Research, Society and Development, v. 11, n. 4, e10811427158, 2022
(CC BY 4.0) | ISSN 2525-3409 | DOI: http://dx.doi.org/10.33448/rsd-v11i4.27158

Production and nutritional value of Mombaça grass with application of whey as an alternative nitrogen source

Produção e valor nutritivo de capim-mombaça com aplicação de soro de leite como fonte alternativa de nitrogênio

Produccíon y valor nutritivo del pasto Mombasa com aplicación de suero como fuente alternativa de nitrógeno

Received: 02/18/2022 | Reviewed: 02/26/2022 | Accept: 03/06/2022 | Published: 03/12/2022

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Abstract
Whey is a waste generated in large quantities in dairy industries, and its use in agriculture as a source of nutrients can be an appropriate destination. Thus, the objective of this study was to evaluate the effect of whey as a nitrogen source for production and nutritional value of Mombaça grass. The experiment was conducted in pots, in a randomized blocks factorial scheme with four replicates. The treatments consisted of 5 doses of whey (0; 100; 200; 300 and 400 mg dm^{-3} N) associated with 3 doses de N-urea (0; 100 and 200 mg dm^{-3} N). Portions of 7 dm^3 soil were incubated with lime and phosphate fertilizer and, 15 days before the end of incubation, the doses of whey were applied. After incubation, sowing followed by thinning (four plants/pot) were carried out, and the doses of N-urea were divided into 3 applications. Three grass cuts were made and, after the first cut, the treatments doses of whey and N-urea were reapplied. Whey fertilization increased the number of tillers, shoot dry matter production and crude protein of Mombaça grass, and the increases obtained varied as a funcion of the grass cycle and the N-ureea dose. The agronomic efficiency index of whey with N source in relation to urea was, on average, 69%. The whey increases production and improves the nutritional value of Mombaça grass, being an efficient alternative source of N for the forage.
Keywords: Organic fertilization; Nitrogen fertilization; Organic waste; Forage grasses; Pasture.

Resumo
O soro de leite é um resíduo gerado em grandes quantidades nos laticínios, e o uso na agricultura como fonte de nutrientes pode ser um destino adequado. Objetivou-se avaliar o efeito do soro de leite como fonte de nitrogênio para produção e valor nutritivo do capim-mombaça. O experimento foi conduzido em vasos, em delineamento em blocos ao acaso, em esquema fatorial, com quatro repetições. Os tratamentos foram constituídos por 5 doses de soro de leite (0;100; 200; 300 e 400 mg dm^{-3} de N) associadas a 3 doses de N-ureia (0; 100 e 200 mg dm^{-3} de N). Porções de 7 dm^3 de solo foram incubadas com calcário e adubo fosfatado, e 15 dias antes do término da incubação aplicou-se as doses de soro de leite. Após a incubação foi realizada a semeadura do capim, seguida de raleio (quatro plantas/vaso), e as doses de N-ureia foram parceladas em 3 vezes. Foram efetuados três cortes do capim, e após o primeiro corte, os tratamentos foram reaplicados. A aplicação de soro de leite aumentou o número de perfilhos vivos, a produção de matéria seca, o teor de proteína bruta na parte aérea do capim-mombaça, e os acréscimos obtidos variaram em função do ciclo do capim e da dose de N-ureia. O índice de eficiência agronômica do soro de leite como fonte de N em relação à ureia foi, em média, de 69%. O soro de leite aumenta a produção e melhora o valor nutritivo do capim-mombaça, sendo uma eficiente fonte alternative de N para a forrageira.
Palavras-chave: Adubação orgânica; Adubação nitrogenada; Resíduo orgânico; Gramíneas forrageiras; Pastagem.

Resumen
El suero es un residuo que se genera en gran cantidad en los productos lácteos, y su uso en la agricultura como fuente de nutrientes puede ser un destino adecuado. El objetivo fue evaluar el efecto del suero de leche como fuente de nitrógeno para la producción y el valor nutricional de la pasto mombasa. El experimento se realizó en macetas, en un diseño de bloques al azar, en esquema factorial, con cuatro repeticiones. Los tratamientos consistieron en 5 dosis de suero de leche (0;100; 200; 300 y 400 mg dm^{-3} de N) asociado a 3 dosis de N-urea (0; 100 y 200 mg dm^{-3} de N). Se incubaron porciones de 7 dm^3 de suelo con caliza y fertilizante fosfatado, y 15 días antes de finalizar la incubación se aplicaron dosis de suero. Después de la incubación, se realizó la siembra del pasto, seguida de raleo (cuatro plantas/maceta), y las dosis de N-urea se dividieron en 3 tiempos. Se realizaron tres cortes de pasto, y luego del primer corte se reaplicaron los tratamientos. La aplicación de suero incrementó el número de macollos vivos, la producción de materia seca, el contenido de proteína cruda en la parte aérea del pasto mombasa y los incrementos obtenidos variaron en función del ciclo del pasto y de la dosis de N-urea. El índice de eficiencia agronómica del suero con fuente de N en relación a la urea fue, en promedio, de 69%. El suero aumenta la producción y mejora el valor nutricional del pasto mombasa, siendo una fuente alternativa eficiente de N para el forraje.
Palabras clave: Fertilización orgánica; Fertilización nitrogenada; Residuo orgánico; Pastos forrajeros; Pastos.

