CORRELATION BETWEEN NUTRIENT CONTENT AND PRODUCTIVITY IN IRRIGATED FORAGES

CORRELAÇÃO ENTRE TEOR DE NUTRIENTES E PRODUTIVIDADE EM FORRAGEIRAS IRRIGADAS

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ABSTRACT: Irregular rainfall can restrict crop development, so irrigation of pastures serves as a strategy to intensify grass-fed animal production systems. Due to the direct relationship between the availability of soil water and nutrients, the objective was to evaluate the nutrient content in forages irrigated by a central pivot system. This work was carried out in the experimental area of irrigated agriculture at the State University of Mato Grosso do Sul, in Aquidauana-MS, Brazil. The experiment was setup in a completely randomized design, with five replications, in subdivided plots. The treatments of the plots were irrigated and non-irrigated, and the treatments of the subplots were the forages *Urochloa brizantha* cv. Xaraes, *Pennisetum purpureum* cv. Napier, *Panicum maximum* cv. Mombasa and *Urochloa ruziziensis* cv. Ruziziensis. Foliar concentrations of the nutrients Nitrogen (N), Phosphorus (P), Potassium (K), Calcium (Ca), Magnesium (Mg), Sulfur (S), Boron (B), Copper (Cu), Iron (Fe), Manganese (Mn) and Zinc (Zn) were evaluated. Statistical analyses performed included analysis of variance, Tukey test at $p < 0.05$ and linear correlation matrix at $p < 0.05$ and $p < 0.01$ between nutrients and productivity. Irrigation results in higher levels of the macronutrients P, K and Mg, and Fe and Mn micronutrients in forages. The nutrients that correlated with productivity were P and Fe, which both presented negative correlation. The nutrients correlated better with each other than with forage productivity.

KEYWORDS: Irrigated pasture. Central pivot. Forage nutrition.

INTRODUCTION

Livestock production represents one of the most important sectors of the Brazilian economy. Its share of the agribusiness gross domestic product (GDP) in 2015 was 43%, with the agribusiness GDP contributing to 21.35% of the national GDP (CEPEA, 2016).

According to the latest IBGE survey (2015), Brazil supports the largest commercial herd of cattle in the world, with more than 215 million head of cattle, which supply the domestic market and are also destined for export. According to the MAPA (2016), Brazil globally ranks first in beef exports.

Pastures represent the most economical method of feeding cattle, with a low cost of production in relation to confinements. Thus, according to Costa et al. (2010) the formation of good pasture is of great importance since it is the best option for feeding the cattle herd because it not only provides low-cost food, bus also offers all the necessary nutrients for good performance of the animals.

Irregularities of rainfall restrict the development of forage plants to the point that even during rainy seasons there are periods of water deficit, when evapotranspiration exceeds precipitation (ALENCAR et al., 2010).

Brazilian pastures are found in an advanced state of degradation, which results in a low stocking of animals per area. According to Mistura et al. (2006), the use of technologies and forage species with greater potential for production is essential to reverse this situation. The most commonly used forages, based on productive potential, are *Pennisetum purpureum*, *Panicum maximum* and *Urochloa brizantha*, and some of the technologies used include fertilization and irrigation.

Pasture irrigation serves as a strategy for the intensification of animal production systems, with the main objective of increasing the forage plant productivity so as to increase the support capacity of the pastures, and consequently increase the weight gain per unit area (KRAESKI, 2016).

Tropical forages present low macro and micronutrient contents where the mineral content is dependent on various factors. According to Alencar et al. (2010), the nutritional value of the forage varies throughout the year in irrigated versus non-irrigated areas. During some summer periods and

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predominantly in winter, there is a decrease in the nutritional value of the forages. Therefore water supplementation via irrigation is important because it changes the bromatological composition and quality of the plants.

Irrigation increases the productive potential of forage because it improves the availability of nutrients to be absorbed. According to Raij (2011), soil water is the carrier of chemical elements, nutrients and other substances to the roots, because when moving through the soil it carries in solution the nutrients that will be absorbed by the plant.

Therefore, it is important to study the effect of irrigation on nutrient availability in forages. This study aimed to evaluate the nutrient content and its correlation with productivity in forages irrigated by central pivot, in Aquidauana-MS, Brazil.

MATERIAL AND METHODS

The work was carried out in an experimental area of irrigated agriculture of the State University of Mato Grosso do Sul - Aquidauana Campus, with geographical coordinates 20°27'08" South latitude, 55°40'15" West longitude and average elevation of 191 meters.

