Revista Ciência Agronômica, v. 55, e20228661, 2024
Centro de Ciências Agrárias - Universidade Federal do Ceará, Fortaleza, CE
www.ccarevista.ufc.br

Scientific Article
ISSN 1806-6690

Nutrient cycling in dairy systems under different levels of intensification[1]

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ABSTRACT - The objective was to evaluate the effect of intensifying dairy systems on the uptake and return of nutrients in pastures. The experiment was conducted using four milk production systems on Mombasa grass pastures in the humid tropics, during the rainy season in 2009. This was a 2 x 2 factorial (two nitrogen fertilization levels and concentrate supplement or not for grazing animals) completely randomized design with four replications (paddocks). Nitrogen levels corresponded to 400 and 800 kg. $ha^{-1}.year^{-1}$, and supplementation was given to only two out of four groups of animals with milk yield above 11 L. day^{-1}. Pastures fertilized with the highest nitrogen level had higher contents of macronutrients in plant tissues and the litter but resulted in lower concentrations of N and Ca in feces. The uptake of macronutrients per grazing cycle was also higher in these pastures. The supplementation caused a decreasing effect on the content of N in dead pasture material, P in litter, and Ca, Mg, and P in feces. Decomposing litter represents the main source of nutrient return to the pasture, especially calcium, phosphorus, and nitrogen.

Key words: Litter. Mombasa Grass. Nitrogen. Supplementation. Pastures.

DOI: 10.5935/1806-6690.20240042
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Received for publication 14/12/2022; approved on 10/07/2023
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INTRODUCTION

Replenishing nutrients absorbed and exported by pasture is undoubtedly an effective measure for extending the life of pastures. Nitrogen and potassium are the nutrients that most influence the productivity of forage plants (GALINDO *et al*., 2018), phosphorus, however, also limits their growth (SOUZA *et al*., 2020). In the Central-West of Brazil, acidic soils and high levels of iron and aluminum are common, these characteristics are responsible for the retention of phosphorus and reducing the availability of this nutrient to plants, reducing their productivity (DUARTE *et al*., 2019).

Nitrogen promotes the growth of forage plants (GALINDO *et al*., 2018). The functions of nitrogen include an increase in tillering (MARTUSCELLO *et al*., 2015), an increase in dry matter production (DUPAS *et al*., 2016; GONÇALVES *et al*., 2022), in addition to changes in nutritional value (PAUSE *et al*., 2021).

Soil nutrient uptake by pastures is accentuated in intensive systems, however, the need for replenishment can be minimized by returning nutrients to the soil from the decomposition of dead pasture biomass, as well as from excreta from grazing animals (SOUZA *et al*., 2018). System sustainability is based on the effectiveness with which nutrient cycling occurs, which is influenced by other factors, such as the type and quality of waste, rate of decomposition, and release of nutrients. Optimizing recycling also brings economic benefits to the system: fewer investments will be used as the need for chemical fertilizers is reduced.

Concentrate supplementation is an additional factor in the nutrient balance in pastoral ecosystems, and can alter the nutrient supply. According to Sørensen (2004), up to 75% of dietary nitrogen can be excreted in feces and urine. For Scholefield *et al*. (1991), nitrogen in urine can represent up to 80% of the total excreted and has greater bioavailability, but also a greater risk of loss by volatilization compared to fecal nitrogen.

In this context, this study aimed to evaluate the effects of intensifying milk production using nitrogen fertilization and concentrate supplementation on the uptake and cycling of nutrients in pastures.

MATERIAL AND METHODS

The experiment was conducted at the School of Veterinary Medicine and Animal Science at the Federal University of Tocantins (EMVZ–UFT), Araguaína Campus, state of Tocantins, located at 7º 5' 37" S latitude and 48º 12' 16" W longitude. According to Koppen, the climate is Aw (hot and humid), with an average temperature of 28 ºC and an average annual rainfall of 1,800 mm. The soil in the area was classified as a typical Quartzarenic Ortic Neosol (EMBRAPA, 2013). The chemical and physical properties of the soil and climatic data during the experimental period, and the organic matter contents of the different treatments, are presented in Table 1, and Figures 1 and 2, respectively.

