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Full Length Research Paper

Evaluating Nitrogen Fertilization and Dehydration Methods for Optimal Tifton 85 Hay Yield

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The objective of this study was to evaluate *Cynodon* species 'Tifton 85' at different hay production phases (harvest, baling, and storage) and different (N) rates. Dehydration of the first crop was carried out in the field, while the second crop was in the shed. Dry matter and protein content increased linearly with the N rates. Dehydration in the shed was not effective for hay production, since dry matter did not reach the desired level of 850 g kg^{-1}. During the hay production period (harvest, baling, and storage), the content of acid detergent fiber of the first crop and the second crop increased by 25.32 and 7.38%, respectively, and that of lignin increased by 21.33 and 32.27%, respectively. Forage digestibility decreased by 4.55%, when dehydration occurred in the field, whereas it decreased by 14.68% when dehydration occurred in the shed, a difference higher than 300% due to the loss of soluble carbohydrates. Overall, the findings of this study indicate that forage dehydration for hay production needs to be carried out in the field under appropriate environmental conditions to prevent nutritional losses. Additionally, dry matter of Tifton 85 increased by 20.40% and protein content increased by 18.65%, which equals 514.27 kg of soybean meal at 100 kg ha^{-1} of N.

Key words: Fertilization rates, hay production, nutrient quality of forage, pasture.

INTRODUCTION

The management of hay production is used to preserve forage through the partial dehydration of plant material. Physical, biological, and chemical processes during harvest and storage cause dry matter (DM) and nutrient losses (Rotz and Shinners, 2007). Thus, the main objective in hay production is to maintain the DM and nutrient content of forage, which is usually stored for at least one year.

Dehydration removes the water that enhances the action of deleterious microorganisms and prevents the

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long preservation of hay (Mufatto et al., 2016). Thus, hay is a forage resource that can cover any seasonal quantitative and qualitative deficiencies and thus, it is important to obtain fodder of high nutritional value (Cavalcanti et al., 2016).

Hay quality is related to its nutritional value, suitable characteristics of forage plants, climatic factors, and management (Gomes et al., 2015; Mufatto et al., 2016). Adverse climatic factors often increase the dehydration time, extending the respiration until the moisture concentration in the forage reaches 400 g kg^{-1} DM and lead to significant losses in carbohydrates and hexoses that are easily digestible (Collins and Clobentz, 2007).

Fertilization is an important factor in hay production management, since grasses require relatively high amounts of nitrogen (N) for their growth (Sanches et al., 2017). In tropical areas, *Cynodon* species is recognized as a valuable forage resource with great versatility that responds to the continuous increase in N applied to the soil, increasing the production of DM per hectare and the percentage of crude protein (CP) (Sohm et al., 2014).

N fertilization and harvest time also influence the concentration of neutral detergent fiber (NDF) and acid detergent fiber (ADF). Both NDF and ADF usually decrease with increasing N rate, but increase during the summer because of the relatively high temperature that promotes cellular aging, and thus, the formation of fibrous tissues (Sohm et al., 2014; Sanches et al., 2017). The nutritional potential of forage is determined by ADF that is composed of lignin (LIG) and modifies the DM digestibility as well as by the nutritional value. N usually increases the CP of forage, since it increases the participation of leaves in the total DM (Ames et al., 2014); thus, it is positively associated with DM digestibility.

This study aimed to evaluate the DM, canopy height, and number of tillers of *Cynodon* spp. 'Tifton 85' prior to harvest as well as the DM, mineral matter (MM), NDF, ADF, neutral detergent insoluble protein (NDIP), acid detergent insoluble protein (ADIP), CP, LIG, cellulose (CEL), hemicellulose (HEM), and *in vitro* dry matter digestibility (IVDMD) at harvest, baling, and storage using five different N fertilization rates and two different dehydration methods.

MATERIALS AND METHODS

The study was carried out at the Experimental Farm of Antonio Carlos Santos Pessoa, Marechal Cândido Rondon campus, Western Paraná State University (24°31′53.0″S, 54°01′03.0″W, 420 m above sea level). According to Koppen, the weather of this area is classified as subtropical Cfa; rainfalls are well distributed throughout the year and summers are hot. The temperature of the coldest quarter ranges from 17 to 18°C, the hottest quarter from 28 to 29°C, and the annual temperature from 22°C to 23°C. The precipitation of the wettest quarter ranges from 400 to 500 mm, the driest quarter from 250 to 350 mm, and the annual precipitation from 1,600 to 1,800 mm (Caviglione et al., 2000).