1. Introduction

Organic waste can change the chemical and physical properties of the soil, and its use in agriculture can be important from an environmental and economic point of view, favoring the sustainability of agricultural production systems (Carnier et al., 2019; Scheid et al., 2020).

Whey is an organic waste generated in large quantities in dairy industries in the cheese production process, so that for each kilogram of cheese produced, 9 liters of this waste are obtained, it is estimated that, in Brazil, 7.2 million m^3 of whey are generated annually (Braos et al., 2020). Although whey is used in animal feed and in the production of dairy beverages, this waste is still remains little used in agriculture, and its improper disposal may cause serious environmental damage, and there is still the aggravation of being a perishable product and not tolerating extended storage (Mantovani et al., 2015; Queiroz, 2018).

Whey is particularly a source of K and N, and its use has provided increased levels of nutrients in the soil, in plant tissues and in the production of dry matter in plants such as Tanzania grass and maize (Gheri et al., 2003; Mantovani et al., 2015). Thus, the agricultural use of this organic waste can be an appropriate destination and a viable alternative, particularly in areas close to the generation points, especially in pastures, intended for milk production.

The Mombaça grass, *Panicum maximum* cv. Mombaça (syn *Megathyrsus maximus*), a forage widely used in the formation of pastures in the tropical region, has a habit of upright cespitous growth, good climatic adaptation, high yield potential and nutritional value (Carvalho et al., 2017; Catuchi et al., 2019; Pereira et al., 2020). Mombaça grass has high demand for N, a nutrient of great importance for maintaining high levels of production and improving the quality of forage grasses (Rosado et al., 2014). Due to the high cost of N fertilizers, whey can provide part of the N required by Mombaça grass. However, studies are needed to evaluate the effect of this organic waste as a source of N exclusively or associated with other sources in forage grasses. Given this context, this study aimed to evaluate the effect of whey as a nitrogen source for production and nutritional value of Mombaça grass.

2. Methodology

The experiment was conducted in pots, in a greenhouse, in Alfenas-MG (21º25’45” S, 45º56’60” W). In the superficial layer (0–20 cm), 500 dm^3 of soil with a clay texture were collected, placed to dry in the air and in the shade, ground, passed through a 4-mm sieve and sampled for routine initial chemical and granulometric (Silva, 2009; Camargo et al., 2009) characterization; the values are presented in Table 1.

Table 1. Initial chemical and granulometric characterization of the soil used in the experiment.

pH $CaCl_2$	OM	Mehlich-P	K^+	Ca^{2+}	Mg^{2+}	Al^{3+}	H+Al	SB	CTC
	g dm^{-3}	mg dm^{-3}	-- $mmol_c$ dm^{-3} --						
4.4	22	2	1.1	5	2	7	42	8	50
V	m	P-rem	Sand	Silt	Clay				
--------- % ---------		mg L^{-1}	------------ g kg^{-1} ---------------						
16	46	10	350	127	523				

OM – Organic matter; H+Al - Potential acidity; SB – Sun of bases; CTC – Cation exchange capacity at pH 7,0; V – Index base saturation; m – index aluminium saturation; P-rem - phosphorus remaining. Source: Authors.

A randomized block design was used, in a 5 x 3 factorial scheme with four replications, totaling 60 experimental units. The treatments consisted of the combination of 5 doses of whey, equivalente at 0; 186; 372; 558 and 744 m^3 ha^{-1}, which were set to provide 0; 100; 200; 300 and 400 mg dm^{-3} N, considering the N content in the organic residue; and 3 doses of N-urea, corresponding to 0; 100 and 200 mg dm^{-3} N. The whey was purchased in a dairy industry located in the municipality of Alfenas-MG and, shortly after the acquisition, chemical characterization was performed (Tedesco et al., 1995), whose values are presented in Table 2.

Table 2. Chemical composition of the whey used in the experiment.

Parameter	Values
pH	5.9
C/N ratio	22/1
C-organic (g L^{-1})	23.94
N (g L^{-1})	1.08
P (g L^{-1})	0.31
K (g L^{-1})	1.40

Source: Authors.

Soil density was determined, and portions equivalent to 7.0 dm^3 of soil were weighed, received dolomitic limestone (CaO = 31%; MgO = 13%; PRNT = 91%), to increase the initial soil base saturation at 70%, and 250 mg dm^{-3} of P, in the form of simple powdered superphosphate. After mixing the inputs with the soil portions, they were transferred to 8-dm^3 pots, moistened with distilled water, at about 70% of the holding capacity, and remained in incubation for 35 days. During the incubation of the soil with the inputs, soil moisture was controlled by periodically weighing the pots and replacing the water, to maintain it at about 70% of the holding capacity.

