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## Nutrition of *Tithonia diversifolia* and attributes of the soil fertilized with biofertilizer in irrigated system

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### Key words:

organic fertilizer  
*Tithonia*  
nutrient content  
rainfed crop  
forage

### ABSTRACT

The fertilization with biofertilizer associated with the use of irrigation favors nutrient uptake by plants and soil chemical properties; however, these effects are little studied in *Tithonia diversifolia* in semiarid regions. This study evaluated the effect of doses of bovine biofertilizer and irrigation on accumulation of nutrients in the leaves of *Tithonia diversifolia* plants and on soil chemical attributes. The study was carried out from December 3, 2014 to November 28, 2015, and arranged in a 2 x 5 factorial scheme, consisting of five doses of bovine biofertilizer (0, 40, 80, 120 and 160 m<sup>3</sup> ha<sup>-1</sup>), combined with and without irrigation. The experiment was set in a randomized block design, using three replicates. Irrigation promoted increased accumulation of N, P, K, Ca, Mg, S, Zn, Fe, Mn, Cu and B in leaves of *Tithonia diversifolia* in the first cutting. However, the high bicarbonate concentration in the irrigation water and the occurrence of rainfall during the second crop increased the accumulation of Cu in the leaves of *Tithonia diversifolia* under rainfed condition, compared with irrigated plants. The increase in biofertilizer doses contributed to the increment of base saturation and the contents of organic matter, P and K in soil.

### Palavras-chave:

adubação orgânica  
Titônia  
conteúdo de nutrientes  
cultivo de sequeiro  
forragem

## Nutrição de *Tithonia diversifolia* e atributos do solo adubado com biofertilizante em sistema irrigado

### RESUMO

Associada ao uso de irrigação, a adubação com biofertilizante favorece a absorção de nutrientes pelas plantas e as propriedades químicas dos solos, porém tais efeitos são pouco estudados no cultivo de *Tithonia diversifolia* em regiões semiáridas. Avaliaram-se os efeitos de doses de biofertilizante bovino e da irrigação no acúmulo foliar de nutrientes em plantas de *Tithonia diversifolia* e nos atributos químicos do solo. O estudo foi conduzido entre 3 de dezembro de 2014 e 28 de novembro de 2015 e distribuído em esquema fatorial 5 x 2, consistindo de cinco doses de biofertilizante bovino (0, 40, 80, 120 e 160 m<sup>3</sup> ha<sup>-1</sup>), combinado com e sem irrigação. O delineamento estatístico do experimento foi em blocos casualizados com três repetições. A irrigação promoveu aumento no acúmulo de N, P, K, Ca, Mg, S, Zn, Fe, Mn, Cu e B em folhas de *Tithonia diversifolia* no primeiro corte; entretanto, a alta concentração de bicarbonato na água de irrigação e a presença de chuvas durante o segundo cultivo aumentaram o acúmulo de Cu nas folhas de *Tithonia diversifolia* em sequeiro quando comparado às plantas irrigadas. O aumento das doses de biofertilizante contribuiu para o incremento da saturação por base e do teor de matéria orgânica, P e K no solo.



## INTRODUCTION

*Tithonia diversifolia*, popularly known as Mexican sunflower, is regarded as a promising source of feed for animals, because it is a perennial fast growing plant and has high capacity of recovery after cutting, even if it is close to the soil, besides achieving yields between 30 and 70 t ha<sup>-1</sup> of green forage of high nutritional value. This forage is a bush from the Asteraceae family, originated from Central America and widely distributed in the tropical regions (Ruíz et al., 2014).

Besides its use as animal feed, *T. diversifolia* can be used as green fertilizer, vegetal cover of the soil, raw material in pharmaceutical industry, hedge and windbreak (Reis et al., 2015). In Brazil, it is frequently found on roadsides, pastures and vacant lots; however, there are no reports in the literature on the water requirements and soil fertility for this species.

The use of biofertilizers can be an interesting alternative for the reuse of organic waste, since they have high energetic content and expressive amounts of macro and micronutrients (Chiconato et al., 2013). The organic matter supplied through organic fertilizers improves soil chemical and physical characteristics and reduces costs with chemical fertilizers, besides allowing better use and storage of water in the soil (Krob et al., 2011; Sampaio et al., 2012).