The soil of the experimental area is classified as Red Eutrophic Latosol (LVe) (EMBRAPA, 2013) with the following chemical characteristics: 8.15 mg dm^{-3} P (Mehlich Puller), 23.92 g dm^{-3} Mo, 0.01 mol L^{-1} $CaCl_2$, 4.30 $cmol_c$ dm^{-3} H + Al, 0.05 $cmol_c$ dm^{-3} Al^{3+} (1 mol L^{-1} KCl), 0.23 $cmol_c$ dm^{-3} K (Mehlich Puller), 3.62 $cmol_c$ dm^{-3} Ca^{2+} (1 mol L^{-1} KCl), 1.69 $cmol_c$ dm^{-3} Mg^{2+} (1 mol L^{-1} KCl), 5.54 $cmol_c$ dm^{-3} Sb, 9.84 $cmol_c$ dm^{-3} CTC, 56.30% V, 0.89% Al, 6.30 mg dm^{-3} Cu (Mehlich extractor), 1.4 mg dm^{-3} Mn (Mehlich extractor), 63.00 mg dm^{-3} Zn (Mehlich extractor, 25.10 mg dm^{-3} Fe (Mehlich extractor)), and 650 g kg^{-1} clay.

The study was carried out in a hay production field, established in 2004. The grass *Cynodon* spp. 'Tifton 85' (*Cynodon dactylon* × *Cynodon nlemfuensis*) was cropped in a randomized complete block design (RCBD) with four blocks and five plots (5 m × 3 m) per block (a total of 20 experimental plots sub-divided by time). The weather conditions throughout the study period are as shown in Figure 1. Harvest for standardizing the forage was conducted on October 30, 2010. Dehydration of the first crop was carried out in the field, whereas that of the second crop in a shed (Table 1).

DM, canopy height and number of tillers per square meter were studied for five N rates (0, 25, 50, 75, and 100 kg ha^{-1} of N) and two harvests, whereas chemical composition and IVDMD were studied for five N rates and two hay production periods (harvest, baling, and storage) (Banzatto and Kronka, 2006).

The DM per hectare was estimated using a 0.25 m^2-metallic frame that placed 5 cm above the ground level (Salman et al., 2006) to harvest the fodder in each experimental unit. Three samplings were performed at each harvest per experimental unit. Samples were labeled, packed in paper bags, weighed, and then dried in a forced ventilation oven at 55°C for 72 h to estimate the DM per hectare. The average plant canopy height (average of three points) was measured prior to harvest using a millimeter ruler. The tiller number per square meter was calculated by multiplying the DM of each 0.25 m^2 area by four and dividing it by the average tiller weight of the same area.

Revolving and turning during forage dehydration were performed daily between 10:00 and 15:00 h. At baling and storage, samples were ground using a Willey mill, passed through a 30-mesh sieve, and stored in plastic bags. Then, they were used for evaluating DM, MM, NDF, ADF, NDIP, ADIP, CP, LIG, CEL, and HEM (Silva and Queiroz, 2009). IVDMD was determined as described by Tilley and Terry (1963) and DM digestibility was analyzed as described by the Association of Official Analytical Chemists (AOAC, 1990). Analysis of variance (ANOVA) in conjunction with Tukey's test was performed to study the effect of dehydration conditions and hay production phases (harvest, baling, and storage) on the variables. The effect of N rate was obtained by regression analysis; the model was selected based on the highest coefficients of determination (R^2), and the partial regression coefficients were calculated with Student's *t*-test (Pimentel-Gomes, 2009). Significance was set at $p < 0.05$. All analyses were performed using Sisvar 5.3 (Ferreira, 2011).

RESULTS AND DISCUSSION

DM increased with increasing N rate (Figure 2); however, no interaction was identified among N rate and DM at the first or second crop. DM increased with increasing N rate as follows: Y (DM ha^{-1}) = 4,308.28 + 8.79X (N rate), showing that at kg ha^{-1} of N, DM was 4,308.28 kg per hectare and that DM increased by 8.79 kg per hectare for each kg of N. These results could be attributed to the higher precipitation after the first harvest (Figure 1) that enhanced the utilization of residual N in the soil. It is known that N stimulates vegetative growth as well as water absorption for cell elongation in the meristem

