Nutritional evaluation of millet at different seeding rates and cutting heights

Avaliação nutricional do milheto submetido a diferentes taxas de semeadura e alturas de corte

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Abstract
This study evaluated the effect of different seeding rates and cutting heights on production and composition of millet. Two randomized block design experiments were performed. In the first trial, 32 parcels (1.2 × 1.2 m) were used for evaluation of seeding rate of 24, 35, 50 and 60 kg/ha. Three cuts were carried out to evaluate plant height, fresh and dry mass yield, dry matter (DM), neutral detergent fiber (NDF), crude protein (CP) and acid detergent lignin (ADL) concentration and *in situ* DM and NDF digestibility. In the second trial, 20 parcels (1.2 × 3.0 m) were used to evaluate 20, 30, 40 and 50 cm of cutting heights for two growing cycles, performing the evaluations previously listed. Seeding rate linearly increased plant height, fresh and dry mass production, and tended to linearly decrease dry matter *in situ* digestibility, without effects on forage composition. Cutting height had no effect on crude protein (CP) concentration, but linearly increased plant height, dry mass production, DM content and tended to decrease NDF *in situ* digestibility and ADL content. Thus, the use of the highest evaluated seeding rates (60 kg/ha) and cutting height (50 cm) increased forage production; however, the use of the lowest residual height increased forage quality.
Keywords: Digestibility. Forage production. Grazing management. Lignin. NDF.

Resumo
Os efeitos de diferentes taxas de semeadura e altura de corte na produção e composição bromatológica do milheto foram avaliados em dois experimentos executados em delineamento em blocos casualizados. No primeiro experimento, foram utilizadas 32 parcelas (1,2 × 1,2 m) e avaliadas as taxas de semeadura de 24, 35, 50 e 60 kg/ha. Três cortes foram realizados para avaliar a altura das plantas, a produção de massa fresca e seca, os teores de matéria seca (MS), fibra em detergente neutro (FDN), proteína bruta (PB) e lignina, assim como a digestibilidade *in situ* da MS e da FDN. No segundo experimento, 20 parcelas (1,2 × 3,0 m) foram usadas para avaliar o efeito das alturas de corte de 20, 30, 40 e 50 cm, sobre as variáveis previamente citadas. De acordo com o aumento da taxa de semeadura, houve aumento linear da altura das plantas e da produção de massa seca e fresca, além de uma tendência de redução linear da digestibilidade *in situ* da matéria seca, sem afetar a composição da forragem. A altura de corte não afetou a concentração de proteína bruta, mas aumentou linearmente a altura das plantas, a produção de massa seca e o teor de matéria seca e tendeu a reduzir a digestibilidade *in situ* da FDN e a concentração de lignina. Assim, o emprego de maiores taxas de semeadura (60 kg/ha) e de altura de corte (50 cm) aumentam a produção de forragem, ao passo que menores alturas de corte aumentam a qualidade da forragem.
Palavras-chave: Digestibilidade. Produção de forragem. Manejo do pasto. Lignina. FDN.

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Received: 04/03/2017
Approved: 01/12/2017

Introduction

Human population growth and development have increased demand for animal protein sources. Ruminants are useful in converting vast renewable resources from rangeland, pasture, and crop residues or other by-products into edible food for humans (GERBER et al., 2015). Grazing production systems are common in Brazil and animal production improvement seems essential for economic and environmental sustainability. In addition, knowledge about animal and plant relationships are important for grazing system optimization. Nutritional forage value manipulation associated with mass availability are the main factors that determine animal performance (NELSON, 2011).