After twenty days of incubation, according to the treatments, the doses of whey were applied, right after their acquisition, on the soil surface of the pots with the aid of a measuring cylinder. The two highest doses of whey were divided into two applications, to prevent percolation of the liquid through the bottom of the pots, and the second application was carried out seven days after the first. Fifteen days after the first application of whey, the Mombaça grass was sowed, at about 1 cm of depth and, ten days after emergence, thinning was carried out, keeping 4 plants per pot.

The N fertilizations, according to the treatments, were divided into 3 applications at 7, 14 and 21 days after thinning. In each fertilization, N was applied through a solution, on the soil surface of each pot, and urea p.a. was used as a source. After each fertilization with N, fertilization was carried out with K, with KCl p.a., via solution, so that all treatments received the same amount of K as the treatment with the highest whey dose. Three cuts of Mombaça grass were made and, during the experiment, a moisture of approximately 70% of the retention capacity was maintained, through daily weighing of the pots and replacement of the lost water.

45 days after thinning, the first grass cut was made, 10 cm from the soil surface. Five days after the first grass cut, the reapplication of whey doses was carried out, in the same way as previously described. The fertilizations with N-urea and K were also repeated, in the same way as described in the first one. After 35 days of the first cut, the second grass cut was made,

10 cm from the soil. After the second cut, the treatments were not reapplied, aiming to assess the residual effect and, 35 days after the second cut, the third cut of Mombaça grass was performed.

After each grass cut, the shoot was washed, separated into leaves and stems, and dried in an oven with forced air circulation, at about 65ºC, until constant weight to determine shoot dry matter (leaves+stems). The number of live tillers per pot was also counted.

In shoot dry matter samples of Mombaça grass, the levels of N (Tedesco et al., 1995), neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined, according to Silva and Queiroz (2002). The crude protein (CP) levels were obtained by multiplying the N levels by a factor of 6.25. The accumulated amounts of N in the shoot were obtained through the product between N content and shoot dry matter.

The agronomic efficiency (EA) and N recovery efficiency (ER) indices were also calculated, based on the formulas presented in Fageria (1998), to assess the use of whey N by Mombaça grass in relation to N-urea. EA and ER evaluate, respectively, the amount of dry matter produced per unit of applied N and the amount of N accumulated in the shoot as a function of the N supplied via whey or urea

EA g g^{-1} = (MSS – MST) ÷ NS
ER % = 100 x ((NAS – NAT) ÷ NS)

where: MSS and MST are, respectively, shoot dry matter in the treatments that received whey and in the control, without application of whey; NS, amount of N applied in the treatments with whey; NAS and NAT, respectively, amount of N accumulated in the plant shoot in the treatments that received whey and in the control.

The results obtained in each grass cut were submitted to analysis of variance; means comparison test (Tukey, at 5% probability) and polynomial regression analyses, using the Agroestat software (Barbosa and Maldonado Jr., 2015).

3. Results and Discussion

Shoot dry matter production and the number of live tillers of Mombaça grass increased with the doses of whey in the first cut (Figures 1A and 1B). According to the regression equations, the values for these parameters varied, respectively, from 22.2 to 42.0 g pot^{-1} and from 45 to 61 tillers pot^{-1}; which corresponded to an increase of 1.9 and 1.4 times, when comparing the control treatment with the one that received the highest whey dose.