As important as the reuse of wastes and reduction in the costs of fertilization is to know the relationship of the irrigation water in the processes of supply of nutrients in the soil and absorption of these nutrients by the plants (Roosta, 2011). This information indicates that the fertilization with biofertilizer and the use of irrigation alter the absorption of nutrients and the chemical attributes of soils cultivated with *T. diversifolia*. In this context, this study evaluated the effect of the use of bovine biofertilizer with and without irrigation on soil chemical attributes and on the accumulation of nutrients in the leaves of *T. diversifolia*.

## MATERIAL AND METHODS

The experiment was carried out from December 3, 2014, to November 28, 2015, in Montes Claros, MG, Brazil (16° 40' 57.70" S; 43° 50' 19.62" W; 650 m). The climate of the region is characterized as Aw, according to Köppen's classification; the soil was classified as eutrophic Haplic Cambisol with loam clayey texture and its physico-chemical characteristics are described in Table 1.

The statistical design was in randomized blocks with three replicates, in a 5 x 2 factorial scheme, composed of five doses of bovine biofertilizer (0, 40, 80, 120 and 160 m<sup>3</sup> ha<sup>-1</sup>) and two

irrigation managements (with and without water application through irrigation). These doses of biofertilizer corresponded to 0, 50, 100, 150 and 200% of the recommendation of N for sunflower (Ribeiro et al., 1999). Since there are no recommendations of fertilization for *T. diversifolia*, the recommendation for sunflower was used as a reference, due to the botanic and morphological proximity between these species.

The biofertilizer was chemically characterized (Table 1), according to the methodology proposed by MAPA (2007). Half of the doses of biofertilizers were applied three days before planting (December 3, 2014) and the other half as top-dressing immediately after the last standardizing cut (June 21, 2015). After top-dressing fertilization, two consecutive crops of *T. diversifolia* were conducted.

At planting, parts of the stem were distributed in an end-to-end scheme in the planting furrows, at the depth of 0.10 m, and later cut at each 0.40 m. The experimental plots were composed of four furrows at spacing of 1.0 m between rows and 3 m of length, totaling 12 m<sup>2</sup> of total area per plot; the observation area of 4 m<sup>2</sup> was delimited in the center of each plot.

Irrigation was performed using a surface drip system with lateral lines (LDPE DN16) along each planting row. Drippers with flow rate of 4.0 L h<sup>-1</sup> and pressure of 100 kPa were installed every 0.60 m in the plots with water replenishment. In addition, a pressure-regulating valve (PRLG-15) and a manometer were installed in the beginning of the experimental area for greater efficiency of the system.

Irrigation was conducted based on reference evapotranspiration (ET<sub>o</sub>), daily calculated through the Penman-Monteith method (Allen et al., 2006) and the meteorological data were obtained from an automatic station (Model - Davis Vantage) (Figure 1).

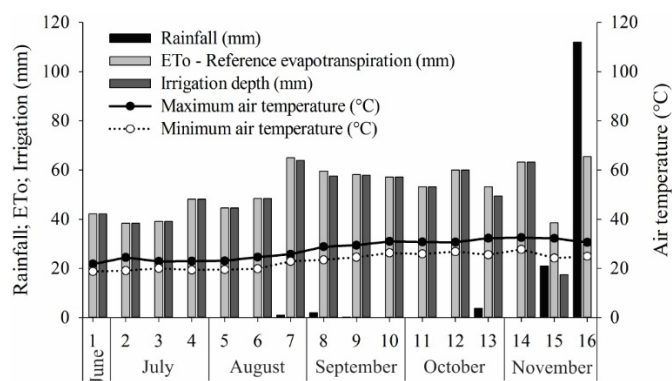


Figure 1. Rainfall, reference evapotranspiration (ET<sub>o</sub>) and irrigation depth accumulated every 10 days and maximum and minimum temperature along the experiment

Table 1. Physico-chemical characteristics of the soil in the experimental area in the layer of 0-0.20 m and chemical characteristics of the bovine biofertilizer applied at planting and as top-dressing in *Tithonia diversifolia*