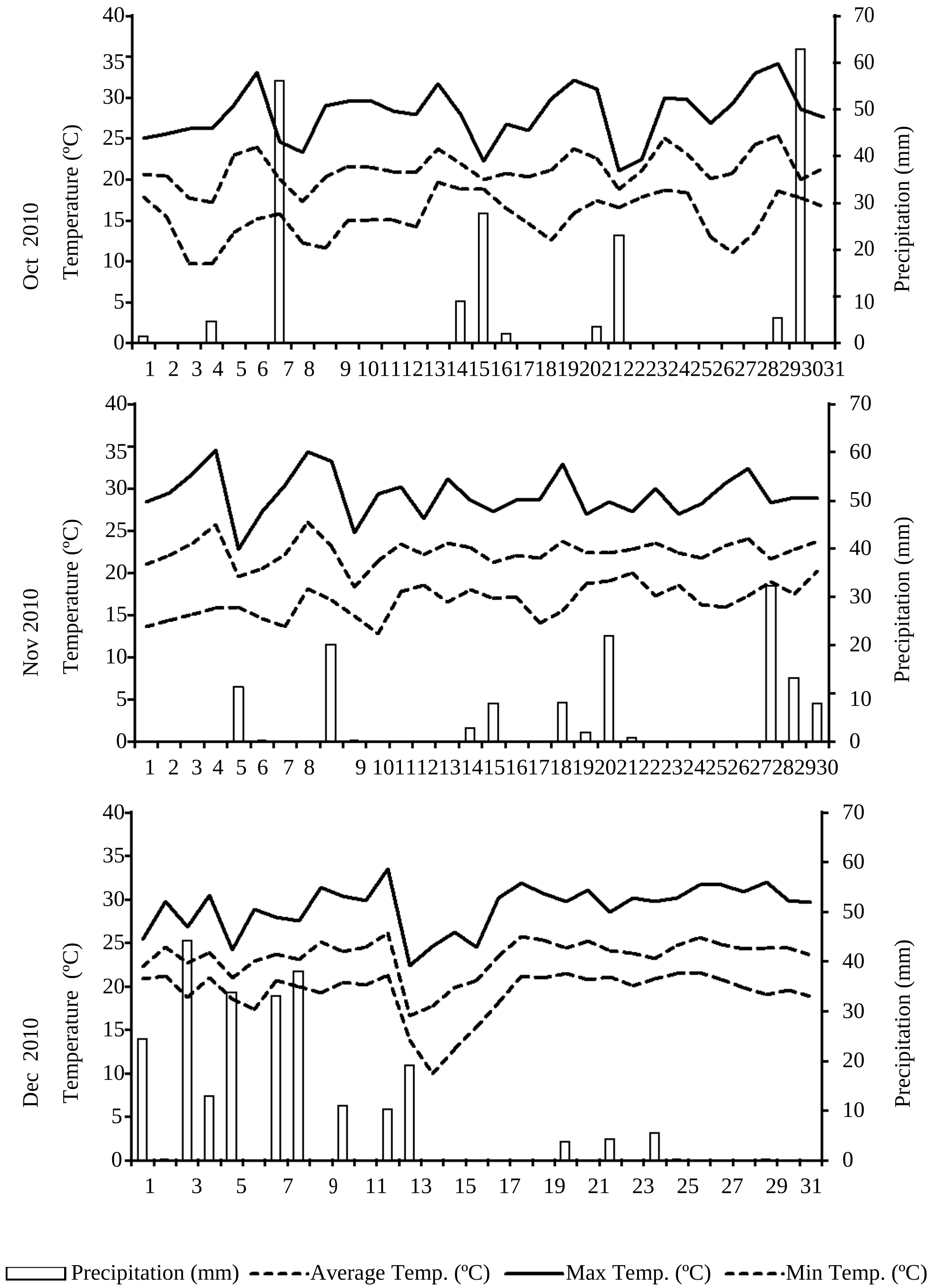


Figure 1. Climatic data throughout the study period (October 1 to December 31, 2010). Source: Agro-meteorological Station of Western Paraná, State University.

(Colussi et al., 2014). Additionally, N increases the photosynthetic efficiency of the leaf because it stimulates the synthesis of the Rubisco (Pereira et al., 2012).

In the present study, the average DM of the first crop was 3,905 kg ha^{-1} and of the second crop was 5,591 kg ha^{-1}. Sanches et al. (2017) observed an average DM of 3,037 kg ha^{-1} at a N rate of 84 kg ha^{-1} N, whereas Colussi et al. (2014) reported an average DM of 3,042 kg ha^{-1}

Table 1. Climatic data during dehydration of the first and second crops of 'Tifton 85' for hay production.