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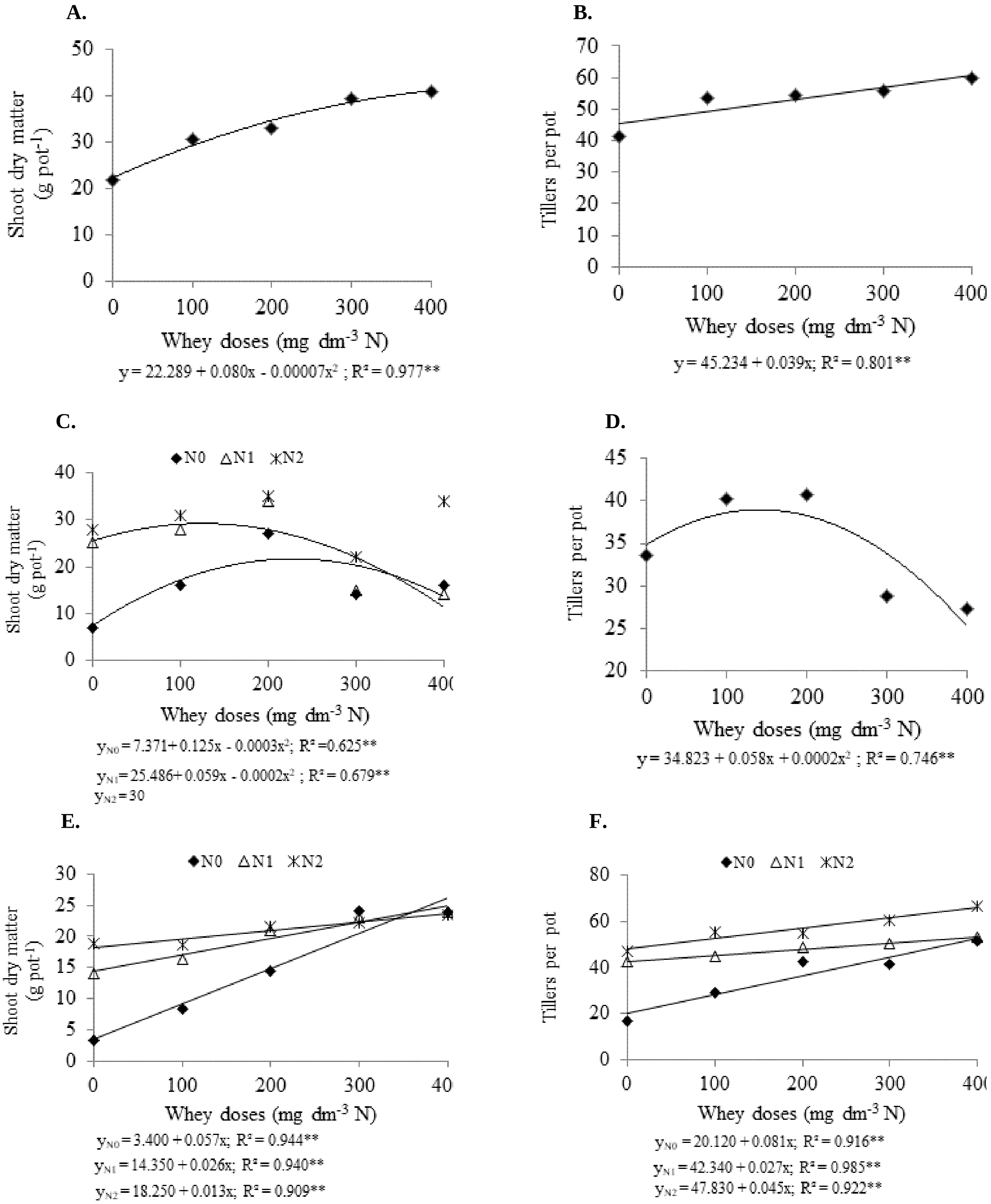
Figure 1. Shoot dry matter production and number of live tillers of Mombaça grass, in the first (A, B), second (C, D) and third (E, F) cut, as a function of whey doses. N_0, N_1 and N_2 correspond to 0; 100 and 200 mg dm^{-3} N, as urea



Source: Authors.

Shoot dry matter production and the number of live tillers of Mombaça grass increased with whey doses in the first cut, due to the N supply of the whey during the first cycle of the grass, since the other macronutrients were applied in equal amounts in all treatments, by mineral fertilization with simple superphosphate and KCl, and liming, in order to raise the soil contents upwards. The availability of whey N was also observed by Braos et al. (2020) and Kuhnen et al. (2021), who found that the fraction of N mineralization in whey was around 50%. Kuhnen et al. (2021) verified rapid mineralization of the whey N up to 28 days of incubation, as about 50% of the mineralized N accumulated during the experiment occurred during this period.

In the second cut (Figures 1C and 1D), Mombaça grass was dependent on the levels of N-urea used. There was a quadratic effect of the organic waste on the shoot dry matter production of the grass, with an increase up to the estimated doses of 208 and 148 mg dm^{-3} N at levels N_0 and N_1 of fertilization with N-urea. However, with the addition of the two highest doses of whey (300 and 400 mg dm^{-3} N), at levels N_0 and N_1, the dry matter production of the grass decreased significantly (Figure 1C). In condition N_2, referring to the highest dose of fertilization with N-urea, the application of whey did not alter the dry matter production of Mombaça grass, and the average value obtained was 30 g pot^{-1}.

The application of whey at doses above 145 mg dm^{-3} N, in the second cut of Mombaça grass, yielded a decrease in the number of live tillers, regardless of fertilization with N-urea (Figure 1D). According to the equation, the use of the highest dose of whey reduced the number of live tillers in the grass by 30%, compared to the control.

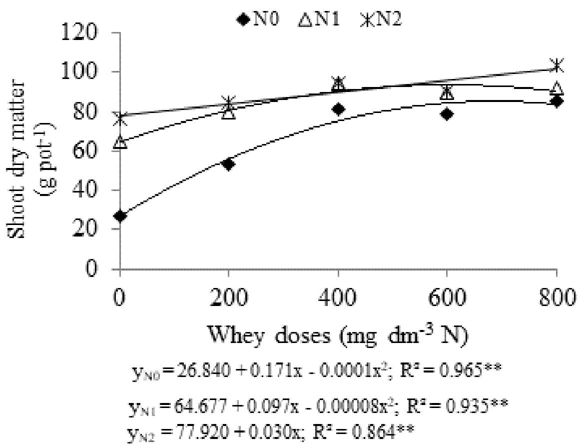
The decrease in dry matter production and in the number of live tillers of Mombaça grass in the second cut, especially in the treatments that received the two highest whey doses, can be possibly explained by immobilization of soil N with reapplication of the organic waste. In the first ten days after reapplication of the two highest whey doses, visual symptoms of N deficiency were observed, that is, the occurrence of chlorosis followed by necrosis in the older leaves of the grass, mainly in the treatments that received the two lowest doses of N-urea. The C/N ratio of the whey used was not high (22/1) but, even so, soil N immobilization occurred due to the use of high doses of organic waste, and the high concentration of lactose in the whey, which is a carbon source of rapid decomposition, favoring the increase in microbial activity and the use of inorganic N by soil microorganisms (Queiroz, 2018).