The regional climate according to the KÖPPEN classification is Aw, defined as sub-humid warm tropical, with rainy season during the summer and dry winter, with average annual rainfall of 1200 mm. The soil was classified as Dystrophic Red Ultisol (SCHIAVO et al., 2010).

The forages *Panicum maximun* cv. Mombasa, *Urochloa ruziziensis* cv. Ruziziensis and *Urochloa brizantha* cv. Xaraés were sown using 25 kg ha^{-1} of pure seeds, while *Pennisetum purpureum* cv. Napier was propagated vegetatively, using 1 t ha^{-1} at spacing of one meter between rows. Implantation was carried out on May 05, 2012 and the full emergency occurred 7 days after sowing both in the non-irrigated area and that irrigated by a central pivot.

In Figure 1 shows the climatic data observed during the experiment.

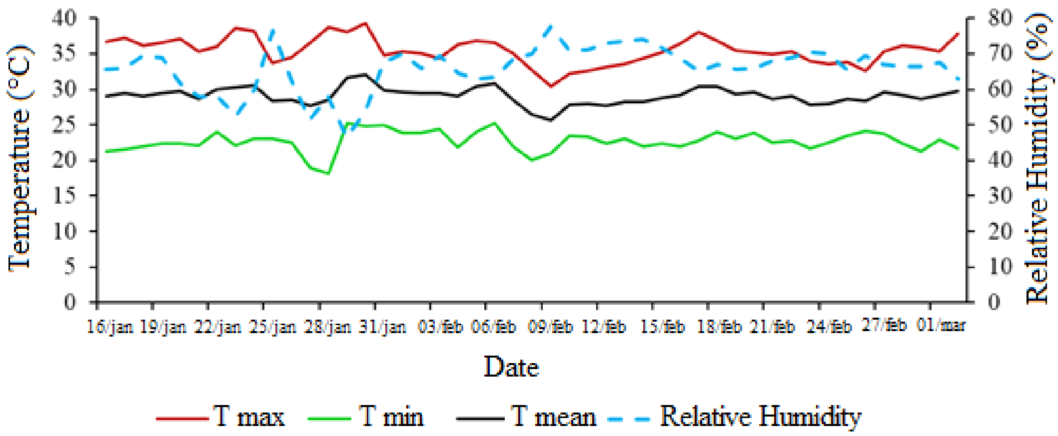

Figure 1. Relative humidity, maximum, minimum and mean temperature observed during the experiment, in Aquidauana-MS, Brazil.

The irrigation method employed utilized a center pivot of the FOCKINK® brand, with 87.2% Christiansen Uniformity Coefficient (CUC) and 78.0% Distribution Uniformity Coefficient (CUD) at 25% of the maximum speed of the center pivot (Figure 2).

The irrigated plot consisted of 8000 m^2, where each forage occupied an area of 2000 m^2 in the layout of pizza, with dimensions of 70 m (pivot radius) by 55 m width at the end. The non-irrigated forages totaled an area of 1170 m^2, each occupying an area of 293 m^2.

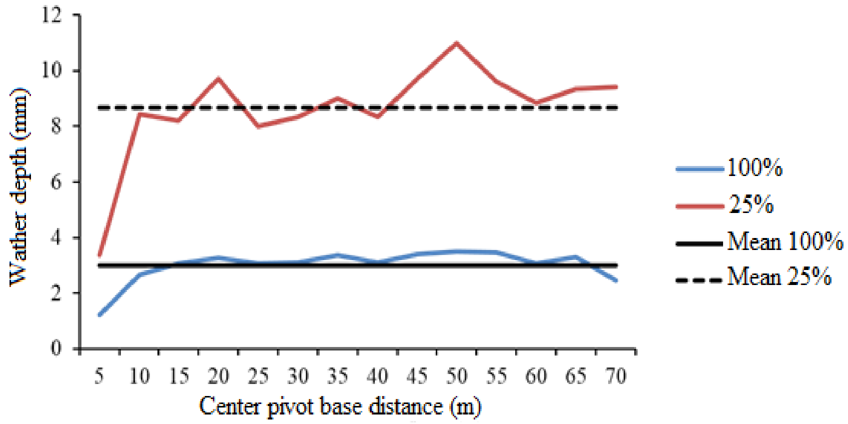

Figure 2. Mean water depths observed at 100% and 25% of the maximum speed of central pivot in Aquidauana-MS, Brazil.