Date	Air temperature (°C)			Relative humidity (%)			Dew point temperature (°C)			Wind speed ($m\ s^{-1}$)	Radiation ($KJ\ m^{-2}$)	Precipitation (mm)
	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.			
							1st harvest-dehydration in the field					
11/26/2010	23.2	30.6	15.9	67.8	93.0	35.0	16.3	18.7	13.1	1.9	31,016.78	0.0
11/27/2010	24.0	32.4	17.3	64.9	90.0	30.0	16.3	19.5	11.6	1.6	15,867.96	0.0
							2nd harvest-dehydration in the shed					
12/24/2010	23.2	29.8	20.9	89.9	97.0	64.0	21.3	24.0	19.8	2.9	15,243.59	5.4
12/25/2010	24.7	30.2	21.5	85.8	97.0	64.0	22.0	24.3	20.7	2.6	23,364.96	0.2
12/26/2010	25.6	31.7	21.6	82.8	97.0	59.0	22.2	25.0	20.0	1.9	25,862.56	0.0
12/27/2010	24.8	31.7	20.8	83.5	94.0	55.0	21.6	24.9	19.7	3.1	25,027.17	0.0
12/28/2010	24.3	30.9	19.9	82.0	95.0	59.0	20.9	24.7	18.5	3.5	23,817.67	0.0
12/29/2010	24.4	32.0	19.0	79.8	95.0	53.0	20.4	24.3	18.0	2.7	26,749.14	0.2

Ave: Average; Max: maximum; Min: minimum. Source: Meteorological Station of Western Paraná State University.

without N and of 5,014 kg ha^{-1} at a N rate of 127.5 kg ha^{-1} N after four harvests during the summer season.

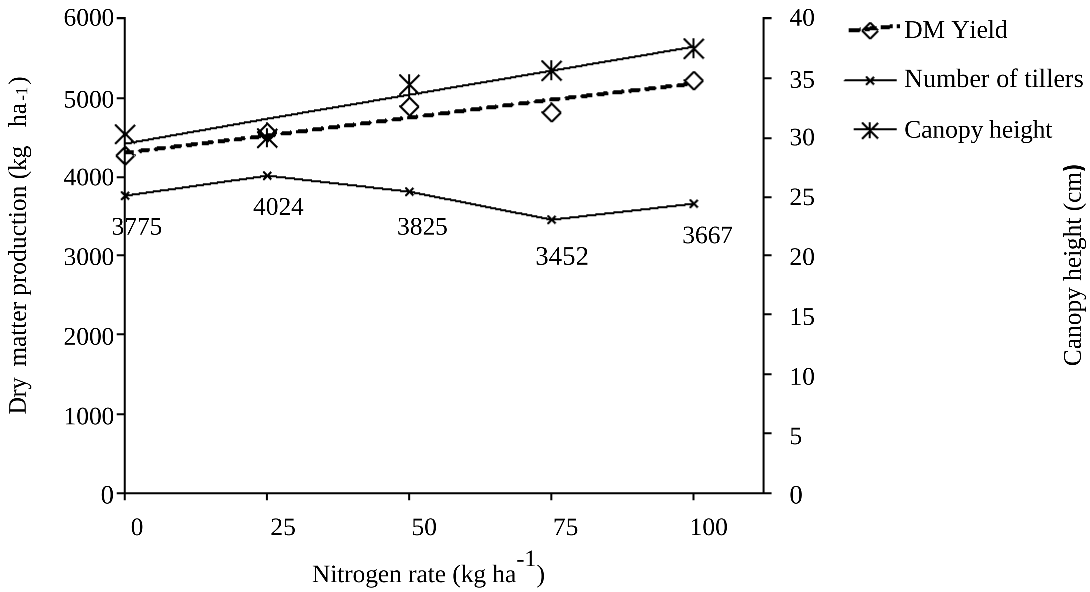
Sohm et al. (2014) suggested that DM and CP of forages are directly related to the N rate and harvest frequency. It was found that the DM of the first crop (dry period; average daily precipitation, 9.3 mm) was lower than that of the second crop (wet period; average daily precipitation, 17.1 mm), because the increased moisture in combination with N fertilization improved the forage yield. In addition, it was observed that the DM of leaves was lower than that of stems in the dry period. Michelangeli et al. (2010) also related the reduction in DM over the years with N fertilization.