During the first cut, the eventual soil N immobilization with the use of whey did not hinder the development of Mombaça grass, as the organic waste was applied fifteen days before sowing the forage. Likewise, Mantovani et al. (2015) found immobilization of N in the soil and symptoms of N deficiency in maize with the application of whey. Thus, the authors recommended the combined use of whey with N fertilization. Gheri et al. (2003) and Santos et al. (2016), on the other hand, obtained an increase in the production of forage grasses with the application of whey or liquid dairy residue, consisting of discards and/or leftovers from the production of yogurt and curd, cleaning water for equipment and installations, and whey. In both experiments, the authors used organic waste as a source of K^+.

In the third cut (Figures 1E and 1F), shoot dry matter production and the number of live tillers of Mombaça grass increased with the doses of whey, especially in the absence of fertilization with N-urea. With the use of the highest dose of whey, there was an increase of 9.6 and 2.7 times in dry matter production and in the number of live tillers, in relation to the control treatment, under the condition in which whey was the exclusive N source (N_0). With the application of the same dose of whey in the treatments that received the highest dose of N-urea (N_2), the increases observed in these parameters in relation to the control were 1.3 and 1.4 times.

Considering the total amounts of whey applied throughout the experiment and the total shoot dry matter production of Mombaça grass (sum of the three cuts), there was an increase in dry matter production with the doses of organic waste, in all the levels of N-urea used (Figure 2). In the absence of fertilization with N-urea (N_0), the total dry matter production of the grass tripled, compared to extreme whey treatments. In treatments that received fertilization such as N-urea, (N_1 and N_2), dry matter production increased 1.4 and 1.3 times, with the use of organic waste.

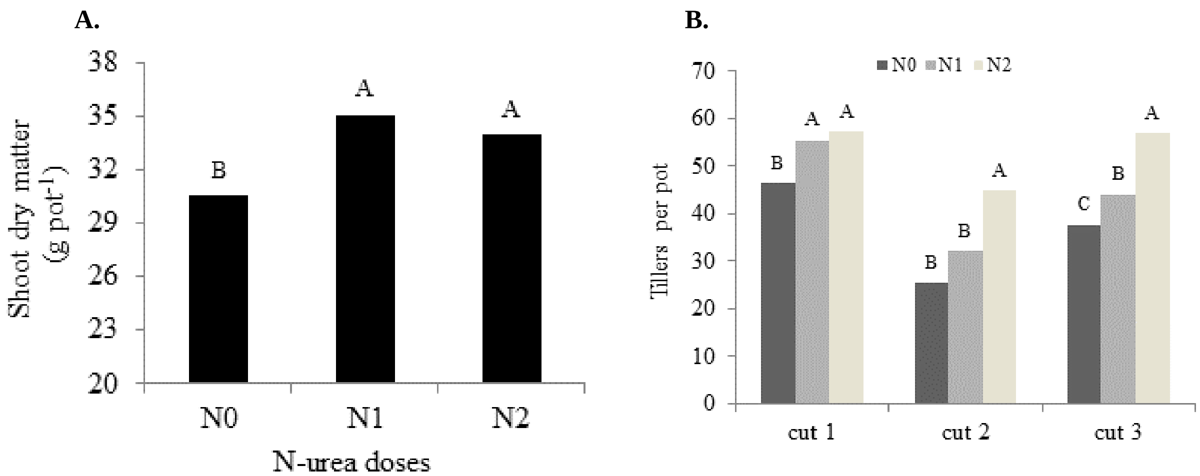
Figure 2. Total shoot dry matter production of Mombaça grass, in the sum of three cuts, as a function of whey Doses. N_0, N_1 and N_2 correspond to 0; 100 and 200 mg dm^{-3} of N-urea.



Source: Authors.

Fertilization with N-urea, at a dose of 200 mg dm^{-3}, increased the shoot dry matter production of Mombaça grass, in the first cut, and the number of live tillers, in the three cuts, in relation to the treatments that did not receive N-urea (Figures 3A and 3B). The additions obtained were, on average, 10 and 45% for the evaluated parameters. In the second and third cuts, regardless of the whey dose used, there was an increase in the shoot dry matter production of the grass (Tables 3 and 4).

Figure 3. Shoot dry matter production of Mombaça grass, in the first cut (A) and number of live tillers of the grass, in the first, second and third cuts (B), as a function of fertilization with N-urea.



N_0, N_1 and N_2 correspond to 0; 100 and 200 mg dm^{-3} N-urea. Same letters, within each cut, do not differ by the Tukey test ($p > 0.05$).
Source: Authors.

Table 3. N-urea fertilization in the dry matter production of Mombaça grass shoot, in the second cut, in each whey dose.