Irrigation management began on the forage emergence date, using the daily reference evapotranspiration estimate (ETo) based on the Penman-Monteith method (Equation 1) (ALLEN et al., 1998), considering 50% of the soil available water capacity (AW) as soil water depletion factor (BERNARDO et al., 2007). The values for the effective root zone (Z) and the crop coefficient (Kc) were 0.4 m and 1.05, respectively.

$$ETo_{(PM)} = \frac{0{,}408\Delta(Rn - G) + \gamma\left(\frac{900U_2}{T_{méd} + 273}\right)(es - ea)}{\Delta + \gamma(1 + 0{,}34U_2)} \qquad (1)$$

Where, $ETo_{(PM)}$ is the reference evapotranspiration by the Penman-Monteith method, mm d^{-1}; Δ is the steam saturation curve declination water, kPa $°C^{-1}$; Rn is the radiation balance, MJ m^{-2} d^{-1}; G is the heat flow in the soil, MJ m^{-2} d^{-1}; γ is the psychrometric constant (0.0659823); u_2 is the average wind speed at 2 m above the soil surface, m s^{-1}; $T_{méd}$ is the average air temperature, °C; es is the vapor saturation pressure, kPa; and ea is the current vapor pressure, kPa.

During the experimental period, ten rain events occurred totaling 167 mm, thus only three irrigations were necessary, which together totaled 62.7 mm. The first was at the beginning of regrowth in January and two in February, one at the beginning and other at the end of the month, maintaining the soil water level within the appropriate range (Figure 3).

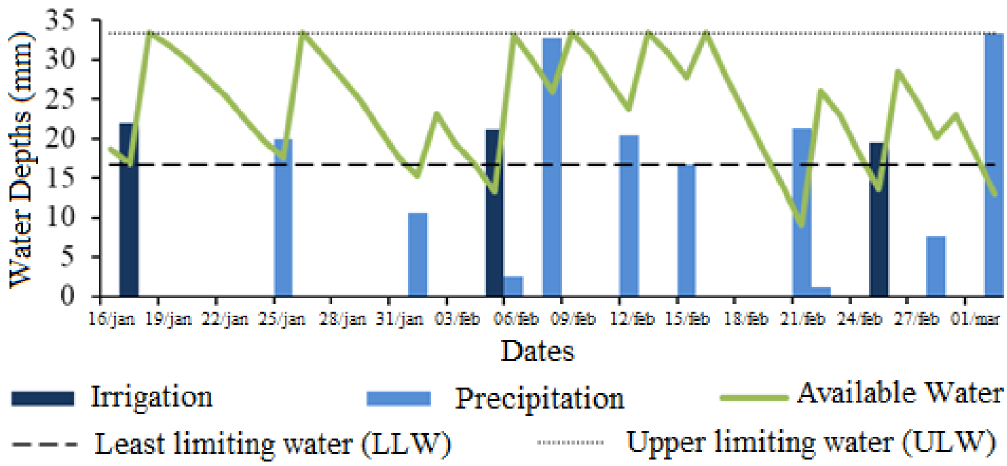

Figure 3. Precipitation and irrigation volumes registered in the area during the experiment, in Aquidauana-MS, Brazil.

Fertilization of the plants was carried out according to soil chemical analysis (Table 1) in agreement with Sousa and Lobato (2004). Coverage fertilization was carried out at the beginning of growth, applying 100 kg ha^{-1} of nitrogen in the form of urea.

Table 1. Soil chemical analysis of the experimental area for irrigated and non-irrigated forages, in the city of Aquidauana - MS, Brazil.

pH H_2O	P mg dm^{-3}	OM g dm^{-3}	K	Ca	Mg	Al	H	BS	CEC	V %
			-------------------	cmol dm^{-3}	-------------------------					
				Irrigated Area						
5.4	45.8	20.3	0.2	3.6	0.9	0.2	3.5	4.7	8.3	55.9
				Non Irrigated Area						
5.2	41.3	19.7	0.2	1.6	0.5	0.0	2.8	2.3	5.1	45.1

P – Phosphorus via the Mehlich Extractor, OM – Organic Matter, BS – Base Sum, CEC – Cation Exchange Capacity, V – Base Saturation.

The experimental design was completely randomized, with five replications, in subdivided plots. Statistical analyses performed included: analysis of variance, Tukey's test at $p < 0.05$ and the linear correlation matrix at $p < 0.05$ and $p < 0.01$ between the nutrients and productivity.

The treatments of the plots were irrigated and non-irrigated, and the treatments of the subplots were the forages *Urochloa brizantha* cv. Xaraés, *Pennisetum purpureum* cv. Napier, *Pannicum maximum* cv. Mombasa and *Urochloa ruziziensis* cv. Ruziziensis.

Sampling was carried out during the regrowth period adopted for 45 days. Evaluations were made 15 days after the start of the season, where a homogenization cut was performed at the height of 30 cm for the napier, mombasa and xaraés forages, and 25 cm for the ruziziensis forage on January 16, 2013, with harvest on March 2 of the same year.