The experiment was conducted during the rainy season, which lasted from December 24, 2009, to May 10, 2010. The experimental area was planted with Mombasa grass (*Megathyrsus maximus*) pasture and divided into four modules under rotational grazing and variable stocking rate. In each module, the test animals were taken to a new paddock (25 m x 48 m, totaling 1,200 m^2) when the regrowing grass had 2.5 new leaves per tiller so that 8 to 12 paddocks were used from each module for management of test animals, according to each treatment or cycle (Table 2). The equilibrium animals were kept in adjacent modules managed similarly to each treatment and taken to the experimental paddocks, when necessary, to lower the pasture to the residual leaf area index (IAFR) 2, according to Cândido *et al*. (2005).

Table 1 - Chemical and physical soil properties in the area planted with Mombasa grass

Layers	O.M.(1)	pH	$H^+ + Al^{3+}$	P	K^+	Ca^{2+}	Mg^{2+}	SB(2)	CEC(3)	CECe(4)
	g.dm^{-3}	$CaCl_2$	cmol.dm^{-3}	g. dm^{-3}		cmol.dm^{-3}			cmol.dm^{-3}	
0-10	16.10	4.06	2.20	0.92	0.003	0.87	0.30	1.30	3.40	1.75
10-20	10.74	4.17	1.60	0.65	0.003	0.90	0.20	1.13	2.73	1.67
	V(5)	m(6)	CE(7)		Sand	Silt	Clay	Text. Class.(8)		
	%		ds m^{-1}							
0-10	35.32	31.40	0.07		94.85	1.90	3.25	Sand		
10-20	41.37	32.36	0.06		93.75	2.75	3.50	Sand		

(1) O.M.: organic matter, (2) SB: sum of bases, (3) CEC: cation exchange capacity, (4) CECe: effective cation exchange capacity, (5) V: base saturation, (6) m: aluminum saturation, (7) EC: electric conductivity (8). Text. Class: textural classification

Figure 1 - Climatic characteristics during the experimental period

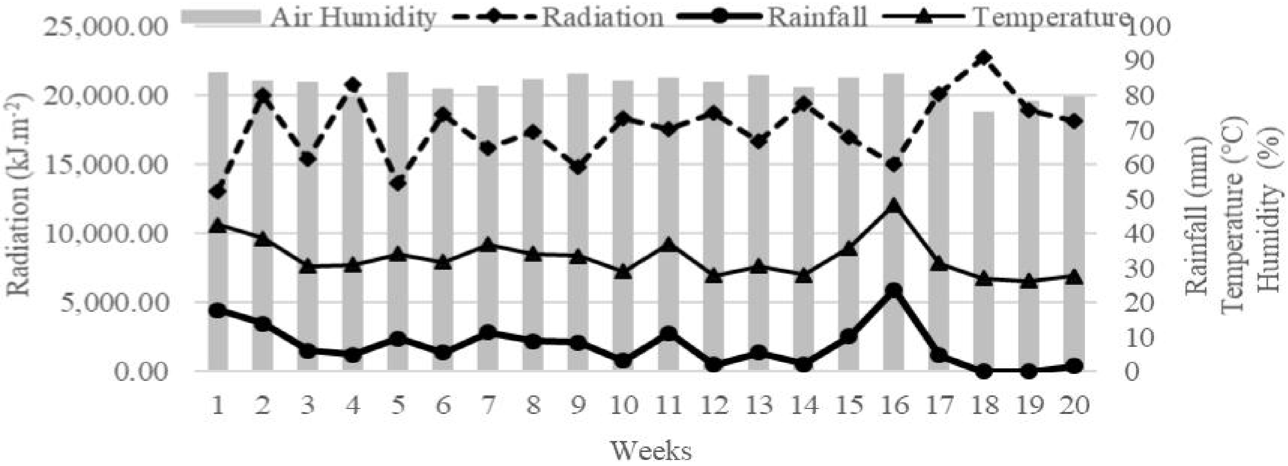
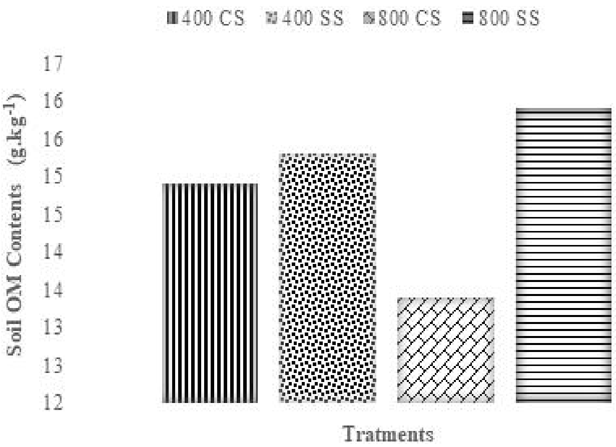