As shown in Figure 2, canopy height increased with increasing N rate as follows: Y (Canopy height) = 29.5 + 0.081X (N rate). The average canopy height of the first crop was 20.5 cm, whereas that of the second crop was 46.6 cm, a difference that could be attributed to the higher precipitation after the first harvest (Figure 1) and also the greater responsiveness of the second crop to N fertilization (Oliveira et al., 2010). Our results were similar to those reported by Tiecher et al. (2016), which found that canopy height increased in relation to the N rate and rainfall.

No significant differences were identified in the number of tillers per square meter among the N rates (Figure 2) and no interaction was observed between the production periods or among the N rates. Vilela et al. (2005) reported that there is no variation in the number of tillers per square meter of *C. dactylon* 'Coastcross' in relation to season (spring, summer, and fall) and that a plant height of ≥20 cm reduces the incidence of solar radiation at the base of the tillers and consequently, their number. Ziech et al. (2016) reported that the number of tillers reduced from 2,846 to 2,090 m^2 for Tifton 85 and from 2,515 to 1,846 m^2 for 'Coastcross,' when the N rate increased from 0 to 75 kg ha^{-1}. Therefore, the number of tillers probably reduces with increasing N rate due to the higher rates of daily leaf growth, since there is a negative relation between plant density and plant height, which compete for nutrient assimilation.

The DM content of both crops increased significantly between harvest and baling (Table 2). At the baling phase, the moisture content decreases from approximately 80% to less than 20%, allowing the safe storage of hay and decreasing the loss indices (Calixto Junior et al., 2012). DM loses are small or even non-detectable when hay moisture after baling is 150 g kg^{-1} and storage lasts for one or two months (Collins and Coblentz, 2007). The moisture condition of 150 g kg^{-1} was not achieved when dehydration occurred in the shed (Table 1). It is known that direct radiation is more important than the pressure deficit between the plant, the environment, and the wind speed due to its effect on the internal moisture content (Rotz, 2003).

Forage dehydration in the field occurred at a



$\hat{Y}_{DM\ Yield\ ha^{-1}} = 4308.2817 + 8.79122X$ $R^2 = 90.18$ CV1 = 14,68% CV2 = 12.08% p = 0.0445

$\hat{Y}_{Canopy\ Height} = 29.5 + 0.081X$ $R^2 = 90.71\%$ CV1 = 7.10% CV2 = 13.77% p = 0.0000

Figure 2. Dry matter, canopy height, and numbers of tillers of 'Tifton 85' at different nitrogen fertilization rates. CV 1: Coefficient of variation of plot; CV 2: Coefficient of variation of subplot.

higher rate than that in the shed (2 g g^{-1} of MS h^{-1} and 0.4898 g g^{-1} of MS h^{-1}, respectively). The rates of dehydration can progressively be close to zero due to the balance between the water vapor pressure of the plant and that of the surrounding environment and may remain stable under favorable environmental conditions (Rotz, 1995). Forage dehydration in the shed requires more time that in the field (2 vs. 6 days) due to the lack of direct radiation. Any other forms of energy used for forage dehydration are uneconomical, since the production of 1 ton of hay involves the removal of 3 tons of moisture, which requires energy equivalent to 270 L of diesel oil or approximately 1.6719 billion calories (Rotz, 1995).

The high moisture content favors the growth of fungi and heating during baling. Fungi can lead to a reduced animal intake and the production of mycotoxins, whereas heating, especially over 40°C, causes the loss of soluble carbohydrates, proteins, lipids, and vitamins A and B (Cecava, 1995; Rotz, 2003). Thus, a fast dehydration process is important to obtain hay appropriate for storage and prevent any degradation in the nutritional value (Calixto Junior et al., 2012).

The least amount of MM of the first crop was found at the baling phase, whereas that of the second crop was found at the storage phase (Table 2). Our values were similar to those reported by Ribeiro and Pereira (2011) and Oliveira et al. (2016), but higher than those reported by Calixto Junior et al. (2012). The MM of the first crop showed a tendency ($p < 0.066$) to increase with increasing N rate; thus, it might be associated with the relatively high soluble N availability and the linear increase in the extraction of other minerals from the soil with the increase in the N rate (Lima et al., 2015). This trend was not observed in the second crop, probably because of the higher precipitation (dilution effect) and the consequent higher DM. Ribeiro and Pereira (2011) reported that the levels of P in the leaf blades and those of Mg in the whole plant of Tifton 85 increase with increasing N rate. However, significant effect was not observes for the different management practices, DM increments, soil type, and various elements on the mineral composition of Tifton 85.