An iron frame measuring 0.25 m^2 in area (50 cm x 50 cm) was used, randomly thrown into the plot, and the forage was cut with a manual swather at a height of 15 cm from the ground.

After cutting, the harvested material was separated into leaves and stems which were weighed to obtain the total green mass (TGM), these were subsequently packaged in paper bags and pre-dried in an oven with forced air ventilation at 65 °C for 72 hours to determine the total dry mass (TDM).

The dry mass accumulation rate (DMAR) was determined from the dry mass productivity (kg ha^{-1}) and cutting period (days), via Equation 2.

$$\mathrm{DMAR} = \frac{\mathrm{Prod_{ms}}}{\mathrm{Interval}} \qquad (2)$$

Where DMAR is the dry mass accumulation rate, kg ha^{-1} dia^{-1}; $Prod_{ms}$ is the dry mass productivity, kg ha^{-1}; and Interval is the cutting period in days.

The aerial part was milled and passed through a 1 mm sieve for subsequent laboratory analysis to determine the levels of the macronutrients N, P, K, Ca, Mg and S and micronutrients B, Cu, Fe, Mn and Zn, according to the methodology proposed by Malavolta et al. (1997).

RESULTS AND DISCUSSION

Irrigation resulted in higher forage productivity, with observed increases of 41.34% for TGM and 40.68% for TDM and DMAR in the irrigated treatment, where Napier was the most productive forage (Table 2). However, it should be noted that this work was carried out in the summer period, during which time it is common to observe smaller increments in productivity in relation to the other times of the year because it is the rainy season (Figure 3).

Other authors also observed increases in productivity of irrigated forages, including Ribeiro et al. (2009) and Aveiro et al. (1991). Ribeiro et al. (2009) observed increases in the availability of TDM for Napier and Mombasa forages of 23 and 48% in the dry season, and 15 and 29% in the rainy season, respectively. Aveiro et al. (1991) observed a 42% increase in TGM in the spring, summer and autumn periods, agreeing with the results obtained in the present work. It was observed that even in the summer irrigation resulted in higher productivity for the studied forages, which shows its importance to increase production even during rainy periods.

The highest levels of the macronutrients P, K and Mg were found in the irrigated treatment. It is observed that the different forages had an effect on the macronutrients contents N, P, K and Ca (Table 3). According to Pires et al. (2006), the nutrient levels in the plants are directly related to the forage and the level of management established.

Table 2. Productivity of different forages, Coefficient of Variation (CV) and least significant difference (LSD).

Treatments	TGM	TDM	DMAR
	kg ha^{-1}		
Irrigated	52054.96 A	16224.28 A	360.54 A
Non irrigated	21517.96 B	6599.46 B	146.65 B
Forages			
Napier	85919.76 a	32857.80 a	730.17 a
Mombasa	27339.96 b	5374.52 b	119.43 b
Xaraés	18215.44 b	4235.44 b	94.12 b
Ruziziensis	15669.24 b	3179.72 b	70.66 b
CV (%)	43.80	41.09	41.09
LSD			
Irrigation	14146.68	4117.20	91.49
Forage	29326.14	8534.99	189.67

Total green mass (TGM), total dry matter (TDM) and dry mass accumulation rate (DMAR). Averages followed by equal letters in the column, uppercase and lowercase in the plot and subplot, respectively, do not statistically differ from each other by the Tukey test p <0.05.

Table 3. Macronutrient contents in leaves of different forages, Coefficient of Variation (CV) and least significant difference (LSD).

Treatments	N	P	K	Ca	Mg	S
	g kg^{-1}					
Irrigated	18.15 A	3.98 A	20.13 A	3.95 A	2.05 A	1.35 A
Non irrigated	18.14 A	3.29 B	17.91 B	4.29 A	1.77 B	1.31 A
Forages						
Napier	20.41 a	3.98 a	22.50 a	4.98 a	1.85 a	1.52 a
Mombasa	16.06 b	3.68 a	19.25 ab	4.02 ab	2.00 a	1.17 a
Xaraés	17.99 ab	2.92 b	17.06 b	3.87 ab	1.83 a	1.20 a
Ruziziensis	18.10 ab	3.95 a	17.25 b	3.61 b	1.94 a	1.42 a
CV (%)	13.75	11.40	17.20	23.15	14.03	22.47
LSD						
Irrigation	1.61	0.27	2.11	0.61	0.17	0.19
Forage	3.02	0.50	3.96	1.15	0.32	0.36

Averages followed by equal letters in the column, uppercase and lowercase, in the plot and subplot, respectively, do not statistically differ from each other by the Tukey test p <0.05.