Figure 2 - Organic matter content of the soil before the experiment using different levels of intensification of the dairy system in Mombasa grass (*Megathyrsus maximus*) pastures, with 400 SS equal to 400 kg N ha^{-1}.year^{-1} without supplementation, 400 CS equal to N ha^{-1}.year^{-1} with supplementation, 800 SS equal to 800 N ha^{-1}.year^{-1} without supplementation and 800 CS equal to N ha^{-1}.year^{-1} with supplementation



This was a 2 x 2 factorial completely randomized design of two levels of nitrogen fertilizer (400 and 800 kg ha^{-1} year^{-1}) and two levels of supplementation, with and without concentrate. In this way, the treatments consisted of:

Treatment 1: 400 kg N.ha^{-1}.year^{-1} without supplementation (400 SS);

Treatment 2: 400 kg N ha^{-1}.year^{-1} with supplementation (400 CS);

Treatment 3: 800 kg N ha^{-1}.year^{-1} without supplementation (800 SS) and

Treatment 4: 800 kg N ha^{-1}.year^{-1} with supplementation (800 CS).

Forty-eight dairy cows with no defined breed pattern from the farm of the School of Veterinary Medicine and Animal Science were divided into 32 test animals and 16 equilibrium animals. Lots were separated after an observation period of 15 days. During this period, all animals had access to concentrate supplementation ad libitum to express their maximum production potential and were kept on the same pasture. Afterwards, cows were identified by production level. Four groups of eight animals each were made. Two groups were composed of cows that responded to supplementation (> 11.0 L of milk per day). Two other groups were composed of animals that did not respond to supplementation (≤ 11.0 L of milk per day).

The experimental area was fertilized with phosphorus, potassium, and micronutrients at doses of 40.0 kg P_2O_5 (as simple superphosphate), 100.0 kg K_2O (as potassium chloride), and 30.0 kg source of micronutrients (FTE BR12). Phosphorus and FTE BR12 were applied at once at the beginning of the experiment (December 2009). Potassium fertilization was split into two applications, one together with phosphorus and FTE BR12 and the other 60 days later.

The concentrate was formulated to have an average of 20% crude protein, and 80% TDN in dry matter, and consisted of 76.7% ground corn grain, 18.6% soybean meal, 1.25% mineral supplement (Fospec-80), 1.16% calcitic limestone, and 2.32% livestock urea. Table 3 lists the chemical and mineral composition of the concentrate. The concentrate supplement was supplied in the proportion of 1 kg concentrate to 3 kg milk.

Table 2 - Fallow period in days and number of paddocks for treatments, during grazing cycles

Treatments		Cycles			
		1	2	3	4
N (kg.ha^{-1})	Supplementation	Fallow period (days)			
400	SS	30	30	27	27
400	CS	30	30	27	27
800	SS	21	27	24	27
800	CS	27	33	24	30
		Number of paddocks			
400	SS	11	11	10	10
400	CS	11	11	10	10
800	SS	8	10	9	10
800	CS	10	12	9	11

SS: without supplementation; CS: with supplementation

Table 3 - Chemical composition and macro and micronutrient content

Chemical composition	
DM (%)	87.71
CP (%)	20.81
EE (%)	4.07
GE (Mcal.kg^{-1})	3.79
TDN (%)	83.34
Macronutrients (g.kg^{-1} DM)	
Phosphorus	8.59
Potassium	6.39
Sodium	3.28
Calcium	3.84
Magnesium	1.72
Sulfur	1.51
Micronutrients (mg.kg^{-1} DM)	
Copper	85.69
Iron	183.46
Manganese	31.30
Zinc	65.42

(DM) dry matter, (CP) crude protein, (EE) ether extract, (GE) gross energy, (TDN) total digestible nutrients

After each fallow period, forage biomass was cut. Two samples were collected per treatment using a 143 cm × 70 cm frame, with the cut made 5 cm above the ground. Subsequently, the total forage biomass was separated into the biomass fractions of green blade biomass (GBB), green stem biomass (GSB), and dead material biomass (DMB). These samples were dried in a forced ventilation oven at 55 ºC to constant weight.