Soil												
pH in H <sub>2</sub> O	OM g kg <sup>-1</sup>	P mg dm <sup>-3</sup>	K mg dm <sup>-3</sup>	Ca	Mg	Al	H + Al	CEC	V	Sand	Silt	Clay
												%
7.67	36.60	1.88	137.67	7.07	1.60	0.00	1.05	10.06	89.67	19.47	38.80	41.73
Bovine biofertilizer												
pH in CaCl <sub>2</sub>	EC dS m <sup>-1</sup>	OM	OC	N	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O	CaO	Mn	Fe	Mg	S	Na
												g L <sup>-1</sup>
7.66	5.27	16.51	9.14	1.56	1.30	1.76	0.56	0.76	0.32	0.69	0.22	0.26

pH in distilled water. P and K, Mehlich-1 extractor. OM - Organic matter; V - Base saturation; EC - Electrical conductivity; OC - Organic carbon

Inside the observation area of each plot, two disturbed single samples per composite sample of soil were collected in the layer of 0-0.2 m, 30 days after top-dressing fertilization (DAF) and at the first (80 DAF) and second (160 DAF) harvests of *T. diversifolia*. Organic matter, pH in water, H + Al, P, K, Ca, Mg and V were evaluated in the soil (Silva, 2009).

The leaf contents of macro and micronutrients were determined through the collection, at 80 and 160 DAF, of the fourth fully expanded leaf from the apex to the base of the branches of 10 plants randomly selected inside the observation area of each plot. The material was taken to the laboratory, dried in a forced-air oven at 65 °C until constant weight, ground in a Wiley-type mill and sieved (2-mm mesh) for later extraction through nitric/perchloric digestion (P, K, Ca, Mg, S, Cu, Fe, Mn and Zn), sulfuric digestion (N) and calcination in a muffle furnace (B), as described by Silva (2009). The N content was determined through Semi-Micro Kjeldahl method and the other nutrients through atomic absorption spectrophotometry (Silva, 2009).

Plants were harvested 80 days after the beginning of each cultivation with one cut at 0.40 m from the soil, according to Ruiz et al. (2014). Leaf dry matter production was determined by weighing all the plants in the observation area of each plot and then the leaves and stems of five branches representative of the plot were taken to a forced-air oven at 65 °C until constant weight; the accumulation of nutrients in the leaves was determined based on the data of dry matter and contents of nutrients in the leaves.

Quantitative data were subjected to analysis of variance by F test at 0.05 probability level and, in cases of significance, regression analysis was applied for the biofertilizer doses using the statistical program R-plus® 3.2.1.

## RESULTS AND DISCUSSION

The increase in biofertilizer doses in the non-irrigated cultivation of *T. diversifolia* promoted decrease in soil pH at 30 DAF (Figure 2A), which may be attributed to the release of H<sup>+</sup> by the increment in microbial activity and to the formation of organic acids during the degradation of the organic matter in the soil (Villanueva et al., 2012). The addition of organic

fertilizers in the soil promotes, initially, an increase in microbial activity (Figueiredo et al., 2012) and in the concentration of carbonic acid ( $\text{CO}_2 + \text{H}_2\text{O} \leftrightarrow \text{H}_2\text{CO}_3$ ) with its subsequent dissociation ( $\text{H}_2\text{CO}_3 \leftrightarrow \text{HCO}_3^- + \text{H}^+$ ), which releases H<sup>+</sup> ions in the soil. These results corroborate those of Villanueva et al. (2012), who observed, in the same period (30 days), reduction in soil pH with the increase in the applied dose of sewage sludge.

The biofertilizer doses did not alter soil pH in the irrigated plots at 30 DAF, which remained at 7.65 (Figure 2A). The bicarbonate present in the irrigation water (452.80 mg L<sup>-1</sup>) may have contributed to the maintenance of a constant soil pH, since the HCO<sub>3</sub><sup>-</sup> contributed to the alkalization of the medium (Roosta, 2011).

Soil pH increased with the increment in the biofertilizer doses at 80 and 160 DAF (Figure 2B; Table 2). The degradation of the organic matter present in this fertilizer probably resulted in the release of organic compounds of simple molecular chain, such as low-molecular-weight organic acids, which favors the increase in pH due to the reaction of ligand exchange between organic anions and the terminal OH<sup>-</sup> in Fe and Al oxides (Pavinato & Rosolem, 2008). The presence of CaO in the biofertilizer, due to its alkalizing effect, can also contribute to the increase of soil pH (Silva et al., 2014).