Tropical grasses are usually used for ruminant feeding on Brazilian farms. Millet (*Pennisetum glaucum* (L.) is an annual tropical grass that has high environmental adaptation, great production and nutritional quality (JORNADA et al., 2008). Millet has been used in farms as soil cover, due to its high growth rate (SOUZA NETO et al., 2008; HIRATA et al., 2015). However, it could be also used for hay production (ANJUM; CHEEMA, 2016), grain yield (ALENCAR et al., 2015) and grazing (SCHWARTZ et al., 2003; BRUM et al., 2008; MONTAGNER et al., 2008; SCARAVELLI ET AL., 2008; CAMARGO et al., 2009; DA SILVA et al., 2014). In the South of Brazil, millet has been used for grazing during summer (SCHWARTZ et al., 2003) because of increased dry matter availability (RIZO et al., 2004). Castro (2002) described that since 1970-decade millet has been used in continuous grazing systems; however, studies focused on grazing management are scarce (CASTRO, 2002; HERINGER; MOOJEN, 2002; PEDROSO et al., 2009; LEÃO et al., 2012).

Pedroso et al. (2009) studied structural characteristics of pearl millet under rotational grazing and recommended lower resting periods to provide 1.5 to 2.0 new leaves, which improves green blade proportion. Castro (2002) evaluated different cutting height (10, 20, 30 and 40 cm) and showed that it affected pasture productivity and morphological structure. Response models indicated 29.2 cm as the best cutting height for maximum lamb daily gain. Heringer and Moojen (2002) studied nitrogen fertilization levels and found highest production at 464 kg/ha. Leão et al. (2012) observed no effect of millet cultivar on *in vitro* digestibility, although plants higher than 100 cm had lower digestibility.

Pasture establishment procedure and grazing management can affect plant structure and production. Forage availability and dry matter yield are associated with mass and density of tiller. In addition, cutting height is strongly associated with plant production in the subsequent growth cycle (FAGUNDES et al., 1999). Therefore, optimal post-grazing residual height could make it easier to identify over-use in non-conventional crops. We hypothesized that increased seeding rate is associated with high plant stand and lower nutritive value. Additionally, lower cutting height decreases plant height and increases forage nutritional value at grazing time. So, this study aimed to evaluate seeding rate and cutting heights on production and composition of millet.

Material and Methods

Experiments were conducted in Agrarian Sciences Center of the Federal University of São Carlos in Araras, SP, Brazil. Two randomized block design experiments were performed. In the first trial, 32 parcels (1.2 × 1.2 m) were used to evaluate the following seeding rates: 24, 35, 50 and 60 kg of seeds per hectare. Mechanical cuts were performed at 45, 70 and 105 days after seeding. Plant height was measured using three points per m^2. Whole parcels were cut at 30 cm of height and samples were collected for bromatological analysis.

In the second trial, 20 parcels (1.2 × 3 m) were used to evaluate the following cutting height: 20, 30, 40 and 50 cm. The residual heights were determined according to the methodology described by Jornada et al. (2008). Forty-five days after seeding, a leveling cut was performed to provide treatment application. Samples were performed at 30 and 60 days after the first treatment application. Plant height was measured using three points per m^2. Two random samples of 1 × 1 m (1 m^2) each were performed per parcel (PENATI et al., 2005). Sampling was performed using a quadrant of metal and at least 10 cm of border.

Chemical composition of soil and climatic condition are shown in Table 1 and Figure 1, respectively. Millet seed of BRS-1501 cultivar (Piraí Sementes, Piracicaba, Brazil), with 95% of purity and 75% of germination rate were used. Seeding was performed on the 15th of November 2014. After cuts, each parcel was individually fertilized with 50 kg N/ha of urea and irrigated daily during the trials. Disposable fresh mass production was evaluated using a scale (BL3200H, Shimadzu®, São Paulo, Brazil). Two samples per parcel, of approximately 300 g, were collected and pre-dried at 60 °C in a forced air oven for 72 hours and subsequently processed in a knives Willey mill with 1 (Method 950.02) (WORWITZ, 2000) and 2 mm pore screen, which were used for chemical analysis and ruminal incubation, respectively.