Feces from test animals were collected immediately after defecation, using newly excreted fecal piles on the ground. The amount collected was approximately 550 g for all treatments. The feces of the animals allocated to each subarea were pre-dried like the pasture fractions.

Decomposing litter was obtained by incubating dead pasture biomass in permeable bags in the soil. The total incubation times used were 244 days with five replications. Nylon bags with approximately 2.0 mm mesh size were filled with 50 g of dead and intact biomass harvested from the pasture. The collected material was pre-dried in a forced ventilation oven at 55 ºC to constant weight.

Evaluations were carried out on three classes of samples. The first class refers to forage samples collected to determine the dry biomass of green blade (BLV), green stems (BCV), and dead forage (BFM). The second sample class concerns feces from newly excreted piles in the respective experimental paddocks. The third class of sample refers to the degrading material of the litter.

Contents of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and sulfur (S) were determined for BLV, BCV, BFM, litter, and feces. Total nitrogen (TN) was quantified through sulfur digestion, followed by Kjeldahl distillation, according to the AOAC method (2012). Phosphorus was determined by molybdenum blue spectroscopy, potassium by flame photometry, calcium and magnesium by atomic absorption spectrophotometry, and sulfur by turbidimetry and UV-VIS spectrometry (CARMO *et al*., 2000).

Data relating to nutrient content in the BLV, BCV, BFM fractions, litter, and feces were tested by analysis of variance and comparison of means. Interactions were broken down when significant at 0.05. Mean values were compared by Tukey's test, at a level of significance of 0.05, using the SAS 9.0 software (SAS INSTITUTE, 2002).

RESULTS AND DISCUSSION

The results obtained for the concentration of minerals in the plant fractions revealed an interaction ($P < 0.05$) between the fertilization and supplementation factors only for the P and Ca contents of the dead material fraction. The other fractions of the plant showed differences in mean nitrogen content depending on the nitrogen level applied (Table 4) regardless of the use of concentrate. Pastures fertilized with the highest level of N had higher N contents and extracted higher amounts of macronutrients than those managed with a lower nitrogen level. There was also an effect of supplementation ($P < 0.05$) on N and K contents in the dead material fraction.

Studies on pastures using nitrogen fertilization have shown greater contents of nitrogen in plant tissues due to increasing levels of fertilization. Similar results were reported by Delongui and Coalho (2018) in Tifton 85 grass, Carvalho *et al*. (2019) in signal grass, and Pause *et al*. (2021) in Mombaça grass. The increase in nitrogen content in plant tissues is because nitrogen is part of all plant amino acids, proteins, enzymes, and pigments, including chlorophyll, with its content increasing with increasing nitrogen levels (PAUSE *et al*., 2021). Other factors, such as nitrogen levels in the soil above those required by the plant, may trigger the storage of this nutrient in specialized organelles in plant cells. According to Barbieri Junior *et al*. (2018), this mechanism is described as luxury consumption.

Table 4 - Nitrogen, phosphorus, and potassium content (g.kg^{-1} DM) of Mombasa grass plant fractions in different levels of intensification of dairy production

	SS	CS	Mean	CV%
		Green blade biomass (N)		
400	17.16 Ba	16.75 Ba	16.95 B	
800	19.98 Aa	19.77 Aa	19.87 A	4.15
Mean	18.57 a	18.26 a		
		Green stem biomass (N)		
400	7.83 Ba	8.37B a	8.10 B	
800	10.48 Aa	10.00 Aa	10.24 A	8.64
Mean	9.15 a	9.19 a		
		Dead forage biomass (N)		
400	5.88 Ba	5.15 Bb	5.51 B	
800	7.77 Aa	7.45 Aa	7.61 A	12.22
Mean	6.82 a	6.30 b		
		Green blade biomass (P)		
400	2.97 Aa	3.14 Aa	3.05 A	
800	2.97 Aa	3.07 Aa	3.02 A	8.73
Mean	2.97 a	3.10 a		
		Green stem biomass (P)		
400	2.91 Aa	2.69 Aa	2.80 A	
800	2.97 Aa	2.59 Aa	2.78 A	11.46
Mean	2.94 a	2.64 a		
		Dead forage biomass (P)		
400	2.01 Aa	1.65 Ab	1.83 A	
800	1.56 Ba	1.66 Aa	1.61 A	12.22
Mean	1.79 a	1.66 a		

