 48 h and the dry weight was recorded. The humid content and DM were obtained from the difference between green weight and dry weight. The rate of DMY was expressed in kilograms per hectare per day (kg ha^{-1} d^{-1}). Then, all the samples were ground to 1 mm in a Wiley® mill for their later chemical analysis and digestibility study.

Chemical composition variables. The following were estimated: total dry matter (105 °C/12 h; AOAC, 934.01); organic matter and ash (600 °C/6 h; AOAC, 942.05); crude protein content (CP, % of N × 6.25; AOAC, 978.04). Soluble neutral detergent fiber (NDF) and soluble acid detergent fiber (ADF), and acid detergent lignin (ADL) were calculated sequentially in the equipment Ankom200® using filter bags F57® with pore size of 25 μm. To determine the ADL, after the ADF test, the bags were immersed in H_2SO_4 at 72% for three hours.

Digestibility variables. The *in vitro* digestibility of DM (IVDMD) and of NDF (IVNDFD) were determined by incubating for 48 h the duplicated samples of each sample in Ankom F57® filter bags in the DaysiII® incubator. The methodology proposed by the company Ankom® was used for these tests. The ruminal culture that was used was a mixture made with the inoculum taken directly from the rumen of three recently slaughtered cows in the municipal meat processor. It is worth pointing out that the diet of these animals was based 100% on grazing of tropical grasses.

Statistical analysis

The data from each variable were analyzed independently, considering plant spacing, season of the year, and their interaction as fixed effects, while the block was randomized. Means comparison was done with Tukey's test at significance level $p \leq 0.05$. The analyses were conducted with the SAS software (SAS Institute, 2004).

RESULTS AND DISCUSSION

The interaction of plant spacing × season of the year for DMY was observed. All the variables studied differed as a result of the season of the year, while the DMY and the CP and ADL contents differed in response to plant spacing.

Dry matter yield (DMY)

In this study, the DM content of Guinea grass cv. Mombasa was 24% and it was lower in plant spacing of 100×25 cm. The DM content was higher in the dry season ($p<0.05$), intermediate in the rainy season, and lower in the cool season (Table 1).

The DMY was 22.5 kg ha^{-1} d^{-1} on average and it was 27.2, 12.7 and 27.5 kg ha^{-1} d^{-1} in the cool, dry and rainy seasons, respectively. The DMY showed an interaction between plant spacing × season of the year ($p=0.0167$); in the cool season the highest DMY was seen with distances of 100×25 cm and 75×25 cm and in the dry season with 100×25 cm (Figure 2).

Table 1. Chemical composition and digestibility of Guinea grass cv. Mombasa established at five distances between plants and harvested in three seasons of the year, in Loma Bonita, Oaxaca, Mexico.

Item	Plant spacing (cm)					SEM	p-value
	Broadcast	25×25	50×25	75×25	100×25		
DM	24.9^{a}	25.0^{a}	24.6^{a}	23.9^{ab}	22.8^{b}	0.440	0.0036
CP	9.1^{b}	9.1^{b}	9.3^{b}	9.8^{ab}	10.4^{a}	0.205	<.0001
NDF	66.9	66.6	66.1	67.1	67.4	0.360	0.1483
ADF	34.5	34.8	34.6	35.3	35.7	0.435	0.2821
ADL	2.97^{ab}	2.60^{b}	3.36^{a}	3.46^{a}	3.29^{a}	0.153	0.0014
IVDMD	70.4	69.7	69.0	69.5	68.9	0.588	0.4116
IVNDFD	55.6	54.6	53.3	54.8	53.9	0.797	0.3347

	Season of the year				
	Cool	Dry	Rainy		
DM	20.9^{c}	27.1^{a}	24.8^{b}	0.341	<.0001
CP	9.4^{b}	10.5^{a}	8.7^{c}	0.159	<.0001
NDF	68.5^{a}	63.5^{b}	68.5^{a}	0.279	<.0001
ADF	36.3^{a}	31.3^{b}	37.3^{a}	0.337	<.0001
ADL	3.38^{b}	2.16^{c}	3.87^{a}	0.119	<.0001
IVDMD	67.9^{b}	74.3^{a}	66.3^{c}	0.456	<.0001
IVNDFD	53.2^{b}	59.4^{a}	50.8^{c}	0.618	<.0001

Values with different letter in the same row are statistically different (Tukey, $p \leq 0.05$); SEM=standard error of the mean.