Whey doses mg dm^{-3} of N	N-urea doses (mg dm^{-3})		
	N_0 - 0	N_1 – 100	N_2 - 200
0	7.3B	24.5A	27.8A
100	15.5B	28.0A	30.5A
200	27.0B	36.8A	34.8A
300	13.8B	14.8B	22.3A
400	16.0B	13.8B	33.8A

Means followed by the same letter in the row, do not differ by the Tukey test ($p>0.05$). Source: Authors.

Table 4. N-urea fertilization in the dry matter production of Mombaça grass shoot, in the third cut, in each whey dose.

Whey doses	N-urea doses (mg dm^{-3})		
mg dm^{-3} of N	N_0 - 0	N_1 – 100	N_2 - 200
0	3.3C	14.0B	18.8A
100	8.3B	16.3A	18.5A
200	14.5B	21.0A	21.5A
300	23.5A	20.3A	22.3A
400	23.8B	23.8B	23.5A

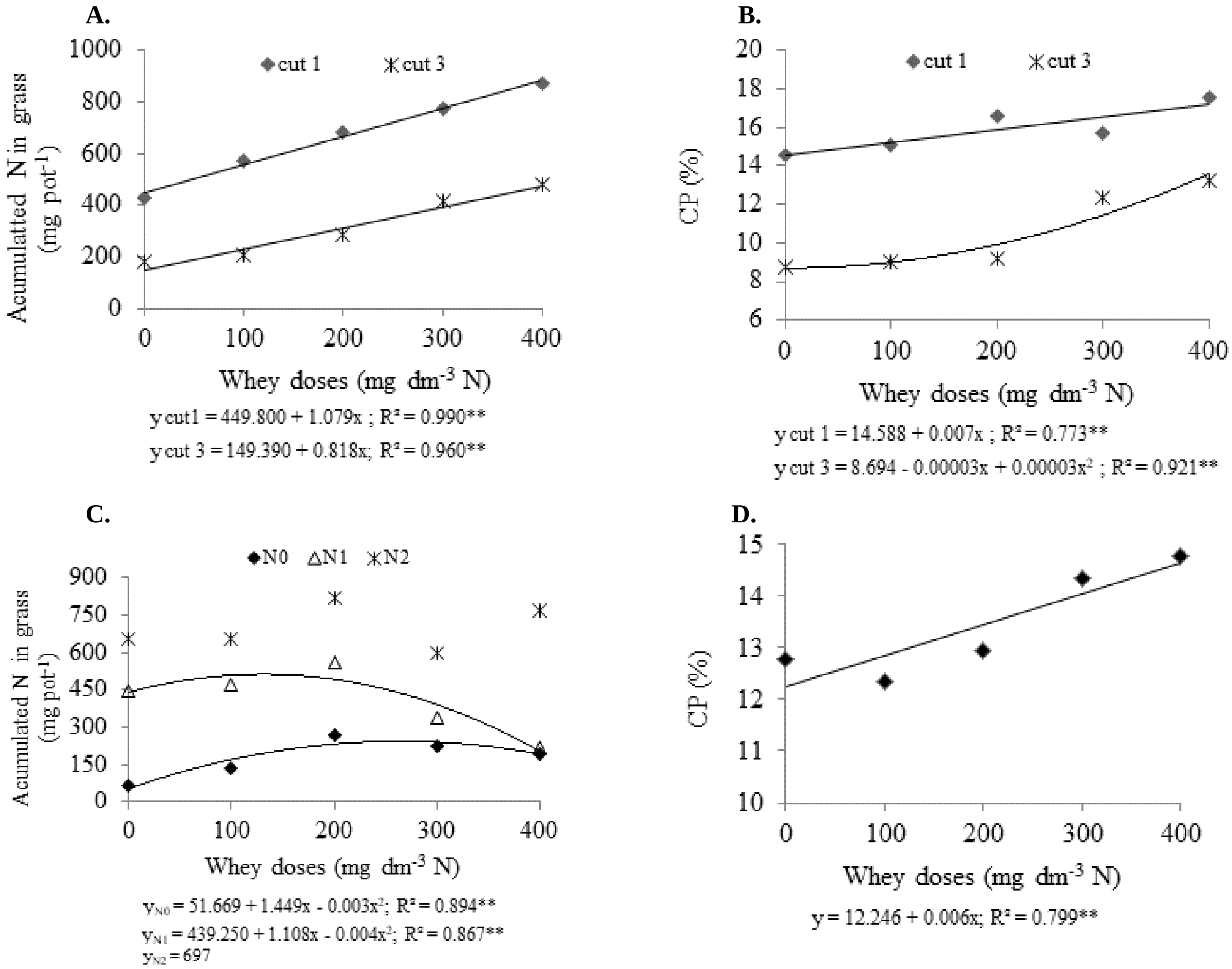
Means followed by the same letter in the row, do not differ by the Tukey test (p>0.05). Source: Authors.