Continuation Table 4

Green blade biomass (K)				
400	14.34 Aa	1,3.08 Aa	13.71 A	
800	19.00 Aa	13.33 Aa	16.16 A	27.00
Mean	16.67 a	13.20 a		
Green stem biomass (K)				
400	18.64 Aa	15.75 Aa	17.19 A	
800	15.59 Aa	15.21 Aa	15.40 A	38.92
Mean	17.11 a	15.48 a		
Dead forage biomass (K)				
400	0.45 Ab	3.88 Aa	2.17 A	
800	0.83 Ab	3.69 Aa	2.26 A	26.45
Mean	0.64 b	3.78 a		

Means followed by different lowercase and uppercase letters, in the same row and the same column, respectively, are significantly different (P > 0.05) by Tand ukey's test. Letters in parentheses correspond to the nutrient analyzed

There was an interaction (P < 0.05) for the P concentration in the BFM fraction (Table 4). The pasture that presented the highest phosphorus content was fertilized with 400 kg N and without supplementation. According to Bezerra *et al*. (2019), phosphorus has a low potential for remobilization in plants, causing accumulation in senescent material. Root growth can be stimulated at a dose of 400 kg N, which may have contributed to the accumulation of P in dead tissues. In a review, Silva *et al*. (2014) found that the greatest root growth of *P. guenoarum* occurred at a dose of 400 kg.ha^{-1}.

Another aspect that contributes to the higher content of phosphorus in the 400 kg N SS treatment may be related to the higher organic matter content in that soil (Figure 2). Soil organic matter contents in pastures managed without supplementation were higher than in pastures managed with supplementation. According to Pereira *et al*. (2010), soils with higher proportions of organic matter can reduce phosphorus adsorption by the iron and aluminum complexes in the soil, resulting in greater uptake by plants.

The potassium content varied between the pasture fractions, although only the BFM fraction showed a significant difference (P < 0.05) for the effect of supplementation (Table 4). Values were higher in systems with supplemented animals. Potassium in the plant has high mobility, allowing its transportation from older to younger leaves (SANTOS *et al*., 2016). Therefore, under low supply, redistribution occurs, making the old and/or senescent parts poorer in potassium.

Potassium remobilization in plants varies depending on the need for physiological processes. Enzyme activation is one of the main processes in which potassium is involved. Potassium is closely linked to nitrogen metabolism and protein synthesis in the plant (GALINDO *et al*., 2018), being more required at high concentrations of N. According to Marschner (2012), K deficiency in the plant can result in high concentrations of ammonium and other nitrogen compounds such as amino acids and proteins. In fact, the N values found for the dead material fraction (Table 4) are higher in pastures with non-supplemented animals, proving that greater levels of potassium were used in these systems. This effect could theoretically have diverted a greater amount of potassium to protein metabolism, which could be in lower concentration in the BFM. The opposite effect was observed in pastures with lower N content in the BFM, as these have higher K contents.

As for calcium, there was no interaction (P < 0.05) between fertilization and supplementation for BLV and BCV fractions. For the BFM fraction, an interaction (P < 0.05) was detected between the N fertilization level and supplementation, which presented the lowest observed value (Table 5).

The greater production of forage biomass due to the higher level of N added to the soil with higher organic matter content may have promoted a calcium dilution effect in plant tissues. According to Ribeiro, Gomide and Paciullo (1999), there is a natural process of calcium dilution when plants are under high levels of nitrogen. According to the author, this effect can occur in antagonism to the potassium levels in the plant.