Higher levels were observed for N and K, independent of the treatment and forage. According to Costa et al. (2010), in forage production systems the nutrients nitrogen and potassium are those the most extracted by forage, in agreement with the results obtained in this work.

According to Embrapa (2001), for the forages studied the results found are in the acceptable ranges. The only exception was for P, which is above the appropriate range. This probably occurred due to the high content of this nutrient in the soil, which according to Raij et al. (2001) is between 31 and 60 mg dm^{-3} (Table 1).

Contents of the micronutrients Mn and Fe were higher in the irrigated areas (Table 4). According to Lopes (1999), soil water content affects the availability of Mn. Therefore, the author reported that because the micronutrients Cu, Fe and Mn are metals they are often in imbalance, so the greater availability of Fe and Mn may have reduced the absorption of Cu by the plant.

There was no effect of irrigation and different forages on the contents of the micronutrients B, Cu and Zn (Table 4). Oliveira et al. (2006) reported that other factors influence the availability of micronutrients for plants, such as texture, organic matter and especially the soil pH.

In relation to Fe and Mn, their contents were also influenced by forage, where the highest results of Fe were for Napier, and Mn for Mombasa. Regarding the extraction of micronutrients, it is observed that Fe and Mn were the micronutrients most absorbed by the forages studied. Pott et al. (1989) also observed higher levels of Fe and Mn in tropical forages. According to Malavolta (2006), Fe is the first and Mn the second most absorbed micronutrient by plants.

Table 4. Micronutrient contents in leaves of different forages, Coefficient of Variation (CV) and least significant difference (LSD).

Treatments	**B**	**Cu**	**Fe**	**Mn**	**Zn**
	------------------------------- mg kg^{-1} -------------------------------				
Irrigated	11.00 A	36.30 A	101.35 A	86.80 A	26.20 A
Non irrigated	11.58 A	33.19 A	77.53 B	65.23 B	25.63 A
Forages	-------------	-------------	-------------	-------------	------------
Napier	9.70 a	40.50 a	111.50 a	68.20 b	35.20 a
Mombasa	12.00 a	38.10 a	78.40 b	98.40 a	25.00 a
Xaraés	11.85 a	35.38 a	84.25 b	72.95 b	20.75 a
Ruziziensis	11.60 a	25.00 a	83.60 b	64.50 b	22.70 a
CV (%)	26.31	39.88	19.69	19.08	62.18
			LSD		
Irrigation	1.91	8.92	11.34	9.34	10.38
Forage	3.60	16.79	21.33	17.57	19.52

Averages followed by equal letters in the column, uppercase and lowercase, in the plot and subplot, respectively, do not differ statistically from each other by the Tukey test p <0.05.

According to Embrapa (2001), independent of the treatment the contents of B, Cu and Zn were close to the adequate range, while the Fe and Mn contents were higher than expected, even though these micronutrients had not been applied. Although they were not applied, the micronutrient levels are within the appropriate range and above it, and this can be attributed to the existence of these elements in the local soil, from fertilization of previous crops or due to the soil source material.

Different correlations were observed between the studied forages. There was a negative correlation (p <0.05) between P and TGM for the Napier forage, which was the only significant correlation observed for the macronutrients (Table 5). This negative correlation may be due to the high levels of P in the soil (Table 1) and in the plant (Table 3).

Table 5. Simple linear correlation matrix between macronutrients (N, P, K, Ca, Mg and S) and total green mass (TGM), total dry matter (TDM) and dry mass accumulation rate (DMAR) for irrigated forages.

			Napier			
	N	**P**	**K**	**Ca**	**Mg**	**S**
TGM	0.060	-0.909*	0.128	0.589	-0.087	-0.312
TDM	0.664	-0.851	-0.473	0.698	0.563	0.063
DMAR	0.664	-0.851	-0.473	0.698	0.563	0.063
			Mombasa			
	N	**P**	**K**	**Ca**	**Mg**	**S**
TGM	0.080	0.166	-0.676	-0.631	-0.399	0.491
TDM	0.505	0.489	-0.711	-0.753	-0.660	0.523
DMAR	0.505	0.489	-0.711	-0.753	-0.660	0.523
			Xaraés			
	N	**P**	**K**	**Ca**	**Mg**	**S**
TGM	0.219	-0.713	-0.093	-0.393	-0.189	0.123
TDM	0.366	-0.687	-0.176	-0.340	-0.223	0.105
DMAR	0.366	-0.687	-0.176	-0.340	-0.223	0.105
			Ruziziensis			
	N	**P**	**K**	**Ca**	**Mg**	**S**
TGM	0.438	0.267	0.634	-0.067	-0.363	-0.294
TDM	0.196	0.506	0.784	-0.032	-0.364	-0.200
DMAR	0.196	0.506	0.784	-0.032	-0.364	-0.200

Values followed by (*) and (**) show correlation at p <0.05 and 0.01, respectively.