The application of the highest dose of N-urea increased shoot dry matter production of Mombaça grass, in the second and third cuts, regardless of the whey dose used, showing that the whey did supply all N required by the Mombaça grass and that the most suitable is the use of whey as a source of N for Mombaça grass associated with N fertilization, instead of its exclusive use as a source of N for the forage. This increase is due to N influencing the structural components of forages, such as leaf length and number of live leaves per tiller which, in turn, determine the leaf area index and, consequently, forage production (Rosado et al., 2014).

The accumulation of N and the levels of CP in the shoot of Mombaça grass increased with the doses of whey, in the first and third cuts, despite the fertilization with N-urea (Figures 4A and 4B). It was found that the additions obtained for these parameters, when comparing the extreme treatments were, respectively, 2.0 and 1.2 times in the first cut, and 3.2 and 1.5 times in the third, which shows the gradual N release by the organic waste.

In the second cut, the accumulation of N in the grass shoot as a function of whey doses showed a different behavior in relation to the other cuts. This probably occurred due to the immobilization of N from the soil and the consequent decrease in the growth of Mombaça grass, with the reapplication of the two highest doses of whey, especially at the levels N_0 and N_1 of fertilization with N-urea (Figure 4C). Even under this condition, the CP content of Mombaça grass increased with the application of whey (Figure 4D).

Figure 4. Accumulated amount of N and crude protein (CP) content in the shoot of Mombaça grass, in the first (A,B), second (c,d) and third cuts (A,B), as a function of whey doses. N_0, N_1 and N_2 correspond to 0; 100 and 200 mg dm^{-3} of N-urea.



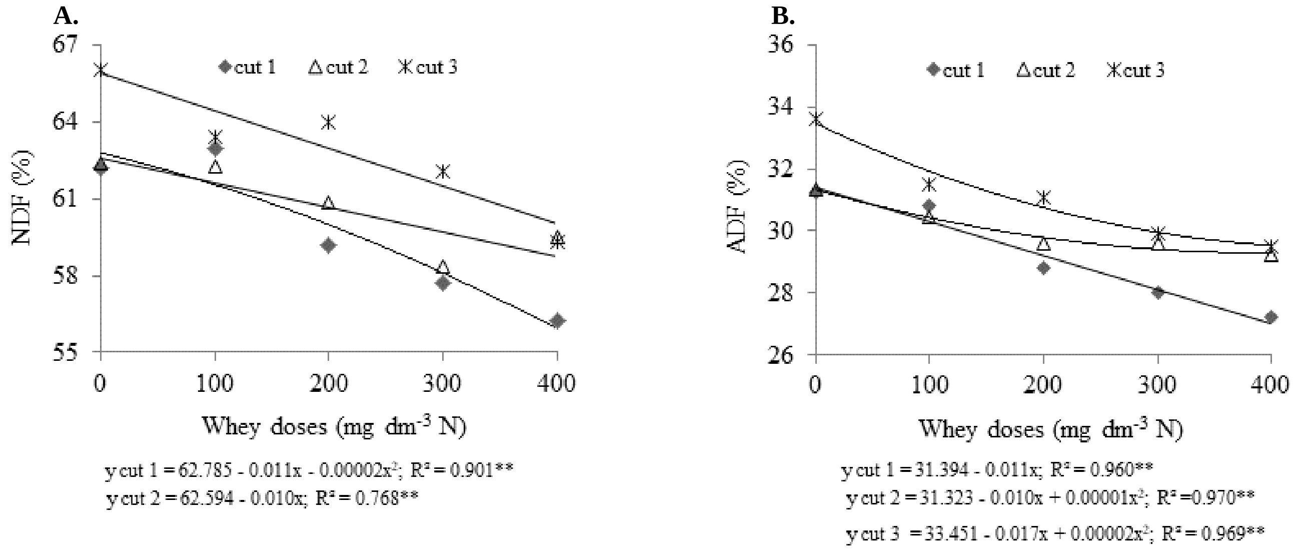
Source: Authors.

The indexes EA and ER obtained from the dry matter production and N accumulation in the grass shoot referring to the sum of the three cuts were, 15 g g^{-1} and 20%, considering the N provided by the whey, and 22 g g^{-1} and 55% for N-urea. Thus, the whey EA and ER in relation to urea were 69% and 37%, which shows that whey is an efficient N source for Mombaça grass.

Organic sources have demonstrated high potential in N supply (Silva et al., 2019). The results of the EA and ER indexes highlight the efficiency of the use of whey compared to urea, in addition to resulting in an ecologically appropriate destination for the waste. Oliveira et al. (2008) and Coelho et al. (2015) also found through these parameters, EA and ER, that the waste from the leather industry met the need for N from elephant grass and wheat similarly to N fertilization and, therefore, it was considered a good alternative source of N for these crops.