The application of 160 m<sup>3</sup> ha<sup>-1</sup> of biofertilizer increased soil pH by 0.74 units compared with the non-fertilized plots, at 80 DAF (Table 2); at 160 DAF, there was also increase of soil pH with the doses of biofertilizer (Figure 2B) and the biofertilizer dose of 130.00 m<sup>3</sup> ha<sup>-1</sup> promoted maximum values of pH, equal to 7.84 and 7.74 for the soil with and without irrigation, respectively. These results corroborate those of Alves et al. (2009), who observed increase in soil pH with the addition of biofertilizer.

Irrigation also promoted increment in pH and reduction in potential acidity (H + Al) in all soil sampling periods (Figure 2; Table 2; Table 3), which can be justified by the fact that the water used in the experiment has low electrical conductivity (0.36 dS m<sup>-1</sup>) and high content of HCO<sub>3</sub><sup>-</sup> (452.80 mg L<sup>-1</sup>), which may lead to increase in soil pH (Roosta, 2011). Shahabi et al. (2005) observed increase of pH due to the addition of bicarbonate to the soil through the irrigation water.

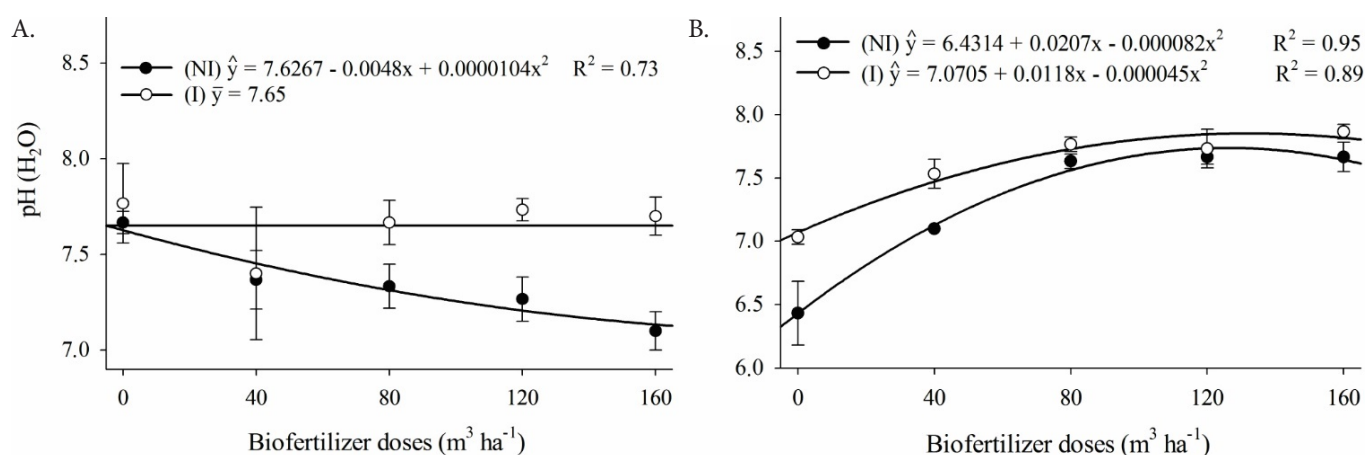


Figure 2. Values of pH of soil samples collected in the layer of 0-20 cm cultivated with *Tithonia diversifolia* fertilized with bovine biofertilizer under irrigated (I) and non-irrigated (NI) conditions at 30 (A) and 160 (B) days after the beginning of the experiment

Table 2. Regression equations relative to soil chemical attributes as a function of the application of bovine biofertilizer