There was no difference in the magnesium and sulfur content of each plant fraction between the pastures studied

Table 5 - Calcium, magnesium, and sulfur content (g.kg^{-1} DM) of Mombasa grass plant fractions in different milk production intensification levels

	SS	CS	Mean	CV%
		Green blade biomass (Ca)		
400	4.00A a	4.63 Aa	4.31 A	
800	8.03A a	3.85 Aa	5.94 A	76.12
Mean	6.01 a	4.24 a		
		Green stem biomass (Ca)		
400	2.24 Aa	2.22 Aa	2.23 A	
800	1.92 Aa	2.26 Aa	2.09 A	19.54
Mean	2.08 a	2.24 a		
		Dead forage biomass (Ca)		
400	5.88 Aa	6.71 Aa	6.29 A	
800	4.76 Bb	6.80 Aa	5.78 A	11.29
Mean	5.32 b	6.76 a		
		Green blade biomass (Mg)		
400	4.45 Aa	4.51 Aa	4.48 A	
800	5.48 Aa	4.29 Aa	4.89 A	11.63
Mean	4.97 a	4.40 a		
		Green stem biomass (Mg)		
400	4.64 Aa	4.96 Aa	4.80 A	
800	5.08 Aa	4.96 Aa	5.02 A	13.57
Mean	4.86 a	4.96 a		
		Dead forage biomass (Mg)		
400	3.99 Aa	4.08 Aa	4.04 A	
800	3.85 Aa	3.82 Aa	3.83 A	14.81
Mean	3.92 a	3.95 a		
		Green blade biomass (S)		
400	2.91 Aa	3.75 Aa	3.33 A	
800	3.92 Aa	6.46 Aa	5.19 A	73.16
Mean	3.41 a	5.10 a		
		Green stem biomass (S)		
400	5.04 Aa	5.63 Aa	5.33 A	
800	4.37 Aa	3.87 Aa	4.12 A	25.06
Média	4.70 a	4.75 a		
		Dead forage biomass (S)		
400	1.96 Aa	1.74 Aa	1.85 A	
800	2.04 Aa	1.71 Aa	1.88 A	14.57
Mean	2.00 a	1.73 a		

Means followed by different lowercase and uppercase letters, in the same row and the same column, respectively, are significantly different (P > 0.05) by Tukey's test. Letters in parentheses correspond to the nutrient analyzed

(Table 5). The magnesium contents in the green blade fraction were similar to those reported by Conceição *et al.* (2013).

Magnesium is a component of the chlorophyll molecule (CONCEIÇÃO *et al*., 2013), and as well as nitrogen, should have increasing proportions according to the increase in the level of N. However, as it is a nutrient required in smaller quantities by plants, its variations are smaller compared to nitrogen.

The sulfur content in grass leaf blades can vary depending on the N level applied (ANJUM *et al*., 2015). The reason for the variation in sulfur content is the need for sulfur for the synthesis of sulfur amino acids, involved in photosynthesis and root formation. Indeed, there was an increase in sulfur content at a level of 800 kg ha^{-1} year, however, it was not enough to significantly distinguish the pastures.

Nutrient uptake

The total amount of nutrients absorbed by plants varied depending on the level of N applied (Table 6). The higher amount of N ($P < 0.05$) in the soil (800 kg ha^{-1} year) contributed to increasing the demand for other nutrients, possibly due to the greater growth of leaf blades and other plant organs. Plant nutrient uptake is the product of the levels of these nutrients in their tissues (g nutrients per kg DM) by the biomass produced over a period of time (cycle). The highest values observed in terms of uptake belong to N and K, which reached 64.6 and 61.3 kg $ha^{-1}.cycle^{-1}$ respectively. The other macronutrients Ca, S, Mg, and P presented 25.6; 18.0; 17.8, and 9.6 kg $ha^{-1}.cycle^{-1}$, respectively.

Litter

Only nitrogen and phosphorus presented higher mean values ($P < 0.05$) in pastures fertilized with 800 kg N. A higher mean value was also observed for phosphorus in pastures grazed by non-supplemented animals.

Table 6 - Nutrient uptake of the leaf blade ($kg.ha^{-1}.cycle^{-1}$), in different milk production intensification systems