According to Raij et al. (2011), excess P does not affect plant growth. Malavolta (2006) reported that direct symptoms of P excess are not recognized, but there may be micronutrient deficiency, especially heavy metals such as Cu, Fe, Mn and Zn. The same authors noted that the hidden excess of nutrients can cause reduced growth and production without visible symptoms, as in this work in which a negative correlation was observed with the production of green mass.

Although N is one of the nutrients most absorbed by the forages, no significant correlation was observed with productivity for the four forages studied. According to Garcez Neto el al. (2002), productivity can be stimulated through the supply of N and to vary in terms of the dose and species used.

This non-significant correlation between N and productivity may be due to application of the recommended dose instead of different doses as reported in other studies. Andrade et al. (2003) researching different doses of N and reported linear increases in production with nitrogen fertilization.

Regarding micronutrients, there was a significant negative correlation for Fe in the Xaraés forage, $p < 0.01$ between Fe and TGM, and $p < 0.05$ between the same micronutrient and TDM and DMAR (Table 6).

Table 6. Simple linear correlation matrix between micronutrients (B, Cu, Fe, Mn and Zn) and total green mass (TGM), total dry matter (TDM) and dry mass accumulation rate (DMAR) for irrigated forages.

	B	**Cu**	**Fe**	**Mn**	**Zn**
Napier					
TGM	0.681	0.086	-0.078	0.075	-0.638
TDM	0.744	0.020	0.558	0.048	-0.242
DMAR	0.744	0.020	0.558	0.048	-0.242
Mombasa					
TGM	-0.206	-0.817	-0.097	-0.058	-0.270
TDM	-0.316	-0.742	0.202	-0.152	-0.088
DMAR	-0.316	-0.742	0.202	-0.152	-0.088
Xaraés					
TGM	-0.851	-0.832	-0.978**	0.067	-0.765
TDM	-0.849	-0.759	-0.952*	0.217	-0.700
DMAR	-0.849	-0.759	-0.952*	0.217	-0.700
Ruziziensis					
TGM	-0.319	0.545	-0.497	0.142	0.236
TDM	-0.462	0.298	-0.513	0.125	0.057
DMAR	-0.462	0.298	-0.513	0.125	0.057

Values followed by (*) and (**) show correlation $p < 0.05$ and 0.01 respectively.

Gontijo et al. (2012), when evaluating the productivity of another crop also observed a significant negative correlation between the Fe content in the soil and productivity, attributing this effect to the high content of this element in the soil, as observed in the present study. The same authors reported that excess Fe promotes its excessive absorption, causing nutritional imbalance which can lead to production losses.

The high Fe content may be associated with the soil source material, because high Fe levels are common in soils of the region. Gontijo et al. (2012) also attribute the high Fe content observed to the source material and complemented that this Fe concentration causes the gradual loss by lixiviation of other elements.

A similar result for N was observed for Mn, which although it was one of the most absorbed nutrients showed no significant correlation. Mingotte et al. (2011) studied different doses of Mn and observed that the application of Mn increased dry mass production. Another fact that may have contributed is the high content of this micronutrient in the soil, exceeding the adequate range.

Kliemann et al (2003) reviewed the relationship between nutrients and the production of green mass from *Urochloa brizantha*. They found no relationship between the Fe and Mn contents available in the soil and the production of green mass from *Urochloa brizantha*, in agreement with the results obtained in this work.

It was observed that nutrient contents correlated better with each other than with forage productivity (Table 7). For each forage studied there was a different behavior among the nutrients, verifying the influence of the species on nutrient availability.

Table 7. Simple linear correlation matrix between nutrients for irrigated forages.