The NDF of Tifton 85 is typically high, but does not affect the forage digestibility due to the low occurrence of ferulates linked to cell wall carbohydrates by ether bonds that contribute to an efficient rumen microbial action (Ribeiro and Pereira, 2010). In the present study, the NDF of the first crop was higher at the storage phase, followed by that at the baling and harvest phases, whereas the opposite trend was observed for the NDF of the second crop. Similarly, Pasqualotto et al. (2015) found that NDF, ADF, NDIP, ADIP, and LIG increase significantly during the first 12 days of storage, but then reach a plateau (Collins and Coblentz, 2007). Dehydration of the second crop occurred in the shed, and thus, the time to reach 30% DM was greater than that needed for dehydration of the first crop in the field,

Table 2. Dry matter (DM), mineral matter (MM), neutral detergent fiber (NDF), acid detergent fiber (ADF), neutral detergent insoluble protein (NDIP), acid detergent insoluble protein (ADIP), crude protein (CP), lignin (LIG), cellulose (CEL), hemicellulose (HEM), and *in vitro* dry matter digestibility (IVDMD) of the first and second crop of 'Tifton 85' at the harvest, baling, and storage phases of hay production.

Crop	Hay production			CV 1 (%)	CV 2 (%)
	Harvest	Baling	Storage		
			DM (g kg^{-1})		
1st	221.4^{c}	802.7^{b}	841.7^{a}	5.95	6.89
2nd	216.2^{c}	682.1^{b}	800.5^{a}	3.77	4.15
			MM (g kg^{-1} DM)		
1st	77.8^{a}	67.8^{b}	80.8^{a}	12.64	11.69
2nd	74.8^{a}	77.44^{a}	60.7^{b}	11.50	12.61
			NDF (g kg^{-1} DM)		
1st	777.2^{b}	798.3^{ab}	810.2^{a}	5.55	4.68
2nd	827.5^{a}	738.3^{c}	790.0^{b}	6.24	4.81
			ADF (g kg^{-1} DM)		
1st	427.7^{c}	466.9^{b}	536.0^{a}	19.16	10.59
2nd	493.2^{a}	491.9^{a}	529.6^{a}	11.88	8.90
			ADIP (g kg^{-1} DM)		
1st	93.1^{b}	129.5^{a}	132.9^{a}	20.55	11.81
2nd	78.4^{a}	60.4^{b}	62.3^{b}	17.70	14.76
			NDIP (g kg^{-1} DM)		
1st	101.2^{b}	120.7^{a}	107.8^{b}	19.59	14.58
2nd	78.8^{a}	48.5^{b}	57.1^{b}	15.86	22.02
			CP (g kg^{-1} DM)		
1st	185.4^{ab}	189.4^{a}	175.9^{b}	15.95	8.61
2nd	140.0^{a}	135.2^{a}	135.9^{a}	5.02	6.85
			LIG (g kg^{-1} DM)		
1st	167.3^{c}	265.8^{a}	203.0^{b}	27.54	19.88
2nd	179.4^{b}	219.3^{ab}	237.3^{a}	28.96	34.53
			CEL (g kg^{-1} DM)		
1st	278.3^{a}	285.4^{a}	293.9^{a}	17.95	17.26
2nd	352.5^{a}	353.4^{a}	356.1^{a}	15.84	10.16
			HEM (g kg^{-1} DM)		
1st	349.5^{a}	331.4^{a}	274.2^{b}	28.70	19.81
2nd	334.3^{a}	246.4^{b}	260.5^{b}	31.10	17.79
			IVDMS (%)		
1st	52.26^{a}	48.95^{b}	49.88^{ab}	7.71	7.66
2nd	48.02^{a}	44.00^{ab}	40.97^{b}	8.16	12.82

CV 1: Coefficient of variation of plot; CV 2: coefficient of variation of subplot. Different letters indicate significant differences at $p < 0.05$.

resulting in a continuously increased plant respiration (Moser, 1995). Thus, the second crop had a lower content of HEM than the first crop (McDonald and Clark, 1987), due to an increase in LIG with time (Table 2).

Tifton 85 has a relatively high concentration of glucose and other sugars (Mandebvu et al., 1999; Hatfield et al., 1997), known as reactive structural carbohydrates, which may explain the negative relationship between hay heating as a function of the increased moisture content at the baling phase and the degradability of NDF in the rumen (Coblentz and Hoffmann, 2009).