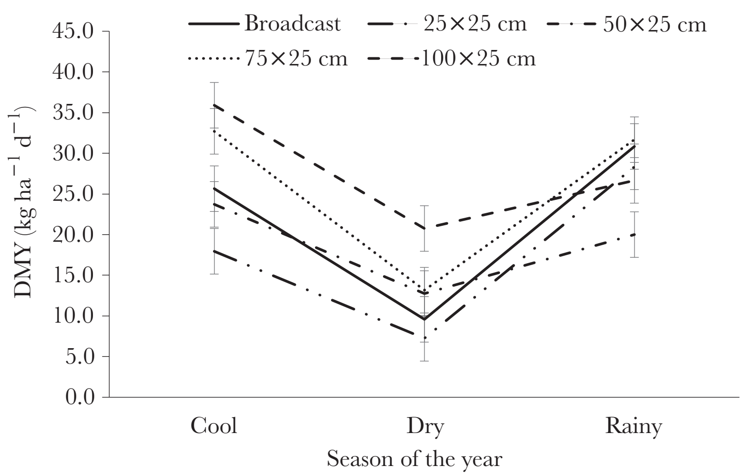

Figure 2. Dry matter yield (DMY) of Guinea grass cv. Mombasa established at five distances between plants and harvested in three seasons of the year, in Loma Bonita, Oaxaca, Mexico.

The lower DMY obtained in the dry season was attributed to the lack of rainfall recorded in this period (Figure 1). Water availability and temperature influence the development and nutritional quality of tropical fodder plants, in addition to modifying their morphological, physiological and biological structure (Verdecia *et al.*, 2012). Figure 2 shows for the rainy season a lower variation between plant spacing for DMY, which is explained by the high temperatures and relative humidity, and by the amount and better distribution of rainfall that happened in this period. In addition, it shows that the broadcasting treatment (higher plant density m^2) responds better in the rainy season (period of greater precipitation and higher temperatures, Figure 1), and the inverse is observed with the distance of 100×25 cm (lower plant density). This confirms the relationship between the number of plants and the amount of water available.

The highest DMY was obtained with the distances of 100×25 cm, 75×25 cm and by broadcasting (27.8, 25.8 and 22.0 kg ha^{-1} d^{-1}, respectively). In their study, Basile *et al.*, (2019) evaluated distances between plants of 20×20, 40×40, 60×60 and 80×80 cm, and they observed that the highest DMY (6.4 t ha^{-1}) was found at spacing of 60×60 cm. The highest biomass yield is a common condition in tropical grasslands with low plant density m^2 (Hare *et al.*, 2014; Basile *et al.*, 2019); however, in a study it was concluded that plant density showed low effect on the DMY (Freitas *et al.*, 2012).

The DMY, as a result of the effect of season of the year observed in this study, is expected, since they are patterns of growth that are characteristic of tropical grasses (Ramírez *et al.*, 2009). Regarding this, Ramírez *et al.* (2009) reported in their study an increase of 79.6% in the fodder yield of the Mombasa grass harvested in the rainy season compared to the dry season. Finally, it is important to highlight that the DMY obtained in this study was low (Figure 2), which is explained primarily by the lack of fertilization of the plots and the acid pH (3.68) of the soil. In the same study area, Sánchez-Hernández *et al.* (2019) reported 81.8% of the increase in DMY of Mombasa grass, harvested at 29 d of regrowth, going from a fertilization N:P:K formula of 00-00-00 to 140-20-00. For their part, Ramírez *et al.* (2009) reported a growth rate of 21.4 and 118.8 kg ha^{-1} d^{-1} of DM at similar days of regrowth in the dry and rainy seasons, while Hernández *et al.* (2020) reported values of 680±240 and 2,270±240 kg ha^{-1}, respectively. Fodder accumulation as a result of the season of the year confirms the seasonality in biomass production in tropical grasses.

Chemical composition

Crude protein (CP). The CP content varied due to plant spacing and was higher with distances of 75×20 and 100×20 cm. The CP was the highest in the dry season ($p<0.05$), intermediate in the cool, and lowest in the rainy season (Table 1).

The highest content of CP observed at 75×25 and 100×25 cm is explained by the strong activity of nitrogen fixation by the plant, which is more intense at the beginning of the vegetative stage and is normally accompanied with a low content of DM and a higher proportion of leaf (Ramírez *et al.*, 2009).

Typically, when increasing the biomass and the DM, the CP tends to decrease from the effect of dilution of the plant's nitrogen (Patiño *et al.*, 2018), fact that results from the effect of maturity (Van Soest, 1994). However, the lowest content ($p<0.05$) of CP observed in the cool and rainy seasons, in comparison to the dry season (Table 1), is explained by the higher accumulation of biomass that occurs in these two seasons promoted by higher rainfall, fact that causes greater dilution of the nitrogen (Muñoz-González *et al.*, 2016). In this regard, Muñoz-González *et al.* (2016) evaluated three fodder grasses in three seasons of the year in the southeast of Mexico, and they observed that the CP was higher in the dry season (13.9%), intermediate in the cool season (10.8%) and lower in the rainy season (9.3%), behavior similar to the one obtained in this study. For their part, Verdecia *et al.* (2012) reported a negative correlation between the availability of water and the CP content in the fodder.