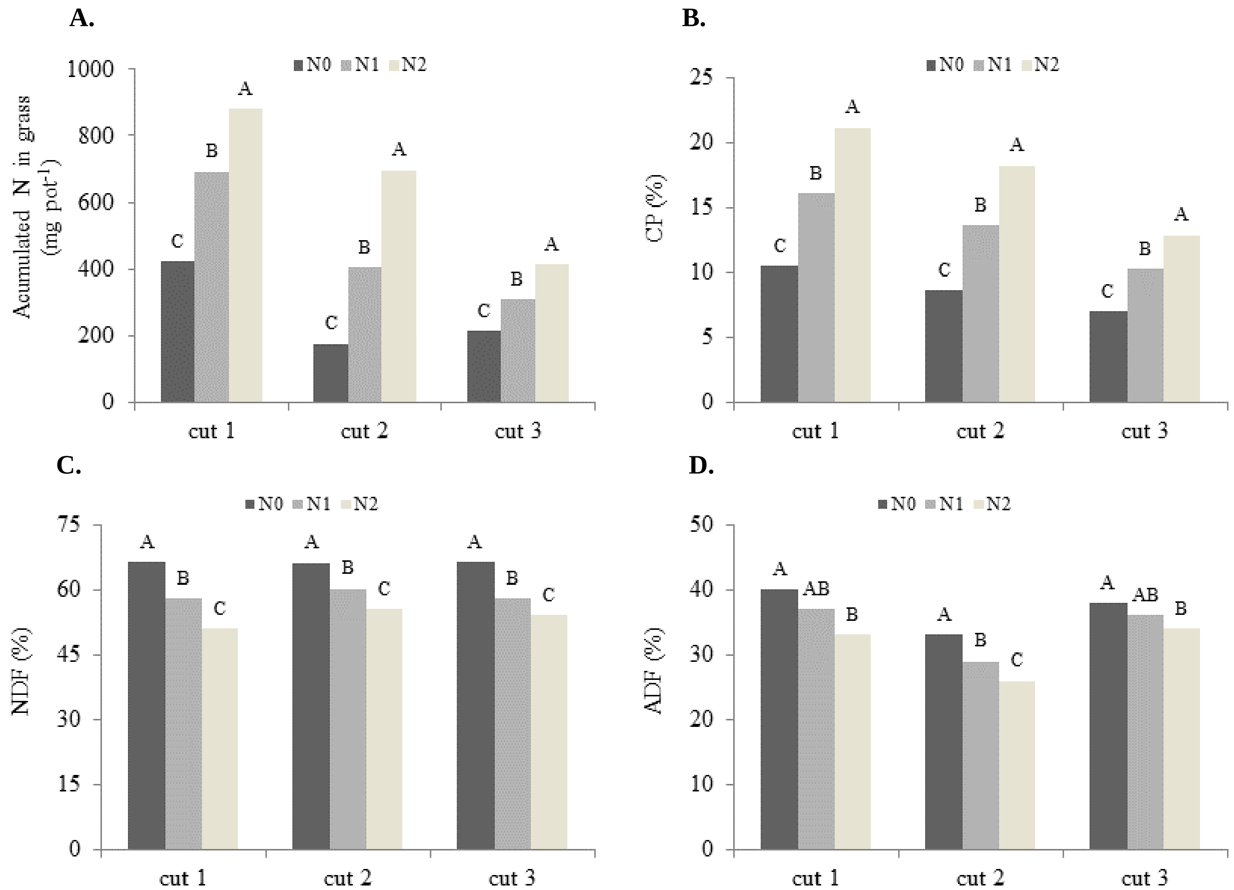
The levels of NDF and ADF in Mombaça grass decreased with the doses of whey, in the three cuts evaluated, and, on average, the decreases were 8 and 11%, when comparing the control treatments with the one that received the highest dose of whey (Figure 5). Fertilization with N-urea showed a behavior similar to the whey in relation to the nutritional value of Mombaça grass, in the three cuts, that is, an increase in the accumulated amounts of N and CP and a decrease in NDF and ADF with the increased doses (Figure 6).

Figure 5. Content of neutral detergent fiber (NDF) (A) and acid detergent fiber (B) in the shoot of Mombaça grass, in the first, second and third cut, as a function of whey doses.



Source: Authors.

Figure 6. Accumulated amount of N (A), crude protein (CP) content (B), neutral detergent fiber (NDF) content (C) and acid detergent fiber (ADF) content (D) in the shoot of Mombaça grass , in the first, second and third cut, as a function of fertilization with N-urea. N_0, N_1 and N_2 correspond to 0; 100 and 200 mg dm^{-3} of N-urea.



Same letters, within each cut, do not differ by the Tukey test (p>0.05). Source: Authors.

NDF and ADF had their indexes decreased with the application of whey and urea, as sources of N, due to the fact that N participates in the formation of amino acids and proteins, which accumulate mainly in the cell content, causing a proporcional decrease in the cell wall and increased forage digestibility (Viana et al., 2011; Costa et al., 2013). Thus, both whey and urea, as sources of N, provided an improvement in the nutritional value of Mombaça grass.

4. Conclusion

The whey increases production and improves the nutritional value of Mombaça grass, being an efficient alternative source of N for the forage.

Acknowledgments

The authors would like to thank Fundação de Amparo à Pesquisa de Minas Gerais (Fapemig) for the financial support of doctorate, master's and undergraduate research grants.

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