The ADF of the first crop significantly increased during the hay production period (harvest, baling, and storage), whereas that of the second crop did not show any differences among the hay production phases. These results were in agreement with those reported by Pasqualotto et al. (2015). The N rates or the interaction of N rates and dehydration conditions did not significantly affect ADF; however, a decreasing trend was observed with the N rate, which was in accordance with the results reported by Sohm et al. (2014).

The NDF and ADF of the first crop were lower than those of the second crop (Table 2), results that were in agreement with those reported by Neres et al. (2012). Sohm et al. (2014) supported that NDF and ADF decrease with increasing N rates and are influenced by the harvest season and crop year.

The NDIP of the first and second crop was higher at harvest and baling, respectively (Table 2), results that were in agreement with those reported by Castagnara et al. (2011). Pasqualotto et al. (2015) showed that NDIP is reduced with time when hay production occurs under high conditioning intensity, whereas no change was observed when hay production occurs under low conditioning intensity.

The ADIP of the first crop increased between harvest and baling, whereas that of the second crop decreased (Table 2); thus, dehydration in the field increased the amount of ADIP, since this variable increases with temperature (Collins and Coblentz, 2007). The ADIP increases with storage time, similar to other fibrous components, but the greatest change occurs during the first two weeks of storage (Collins and Coblentz, 2007). In the present study, the ADIP of the first crop was higher at the baling and storage phase (Table 2), whereas that of the second crop at harvest, differences that can be attributed to the different dehydration conditions. The ADIP of Tifton 85 showed a higher increase compared with that of alfalfa when submitted to heating at temperatures higher than 30°C, probably due to the relatively higher HEM content of the former (Collins and Coblentz, 2007). Pasqualotto et al. (2015) and Ames et al. (2014) reported a higher ADIP at the storage phase, followed by that at harvest and baling phases.

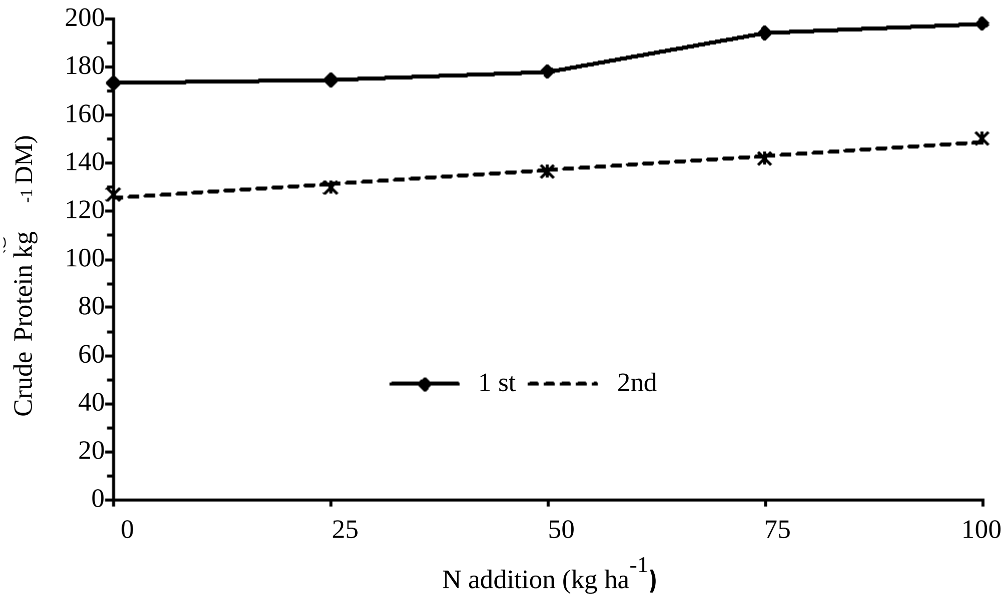
The higher NDIP and ADIP of the first crop could be explained by the high temperature in the field (>35°C; Figure 1 and Table 1), which is positively associated with the increased N concentration in the fiber after short-term storage (Turner et al., 2002). The NDIP and ADIP represent the N that remains in the NDF and ADF residue. Both indices represent an estimate of nutrient unavailability, mainly of CP caused by heating at temperatures higher than 55°C during the hay production period, since heating usually makes protein unavailable to animals (Pasqualotto et al., 2015; Ames et al., 2014). It has been estimated that an ADIP less than 100 g kg^{-1} is present in all forages and tends to increase linearly with heating in alfalfa and grasses due to Maillard reactions (Collins and Coblentz, 2007).