Table 1 – Soil chemical composition before millet seeding – Araras, Brazil, 2016

Item	Sampling depth (cm)	
	0-20	20-40
Organic Matter, g/L	62	41
pH	5.9	6.2
Phosphorus, mg/L	660	510
Potassium, mmol/L	15	15
Calcium, mmol/L	95	73
Magnesium, mmol/L	25	22
Aluminium, mmol/L	0.5	0.4
CEC[1], mmol/L	160	129
Sulfur, mg/L	109	60
Boron, mg/L	0.53	0.4
Cupper, mg/L	4.8	2.7
Iron, mg/L	61	45
Magnesium, mg/L	27.6	21.7
Zinc, mg/L	12.0	9.4

[1] CEC: cation-exchange capacity

Samples were analyzed for dry matter (method 930.15) (WORWITZ, 2000), crude protein (N × 6.25; method 984.13) (WORWITZ, 2000) and neutral detergent fiber (NDF), using Van Soest et al. (1991) detergents and digestion for one hour at 90 °C. Acid detergent lignin (ADL) was analyzed using 72 percent sulfuric acid (VAN SOEST et al., 1991). For *in situ* digestibility evaluation, approximately 500 mg were weighed, placed in 5 × 5 cm bags and ruminal incubated for 96 hours, in two ruminal cannulated dairy cows, fed with 700 g/kg of corn silage. After ruminal removal, bags were water washed, pre-dried at 60 °C for 24 hours and dried for one hour at 105 °C. Then, bags were washed in NDF solution (VAN SOEST et al., 1991), for one hour at 90 °C. Digestibility of NDF (NDFd) was estimated according to the following equation:

$$\text{NDFd}\left(\frac{g}{kg}\right) = \text{NDF}\left(\frac{g}{kg}\right) - \text{iNDF}\left(\frac{g}{kg}\right)$$

Where, NDF was the forage NDF concentration and iNDF was the indigestible NDF concentration. Data were analyzed as repeated measures, using the MIXED procedure of SAS 9.3 (SAS INSTITUTE, 2011), according to the following model:

$$Y_{ijk} = \mu + T_i + b_j + \omega_{ij} + C_k + T_i \times C_k + e_{ijk}$$

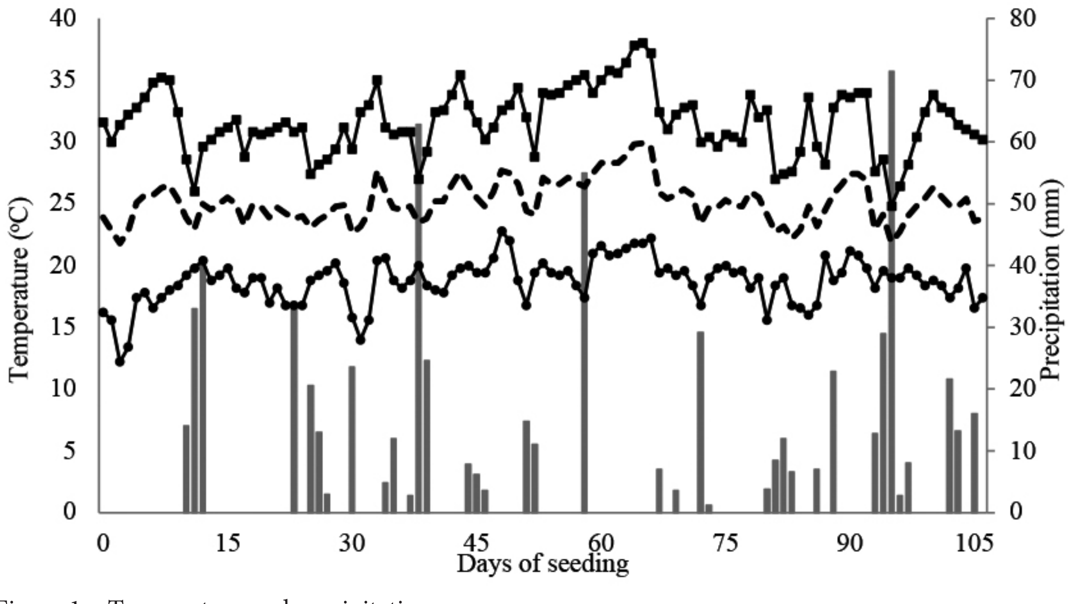

Figure 1 – Temperature and precipitation

Where Y_{ijk} is the value observed in the k growth cycle, for parcel percentage to the j block, which received treatment *i*; μ was the overall mean; T_i was the fixed effect of treatment i (i = 1 to 4 in both experiments); b_j was the random effect of block j (j = 1 to 5 at residual height experiment and j = 1 to 8 at seeding rates trial); ω_{ij} was the random error associated with parcels; C_k was the cycle fixed effect (k = 1 to 2 at residual height trial and j = 1 to 3 the seeding rate experiment); $T_i \times C_k$ was the fixed effect of the treatment and cycle interaction and e_{ijk} was the subplot random error. Kenward and Rogers (1997) method was used for degrees of freedom correction and covariance structure chosen were performed according to the Akaike method. Treatment effects were studied by orthogonal contrasts (linear and quadratic). Significance was declared at $P \leq 0.05$, except in specific situations where the exact probability value was presented. Data from two experiments were subjected to correlation analysis using PROC CORR (SAS 9.3).

Results and Discussion

There was significant growth cycle and seeding rate interaction effects on fresh mass production ($P \leq 0.05$; Table 2). Seeding rate linearly increased fresh mass production during the two first cycles (P = 0.011; Figure 2) and had no effect on the third cycle in fresh mass production (P = 0.101). Regardless of the evaluated growth cycle, seeding rate linearly increased plant height and dry mass production (P = 0.029). These results could be associated with increased plant density, which was more evident in the two first cycles. Plant competition for light stimulates apical dominance and consequently increases plant height (YAN et al., 2012). Moreover, in the initial growth cycles, the tillers density has a strong correlation with forage mass production (CUNHA et al., 2011).

Pereira Filho et al. (2003) observed that 15 to 20 kg/ha of seeds are recommended for millet pasture establishment. However, greater tillering power of the plants can compensate for lower seeding rates. Carberry et al. (1985) studied plant population from 50,000 to 400,000 plants per hectare and found 77% decrease in total weight per plant and 66% reduction in leaf area per plant with higher density and recommended 150,000 plants per hectare. However, despite great millet tillering capacity, in this study, the higher seeding rate (60 kg/ha) showed higher production on the first two growth cycles. In a practical situation, higher seeding rate could reduce plant age at first grazing, without altering forage composition and probably without major effects on digestibility.

There was no effect of seeding rate on DM and NDF concentration (P > 0.10; Table 2). Anjum and Cheema (2016) found 698, 718 and 671 g/kg of NDF concentration for fresh millet, silage and hay, respectively, slightly lower than 740 g/kg of NDF found in this study. However, the former study used millet with 310 g/kg of dry matter, at silage cut point, higher than 114 g/kg in our analysis. On the other hand, Rosser et al. (2013) observed 520 g/kg of NDF and 140 g/kg of dry matter in the head elongation phase. Pariz et al. (2011) found 742 and 642 g/kg of NDF in dry and rainy season, respectively. There was no effect of seeding rate on NDF and CP concentration. Additionally, we found higher NDF content than Rosser et al. (2013), even using plants before head elongation phase. Crude protein concentration averaged 152 g/kg, similarly to Rosser et al. (2013) (186 g/kg at head elongation phase) and Tiritan et al., (2013) (146 g/kg; 30 days after sowing).