	N	P	K	Ca	Mg	S	B	Cu	Fe	Mn	Zn
						Napier					
N	-	-0.2267	-0.9671**	0.0998	0.7195	0.3765	0.2572	-0.5315	0.8898*	0.7690	0.3757
P		-	-0.0133	-0.6734	-0.0896	0.3760	-0.6434	-0.2575	-0.0399	-0.0165	0.6963
K			-	0.0600	-0.7096	-0.5099	-0.1401	0.6538	-0.9109*	-0.8276	-0.5776
Ca				-	0.5268	0.2520	0.9156*	0.5753	0.2820	0.2378	-0.2067
Mg					-	0.7727	0.5640	-0.0227	0.9274*	0.7755	0.5826
S						-	0.4135	-0.2144	0.7454	0.7988	0.8887*
B							-	0.2222	0.4396	0.5250	-0.0348
Cu								-	-0.3881	-0.5692	-0.4487
Fe									-	0.9128*	0.6555
Mn										-	0.6841
Zn											-
						Mombasa					
	N	**P**	**K**	**Ca**	**Mg**	**S**	**B**	**Cu**	**Fe**	**Mn**	**Zn**
N	-	-0.2386	-0.4304	-0.1304	0.0305	0.1300	0.1897	-0.5826	-0.6252	-0.0421	-0.6052
P		-	-0.2495	-0.1364	-0.7699	-0.1078	0.0890	0.0101	0.2468	-0.6494	-0.1714
K			-	0.5334	0.7821	-0.0680	-0.0925	0.2174	-0.0399	-0.3325	-0.0453
Ca				-	0.4144	-0.8548	0.7884	0.7159	-0.6877	-0.3446	-0.5535
Mg					-	0.0674	-0.1047	0.0000	-0.2792	0.0900	-0.0631
S						-	-0.9470*	-0.8459	0.6182	0.2075	0.4807
B							-	0.6390	-0.8001	-0.2579	-0.6841
Cu								-	-0.1737	0.0861	0.0365
Fe									-	0.2839	0.8753
Mn										-	0.6810
Zn											-
						Xaraés					
	N	**P**	**K**	**Ca**	**Mg**	**S**	**B**	**Cu**	**Fe**	**Mn**	**Zn**
N	-	-0.0426	-0.4860	-0.0710	-0.0221	-0.4060	-0.0440	-0.0128	-0.1396	0.8111	0.2316
P		-	0.6100	0.7756	0.7337	-0.5717	0.4333	0.3885	0.8416	-0.2877	0.9304*
K			-	0.5853	0.8077	-0.4104	-0.1838	-0.3330	0.2244	-0.8495	0.3101
Ca				-	0.4204	-0.1368	-0.1050	0.3370	0.5250	-0.1821	0.5981

Mg					-	- 0.8663	0.1225	-0.3145	0.3553	-0.5586	0.6202
S						-	-0.2633	0.2851	- 0.2771	0.1426	-0.6433
B							-	0.6482	0.7892	0.0664	0.6173
Cu								-	0.7626	0.3713	0.5071
Fe									-	-0.0981	0.8744
Mn										-	0.0156
Zn											-
					Ruziziensis						
	N	**P**	**K**	**Ca**	**Mg**	**S**	**B**	**Cu**	**Fe**	**Mn**	**Zn**
N	-	- 0.5152	-0.3212	- 0.4873	- 0.4537	- 0.4677	0.4135	0.9632**	- 0.0333	0.4028	0.8040
P		-	0.7566	- 0.2203	- 0.3685	0.2905	-0.6665	-0.5717	- 0.0301	0.3396	-0.2412
K			-	0.1737	0.0000	0.3953	-0.8919*	-0.2423	- 0.1201	0.0949	-0.1468
Ca				-	0.8778	0.1465	-0.1564	-0.2533	- 0.3320	-0.9174*	-0.6935
Mg					-	0.4732	-0.2034	-0.2989	0.1429	-0.7117	-0.4367
S						-	-0.7655	-0.5255	0.7804	0.2085	0.0812
B							-	0.3935	- 0.3170	-0.2089	0.0149
Cu								-	- 0.2139	0.1755	0.6587
Fe									-	0.5571	0.5190
Mn										-	0.7822
Zn											-

Values followed by (*) and (**) show correlation p <0.05 and 0.01 respectively.

The Napier and Ruziziensis forages provided more correlations between nutrients. Most correlations for the Napier forage where with the micronutrient Fe, which presented positive correlation with N and Mg, and negative correlation with K, both at p <0.05. According to Malavolta (2006), one of the functions of Fe is the assimilation of N in the plants, which explains this positive correlation between the two elements.

In regards to correlations between Fe with Mg and K, Malavolta (2006) reported that excess Fe causes lower absorption of K, Ca and Mg, but there is genetic diversity in the tolerance to toxicity. According to the authors, depending on the concentration of the element there may be synergism or inhibition. It is observed that Fe caused a lower absorption of K, confirming the hypothesis of inhibition, but synergism with Mg.

Potassium presented a negative correlation p <0.01 with N. Primavesi et al. (2006) observed that K increases the efficiency of N use, and they also emphasize that the contents of K in the plant increased with the doses of N, which was not observed in this work.