Normally, tropical grasses present low content of CP. In our study, the Mombasa grass harvested at 30 d of regrowth presented values between 9.1 and 10.4%; however, ranges were reported of 8.1% (Santos *et al.*, 2014) to 12.4% (Fernandes *et al.*, 2014) at similar days of regrowth. Finally, it is important to highlight that in this study the Guinea grass cv. Mombasa presented levels of CP over 7%, value required as minimum for there to be an adequate digestion in a bovine (Van Soest, 1994).

Cell wall components. In general, the cell wall components varied in function of the season of the year. The NDF, ADF and ADL were lower ($p<0.05$) in the dry season and higher in the cool and rainy seasons. The ADL showed an effect from spacing between plants and season at a distance of 25×25 cm and the lowest value was seen (Table 1).

The fact of observing lower content of fiber components in the Mombasa grass during the dry season can be explained by the lower biomass production, consequence of the lack of rainfall. On the contrary, in the cool and rainy seasons, where there was higher precipitation, a better development of the plant was promoted and as consequence an increase in the fiber content, behavior that is characteristic of tropical grasses (Muñoz-González *et al.*, 2016).

Edaphoclimatic factors exert a strong effect on the yield and the nutritional quality of the grasses (Verdecia *et al.*, 2012). In this study, in addition to the lack of fertilization, another limiting factor was rainfall, particularly in the dry season (Figure 1). There is a strong correlation between the rain factor and the quality of the grasses. Another study showed that the cell wall components were positively correlated to the rain factor, while the digestibility presented a negative correlation (Verdecia *et al.*, 2012).

Other authors report fiber values different from those seen in this study, which can be due to the different conditions in which the experiments were carried out, mainly the days of regrowth when they were harvested (Santos *et al.*, 2014; Patiño *et al.*, 2018; Hernández *et al.*, 2020). In these studies the effect that the days of regrowth have on the cell wall components can be appreciated.

It is possible for the effect of season of the year on the behavior of the fiber fractions (NDF, ADF, ADL) to be explained by the intensity of development of the plants in each season. It is documented that the physiological response of the plant in the accumulation of cell walls is strongly influenced by environmental factors such as temperature, soil humidity and luminosity. These factors influence biomass accumulation, leaf:stem ratio, and maturity of plants (Verdecia *et al.*, 2012). It is possible that differences in the cell wall contents found in this study, as a result of season of the year, are because of the influence of these factors, such as temperature which was higher in the rainy season, intermediate in the cool season, and lower in the dry season (Figure 1). It is known that high temperatures promote an increase in lignin accumulation, and it seems that the enzymes that synthesize lignin present greater activity at higher temperatures (Van Soest, 1994). The variation in the cell wall components is consequence of the intensity and combination of factors present in each study (Van Soest, 1994).

In vitro **digestibility**

The IVDMD and IVNDFD only changed from the effect of the season ($p<.0001$). The values of IVDMD and IVNDFD were higher in the dry season, intermediate in the cool season, and low in the rainy season (Table 1).

The higher values of IVDMD and IVNDFD observed in the dry season are attributed to lower contents of ADF and ADL that the Guinea grass cv. Mombasa presented in that season (Table 1). This relationship between the IVDMD and the IVNDFD with the fractions of the cell wall (lignin and cellulose, mainly) and the CP are to be expected; the strong relationship present between these fractions and the digestibility is documented (Van Soest, 1994; Fernandes *et al.*, 2014). It is also documented that there is a strong relationship between the digestibility of the cell wall and the digestibility of organic matter (Moore and Mott, 1973). At the same time, the digestibility of the cell wall depends on its degree of lignification. Therefore, lignin is considered to be the main inhibiting component of the quality of tropical grasses (Moore and Mott, 1973).

Finally, it is of interest to point out that the low fiber content and the higher CP content and digestibility of Mombasa grass can be attributed to the fodder being harvested in an early stage of maturity (30 days of regrowth).

CONCLUSIONS

In this study, the dry matter yield of the Guinea grass cv. Mombasa is higher at greater distance between plants, and is higher in the cool and rainy seasons, when there is more rainfall. The crude protein content is better in the dry season. Plant spacing does not affect the fractions of the cell wall or the digestibility of the fodder, although it does the lignin content. The fodder harvested in the dry season presents better quality, since it contains fewer cell walls and is more digestible. Due to its higher yield and crude protein content, the quality of the Guinea grass fodder improves at greater plant spacing (75×25 and 100×25 cm).

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