Concentration of ADL averaged 48.3 and 65.5 g/kg of DM and NDF, respectively, but was not affected by seeding rate. Increased seeding rate had no effect on NDFd but tended to decrease DM digestibility (P = 0.089), which resulted in no effect on digestible DM production (P = 0.153). However, Rosser et al. (2013) found a quadratic increase of digestible mass production according to millet growth. According to these authors, the lack of decline in DM and OM digestibility as plants matured could be explained by non-fiber carbohydrate increase and NDF and CP concentration decrease. In this study, there was no effect of seeding rate on ADL, NDF and CP concentrations and DM digestibility decrease seems to be associated with morphology modification. When data of both two experiments were analyzed, the main factor associated with DM digestibility was plant height (P = 0.032; R = -0.185) and ADL could not be associated (P = 0.489), although Tylutki et al. (2008) used lignin for carbohydrate indigestible fraction estimation.

Plant height, DM concentration and DM production linearly increased with increased cutting height (P = 0.008; Table 3). Increased DM content could be associated with plant growth stage modification (CARBERRY et al., 1985; MÜLLER et al., 2006). Yet, Pariz et al. (2011) observed no effect of seeding time on total digestible nutrients throughout the seasons, as higher post-grazing increases remaining leaves, which are older at the end of the next growth cycle. Increased dried leaves associated with higher post-grazing residual height had higher effects on chemical composition and *in situ* digestibility of millet than increased plant density or seeding rate. The average DM production using 30 cm of cutting height in our trial (2.24 ton/ha) was like Schwartz et al. (2003) and higher than reported for Brum et al. (2008), Camargo et al. (2009), and Da Silva et al. (2014). There were no effects of cutting heights on forage NDF and CP content and DM digestibility. However, NDFd tended to decrease when post-grazing residual height increased (P = 0.052). Decreased NDFd could be associated with increased ADL concentration (TYLUTKI et al., 2008). Meanwhile, post-grazing residual height had no effect on DM digestibility (P = 0.205). Leão et al. (2012), studied millet genotypes managed at different heights and found lower lignin contents and higher nutritional value and digestibility in lower heights. Detmann et al. (2014) highlighted that the NDF digestibility is one of the most important feed intake determinants and may directly affect animal performance.

Table 2 – Millet production and chemical composition according to different seeding rates for three growth cycles – Araras, Brazil, 2016

Item	Seeding rates[1]				SEM[2]	Probabilities			
	24	35	50	60		Cycle	Int.[3]	Linear[4]	Quad.[5]
Height, cm	146	149	151	152	1.31	0.245	0.765	0.029	0.622
Fresh mass, ton/ha	30.2	38.2	41.6	45.2	1.39	0.011	0.043	0.001	0.472
Dry mass, ton/ha	3.73	4.27	4.71	4.81	0.19	<0.001	0.696	0.027	0.565
Digestible mass, ton/ha	2.48	2.75	3.00	2.96	1.19	<0.001	0.701	0.153	0.577
Forage composition, g/kg									
Dry Matter	120	112	116	108	3.0	<0.001	0.726	0.158	0.950
NDF[6]	730	751	733	736	4.3	<0.001	0.419	0.908	0.158
Crude protein	156	155	146	150	2.6	0.401	0.762	0.227	0.736
ADL[7]	49.5	46.0	50.5	47.2	0.7	0.039	0.268	0.844	0.853
ADL[7], g/kg of NDF[6]	68.0	61.2	68.7	64.2	0.1	<0.001	0.110	0.872	0.613
In situ digestibility, g/kg									
Dry matter	667	644	642	623	8.0	0.061	0.893	0.089	0.898
NDF[6]	559	508	550	522	12.3	0.045	0.149	0.625	0.636

[1] 24, 35, 50 and 60 kg of seeds per hectare.[2] SEM: standard error of means; [3]Int: treatments and cycle interaction effect; [4] Linear: linear effect of seeding rates; [5] Quad.: quadratic effect of seeding rates; [6] NDF: neutral detergent fiber; [7] ADL: acid detergent lignin