The preferential forms of N to be absorbed by plants are ammonia (NH^{+4}) and nitrate (NO^{-3}) (Malavolta, 2006), which might have caused this negative correlation between K when N is absorbed in the form of ammonia. Andrade et al. (2000) evaluated productivity of the forage Napier and also observed that the K levels decreased with nitrogen fertilization, i.e., it can be concluded that this negative correlation between the two nutrients may be characteristic of the forage species.

Mn presented a positive correlation with Fe and Zn with S, both at p <0.05. With respect to the positive correlation between Zn and S, this may have occurred because the accompanying ion of the sulfate is Zn, thus providing its absorption. Regarding the correlation between Mn and Fe, according to Malavolta (2006) excess Fe may induce Mn deficiency, a fact not observed in this work. The positive correlation between Mn and Fe may have occurred due to the high content of the two elements, since they are above the appropriate range.

For the Mombasa forage, a negative correlation was found between S and B ($p < 0.05$). This negative correlation may be due to competition for the same exchange site, since the absorbed form of both are anions according to Malavolta (2006), where S is absorbed mainly as SO_4^{-2} and B as BO_3^{-2}.

There was a positive correlation ($p < 0.05$) between P and Zn for Xaraés. On the other hand, according to Raij (2011) the phosphates tend to reduce the solubility of Zn, where deficiencies induced of the element by high phosphate fertilizations and known. This is due to the accompanying cation of the phosphate source to inhibit absorption of Zn. This did not occur for the Xaraés forage, which even with high P levels in the soil and plant showed a positive correlation between the two elements.

In the Ruziziensis forage, a positive correlation was observed ($p < 0.01$) between N and Cu, and negative ($p < 0.05$) between K and B, and Ca and Mn. This negative correlation between Ca and Mn is due to competition for the same exchange site. Malavolta (2006) reported that absorption of Mn is reduced by the presence of bivalent cations such as Ca^{+2} and Zn^{+2}. There are no reports of negative correlation between B and K, but this may have occurred because the accompanying cation of B inhibits the K absorption.

In relation to the positive correlation between Cu and N, Primavesi et al. (2006) and Andrade et al. (1996) observed that Cu contents increased with the doses of N. According to Loneragan (1981) this is because Cu has a strong affinity for the N atom of the amino group; additionally soluble nitrogen compounds, such as amino acids, act as chargers of this nutrient.

CONCLUSIONS

Irrigation results in higher levels of the macronutrients P, K and Mg and the micronutrients Fe and Mn in forages.

The nutrients that correlated with productivity were P and Fe, both of which presented negative correlation. Phosphorus showed a negative correlation with the total green mass in the Napier forage, and Fe with the total green mass, total dry mass and accumulation rate in Xaraés forage.

The nutrients correlated better with each other than with forage productivity.

RESUMO: A irregularidade do regime pluviométrico pode tornar-se uma restrição ao desenvolvimento das culturas, de maneira que a irrigação de pastagens serve como estratégia para a intensificação dos sistemas de produção animal a pasto. Devido a relação direta entre a disponibilidade de água no solo e os nutrientes, objetivou-se avaliar os teores dos nutrientes em forrageiras irrigadas por pivô central. O trabalho foi realizado na área experimental de agricultura irrigada da Universidade Estadual de Mato Grosso do Sul, em Aquidauana-MS. Adotou-se o delineamento inteiramente casualizado, com cinco repetições, em parcelas subdivididas. Os tratamentos das parcelas foram, irrigado e não irrigado, e os tratamentos das subparcelas, foram as forrageiras *Urochloa brizantha* cv. Xaraés, *Pennisetum purpureum* cv. Napier, *Panicum maximum* cv. Mombaça e *Urochloa ruziziensis* cv. Ruziziensis. Foram avaliadas as concentrações foliares dos nutrientes Nitrogênio (N), Fósforo (P), Potássio (K), Cálcio (Ca), Magnésio (Mg), Enxofre (S), Cobre (Cu), Ferro (Fe), Manganês (Mn) e Zinco (Zn). Foi realizada a análise de variância, teste Tukey $p<0{,}05$ e matriz de correlação linear $p<0{,}05$ e $p<0{,}01$ entre os nutrientes e a produtividade. A irrigação propicia maiores teores dos macronutrientes P, K e Mg e dos micronutrientes Fe e Mn nas forrageiras. Os teores de nutrientes que correlacionaram com a produtividade foram o P e o Fe, ambos apresentaram correlação negativa. Os teores de nutrientes correlacionaram melhor entre si do que com a produtividade das forrageiras.

PALAVRAS-CHAVE: Pastagem irrigada. Pivô central. Nutrição de forrageiras.

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