The CP of the first crop, but not of the second crop, differed among the hay production phases (Table 2). The CP of both crops was superior to that reported by Neres et al. (2014), but similar to that reported by Sanches et al. (2017). It has been reported that the protein content is affected by the use of conditioners and the frequency of revolving and turning during forage dehydration (Neres and Ames, 2014). The levels of most N components tend to slightly increase when the moisture is 200 to 300 g kg^{-1} due to heating, because the nonstructural carbohydrates are oxidized by plant enzymatic processes and microorganisms associated with storage (Turner et al., 2002). CP tends to reduce by approximately 0.25% per month of storage due to the volatilization of ammonia and other nitrogenous compounds (Neres et al., 2014; Pasqualotto et al., 2015). The CP content in the first harvest did not respond to the increase in N rates, whereas that in the second harvest increased with increasing N rate. These results were in agreement with those reported by Sohm et al. (2014) and Sanches et al. (2017) and could be explained by higher precipitation during the second production period that increased the availability and absorption of N (Figure 3).

As shown in Figure 3, the protein content increased with increasing N rate as follows: Y (Protein content) = 125.392178 + 0.233547X (N rate). The increase in CP per hectare occurs in synergy with the increase in DM (Figure 2). Overall, 100 kg ha^{-1} of N increased the DM of Tifton 85 by up to 20.40% and the protein content by 18.65%, which equals 514.27 kg of soybean meal.

Turner et al. (2002) supported that the content of fibrous components increases with storage time. In the present study, LIG was not affected by the different N rates (Table 2); however, it showed the highest value at the baling and storage phase in the first and second crop, respectively. Additionally, LIG increased during the hay production period (harvest, baling, and storage) by 21.33% in the first crop and by 32.27% in the second crop, results that were in agreement with those reported by Neres et al. (2014). The increase in LIG could be attributed to the loss of soluble nutrients that resulted in lower DM digestibility (Table 1).

CEL ranged between 278.3 and 356.1 g kg^{-1} MS in both crops and was not affected by the N rates or hay production phases (Table 2), similarly as reported by Neres et al. (2014). The HEM of both crops was significantly reduced at the storage phase (Table 2), probably due to the relatively high concentration of soluble sugars (Mandebvu et al., 1999; Hatfield et al.,



$\hat{Y}$ 2nd = 125.392178+0.233547*X CV1=5.02% CV2=6.41% R^2=97.95%

Figure 3. Crude protein of 'Tifton 85' hay according to nitrogen rates.

1997), which are reactive structural carbohydrates (Collins and Coblentz, 2007). These results were in disagreement with those reported by Ames et al. (2014), which showed that no changes occur in HEM between harvests when N fertilization is applied. However, Pasqualotto et al. (2015) reported that HEM decreases with storage time when hay production occurs under high conditioning intensity, whereas the highest levels of HEM were observed at 30 and 60 days of storage when hay production occurs under low conditioning intensity.

The IVDMD of the first crop was 52.2% and that of the second crop was 48.02%. The difference could be attributed to the higher precipitation after the first harvest (Figure 1), which affected DM. The DM digestibility of the first crop was reduced by 4.55%, whereas that of the second crop was reduced by 14.68%, a difference of 322.64%, which could be attributed to the longer dehydration time in the shed, which led to nutrient losses by plant respiration. IVDMD in the present study was lower than that reported by Pasqualotto et al. (2015). Calixto Junior et al. (2007) did not find any differences in the IVDMD of star grass between two N rates (50 and 100 kg ha^{-1}), whereas Quadros and Rodrigues (2006) reported that the DM digestibility of Tanzania and Mombaça grasses increases with increasing N rates (101 to 232 kg ha^{-1}).

Conclusions

The results confirmed that forage dehydration in the field is the most appropriate method for hay production, since it provides the recommended DM for baling. DM increased with increasing N rates, reaching the highest values (20.40%) at 100 kg ha^{-1} N. ADF increased during the hay production period in the first crop, but not in the second crop; however, it was not affected by the N rate. The protein content increased with increasing N rate, reaching approximately 18.65% at 100 kg ha^{-1} of N, but decreased during the hay production period. It was also concluded that the DM digestibility decreases by 4.55% when dehydration occurs in the field, whereas by 14.68% when dehydration occurs in the shed, a difference higher than 300%. Therefore, forage dehydration for hay production needs to be carried out under suitable conditions to prevent nutritional losses.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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