	SS	CS	Mean	CV%
		Nitrogen		
400	47.11 Ba	44.94 Ba	46.03 B	
800	64.59 Aa	59.08 Aa	61.84 A	11.43
Mean	55.85 a	52.01 a		
		Phosphorus		
400	8.11 Ba	8.38 Aa	8.25 B	
800	9.64 Aa	9.14 Aa	9.39 A	10.27
Mean	8.87 a	8.76 a		
		Potassium		
400	39.07 Ba	34.90 Aa	36.98 B	
800	61.28 Aa	39.86 Ab	50.57 A	27.50
Mean	50.17 a	37.37 a		
		Calcium		
400	10.89 Ba	12.29 Aa	11.59 B	
800	25.59 Aa	11.44 Aa	18.51 A	78.90
Mean	18.24 a	11.87 a		
		Magnesium		
400	12.22 Ba	11.99 Aa	12.10 B	
800	17.78 Aa	12.59 Ab	15.18 A	16.86
Mean	14.99 a	12.28 b		
		Sulfur		
400	7.97	10.05	9.01 B	
800	12.78	17.99	15.38 A	62.39
Mean	10.37a	14.02 a		

Means followed by different lowercase and uppercase letters, in the same row and the same column, respectively, are significantly different ($P > 0.05$) by Tukey's test. SS: without supplementation; CS; with supplementation

The nitrogen content of litter was lower (P < 0.05) for pastures fertilized with an N level of 400 kg (Table 7), with no interaction between fertilization and supplementation for this nutrient. The results are coherent, considering the mobility of N in the plant (SILVA *et al*., 2014). The smaller portion of nitrogen compounds in the degrading material probably resulted from remobilization to the younger parts of the plant. This confirms the results for the leaf blade, stem, and dead material fractions, which had lower N contents in pastures with the lowest N level.

A higher mean value (P < 0.05) of phosphorus in the litter material was found because of the effect of the highest level of N in pastures with non-supplemented animals (Table 7). Pastures that received the highest level of N also absorbed the highest content of phosphorus, which may have caused accumulation in the litter, with emphasis on the 800 kg N SS treatment, which contributed to the highest content of phosphorus accumulated in the litter, possibly favoring the highest mean value in non-supplemented pastures.

In pastures fertilized with N and without animal supplementation, organic matter levels were higher than those grazed by supplemented animals (Figure 2). According to Souza *et al*. (2018), soil properties, organic matter, and pH can positively influence the availability of minerals and phosphorus.

Feces

Feces of non-supplemented animals showed higher concentrations of phosphorus (P < 0.05) compared to supplemented animals (Table 8). In ruminants, phosphorus absorption depends on some factors like the relationship with other minerals such as calcium (NRC, 2001). According to Pancoti *et al*. (2013), absorption directly depends on the

Table 7 - Nutrients in pasture litter (g.kg^{-1} DM), in different milk production intensification systems

	SS	CS	Mean	CV%
		Nitrogen		
400	7.19 Ba	7.96 Aa	7.57 B	
800	9.25 Aa	8.36 Aa	8.81 A	11.40
Mean	8.22 a	8.16 a		
		Phosphorus		
400	1.17 Ba	0.66 Aa	0.91 B	
800	3.66 Aa	0.65 Ab	2.16 A	45.25
Mean	2.42 a	0.65 b		
		Potassium		
400	0.29 Aa	0.32 Aa	0.30 A	
800	0.29 Aa	0.33 Aa	0.31 A	53.75
Mean	0.29 a	0.32 a		
		Calcium		
400	3.24 Aa	3.34 Aa	3.29 A	
800	4.14 Aa	4.51 Aa	4.32 A	38.71
Mean	3.69 a	3.92 a		
		Magnesium		
400	1.00 Aa	1.33 Aa	1.16 A	
800	1.32 Aa	1.06 Aa	1.19 A	37.99
Mean	1.16 a	1.20 a		
		Sulfur		
400	1.67 Aa	1.48 Aa	1.58 A	
800	1.61 Aa	1.56 Aa	1.59 A	15.64
Mean	1.64 a	1.52 a		

Means followed by different lowercase and uppercase letters, in the same row and the same column, respectively, are significantly different (P > 0.05) by Tukey's test amount ingested and the source. Absorption is also related to intestinal pH, age, and dietary levels of Calcium, iron, aluminum, manganese, potassium, magnesium, and fat.

Phosphorus excretion in feces is also related to the absorption coefficient associated with each food. The NRC (2001) assumes coefficients of 64 and 70% for forages and concentrates, respectively. Therefore, with less absorption by animals, there would be an increase in fecal excretion of phosphorus.