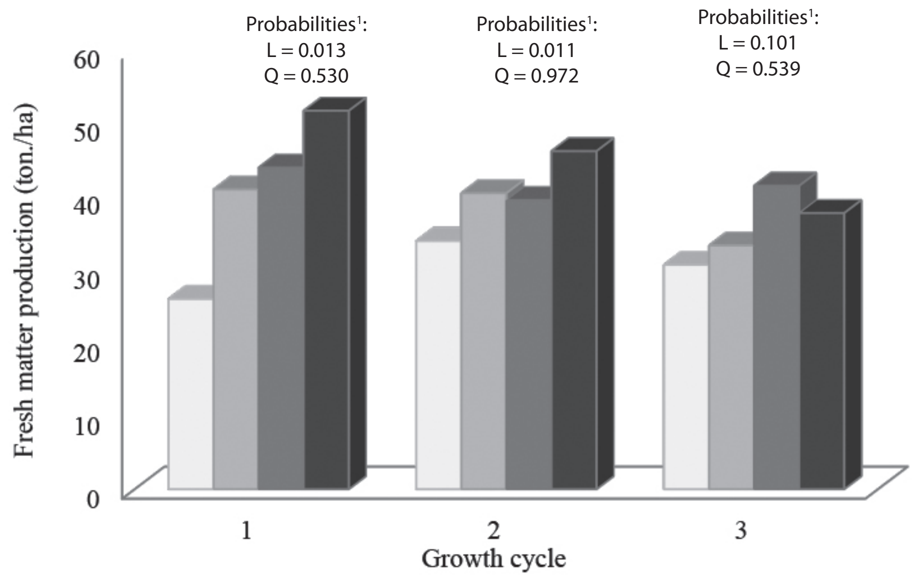

Figure 2 – Millet fresh matter production with 24 (□), 35 (▒), 50 (▓) and 60 (■) kg/ha of seeding rates for three growth cycles. [1] Probabilities: linear and quadratic effect of seeding rate in each growth cycle

Table 3 – Millet production with different cutting heights for two growth cycles – Araras, Brazil, 2016

Item	Cutting heights[1]				SEM[2]	Probabilities			
	20	30	40	50		Cycle	Int.[3]	Linear[4]	Quad.[5]
Height, cm	145	153	155	160	1.81	0.647	0.885	0.002	0.523
Fresh mass, ton/ha	33.1	39.5	41.7	43.5	1.57	0.293	0.156	0.270	0.620
Dry mass, ton/ha	3.50	4.52	4.93	5.52	0.247	0.001	0.642	0.008	0.675
Digestible mass, ton/ha	2.09	2.61	2.90	3.16	0.153	<0.001	0.378	0.008	0.620
Forage composition, g/kg									
Dry matter	103	114	115	126	2.5	0.046	0.210	<0.001	0.955
NDF[7]	720	707	707	717	6.6	<0.001	0.494	0.843	0.214
Crude protein	173	171	166	171	2.8	0.026	0.288	0.730	0.534
ADL	147	162	155	172	3.9	0.094	0.334	0.085	0.933
ADL[8], g/kg NDF	204	230	220	239	5.4	0.800	0.216	0.096	0.785
In situ digestibility, g/kg									
Dry matter	592	577	589	566	8.3	0.001	0.324	0.205	0.733
NDF[7]	478	460	486	423	12.0	0.041	0.339	0.052	0.147

[1] 20, 30, 40 and 50 cm of cutting heights. [2]SEM: standard error of means; [3] Int: treatments and cycle interaction effect; [4] Linear: linear effect of seeding rates; [5] Quad.: quadratic effect of cutting height; [6] Cubic: Cubic effect of cutting height; [7] NDF: neutral detergent fiber; [8] ADL: acid detergent lignin

Conclusion

Higher seeding rate (60 kg/ha) increased plant height and dry mass production, and tended to decrease DM *in situ* digestibility, without any effect on chemical composition and digestible DM production. Higher cutting height (50 cm) provided higher residual plant height, fresh and dry mass production, digestible DM production, tended to increase ADL concentration and decreased NDF *in situ* digestibility.

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