The concentrations of calcium and magnesium in feces were higher ($P < 0.05$) for animals receiving no supplementation (Table 8). According to Braz *et al*. (2002), calcium and magnesium are mainly excreted through feces, with no excretion in urine. The results for the fractions of leaf blades and green stems were not different for the respective pastures, suggesting that the forage did not provide different concentrations of these nutrients. The NRC (2001) adopted calcium absorption coefficients of 30 and 60% for forage and concentrate feeds, respectively. However, balancing the diet for supplemented animals tends to reduce fecal losses, given the knowledge of the requirement for this mineral for those animals.

In ruminants, magnesium absorption depends on some factors, including the pH of the rumen fluid. An increase in ruminal pH generally results in a decrease in solubility and consequent absorption by the mucosa (NRC, 2001). In forage-only diets, the pH of the ruminal fluid presents higher values than in diets containing grains (NRC, 2001). The stimulus for rumination caused by forage contributes to an increase in rumen pH. This is related to fiber carbohydrates that offer the animal conditions for increased salivation (MERTENS, 1997). Therefore, the greater fecal excretion of magnesium may have partially resulted from the lower absorption of magnesium by animals that did not have access to concentrate supplementation.

Table 8 - Nutrient concentrations in feces ($g.kg^{-1}$ DM), in different milk production intensification systems

	SS	CS	Mean	CV%
		Nitrogen		
400	11.63 Aa	11.25 Aa	11.44 A	
800	12.04 Aa	9.04 Bb	10.54 A	8.93
Mean	11.84 a	10.15 b		
		Phosphorus		
400	5.69 Aa	3.57 Ab	4.63 A	
800	4.41 Ba	3.86 Aa	4.13 A	17.69
Mean	5.05 a	3.71 b		
		Potassium		
400	2.58 Aa	2.36 Aa	2.47 A	
800	2.48 Aa	2.26 Aa	2.37 A	17.48
Mean	2.53 a	2.31 a		
		Calcium		
400	9.10 Aa	7.26 Ab	8.18 A	
800	8.17 Ba	6.80 Ab	7.48 B	8.16
Mean	8.63 a	7.03 b		
		Magnesium		
400	7.24 Aa	4.57 Ab	5.91 A	
800	7.45 Aa	5.03 Ab	6.24 A	10.72
Mean	7.34 a	4.80 b		
		Sulfur		
400	1.53 Aa	1.39 Aa	1.46 A	
800	1.52 Aa	1.37 Aa	1.44 A	10.16
Mean	1.52 a	1.38 a		

Means followed by different lowercase and uppercase letters, in the same row and the same column, respectively, are significantly different ($P > 0.05$) by Tukey's test

Table 9 - Macronutrient dynamics in Mombasa grass pasture

Nutrients	Extraction	Return			
		Feces	Litter	Total	(%)
		(kg.ha^{-1}.cycle^{-1})			
Nitrogen	53.93	3.01	22.95	25.96	48.13
Phosphorus	8.82	1.20	4.31	5.51	62.47
Potassium	43.78	0.66	0.87	1.53	3.49
Calcium	15.04	2.14	10.67	12.81	85.17
Magnesium	13.65	1.66	3.30	4.96	36.33
Sulfur	12.20	0.4	4.42	4.82	39.50

The total amount of nutrients returned to the soil is listed in Table 9. Calcium, phosphorus, and nitrogen were the nutrients with the highest capacity of return per grazing cycle. This is due to the greater quantities of these nutrients in the organic matter in degradation and feces. Feces contributed a smaller portion of the total nutrients recycled in the pasture. Potassium presented the lowest return to the soil; however, it had the greatest contribution from feces, which accounted for more than 43% of the total potassium recycled in the pasture.

CONCLUSIONS

The intensification of dairy production systems by fertilization increases the pasture nutrient uptake, mainly nitrogen and potassium. Calcium, phosphorus, and nitrogen are the mineral nutrients with the highest capacity to return to the pasture, however, potassium is the nutrient that returns the least to the soil. Decomposing litter is the main source responsible for returning nutrients to the pasture soil.

ACKNOWLEDGEMENTS

This manuscript was extracted from the doctoral thesis presented to the Graduate Program in Animal Science, at the Federal University of Ceará. Concentration Area: Forage and Pasture Production. The thesis was financed with resources from the Coordination for the Improvement of Higher Education Personnel (CAPES), and the National Council for Scientific and Technological Development (CNPq).

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