Variables	Unit	Equation	R <sup>2</sup>	BFB (m <sup>3</sup> ha <sup>-1</sup> )	MxMn	CF
pH (80 DAF)	in H <sub>2</sub> O	$\hat{Y} = 6.9175 + 0.0078^{***}x - 0.00002x^2$	0.76	160.00	7.65	VH
H + Al (80 DAF)	cmol <sub>c</sub> dm <sup>-3</sup>	$\hat{Y} = 1.0986 - 0.0038^{***}x + 0.00002^{***}x^2$	0.75	95.00	0.56	VL
Ca (30 DAF)		$\hat{Y} = Ym = 6.99$			6.99	VG
Ca (80 DAF)	cmol <sub>c</sub> dm <sup>-3</sup>	$\hat{Y} = 8.3850 - 0.0067^{***}x$	0.68	160.00	7.31	VG
Ca (160 DAF)		$\hat{Y} = Ym = 7.30$			7.30	VG
Mg (30 DAF)		$\hat{Y} = Ym = 6.16$			6.16	VG
Mg (80 DAF)	cmol <sub>c</sub> dm <sup>-3</sup>	$\hat{Y} = 1.6578 + 0.0086^{**}x$	0.74	160.03	3.03	VG
Mg (160 DAF)		$\hat{Y} = 2.5157 - 0.0156^{***}x + 0.00005x^2$	0.77	160.00	1.24	G
P (30 DAF)		$\hat{Y} = 0.8035 + 0.0131^{***}x$	0.81	160.00	2.90	VL
P (80 DAF)	mg dm <sup>-3</sup>	$\hat{Y} = Ym = 5.23$			5.23	G
P (160 DAF)		$\hat{Y} = Ym = 4.22$			4.22	G
K (30 DAF)		$\hat{Y} = Ym = 153.93$			153.93	VG
K (80 DAF)	mg dm <sup>-3</sup>	$\hat{Y} = 15.632 + 0.1922^{***}x$	0.87	160.00	46.38	M
K (160 DAF)		$\hat{Y} = Ym = 148.00$			148.00	VG
OM (30 DAF)		$\hat{Y} = Ym = 3.65$			3.65	M
OM (80 DAF)	dag kg <sup>-1</sup>	$\hat{Y} = Ym = 3.21$			3.21	M
OM (160 DAF)		$\hat{Y} = 3.1391 + 0.0192^{***}x - 0.00006^{***}x^2$	0.82	160.00	4.67	G
V (30 DAF)		$\hat{Y} = Ym = 90.37$			90.37	VG
V (80 DAF)	%	$\hat{Y} = 89.366 + 0.0583^{***}x - 0.0003^{***}x^2$	0.76	86.59	86.59	VG
V (160 DAF)		$\hat{Y} = Ym = 91.47$			91.47	VG

DAF - Days after top-dressing fertilization; BFB - Bovine biofertilizer dose responsible for the highest or lowest value of the variable; MxMn - Maximum and minimum value of the variable; CF - Class of fertility of the variable: VL - Very low; M - medium; G - Good; VG - Very good and VH - Very high, according to Ribeiro et al. (1999); °, \*, \*\*, \*\*\*Significant at 0.1, 0.05, 0.01 and 0.001 probability levels by t-test, respectively

Table 3. Values of pH, potential acidity (H + Al) and contents of phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), organic matter (OM) and base saturation (V) in soil cultivated with *T. diversifolia* and sampled in different periods, in response to different water regimes

Variables	DAF	Rainfed	Irrigated
pH in H <sub>2</sub> O	80	7.16 b	7.40 a
H + Al	30	1.09 a	0.99 b
(cmol <sub>c</sub> dm <sup>-3</sup> )	80	0.99 a	0.91 b
	160	0.93 a	0.81 b
P	30	1.92 a	2.35 a
(mg dm <sup>-3</sup> )	80	5.03 a	5.44 a
	160	4.46 a	4.16 a
K	30	170.73 a	137.13 b
(mg dm <sup>-3</sup> )	80	39.00 a	23.67 b
	160	177.57 a	116.77 b
Ca	30	7.03 a	6.95 a
(cmol <sub>c</sub> dm <sup>-3</sup> )	80	7.73 a	7.90 a
	160	7.13 b	7.49 a
Mg	30	1.91 a	2.35 a
(cmol <sub>c</sub> dm <sup>-3</sup> )	80	2.31 a	2.16 a
	160	1.94 a	1.47 b
OM	30	3.55 a	3.75 a
(dag kg <sup>-1</sup> )	80	3.17 a	3.25 a
	160	3.70 a	3.73 a
V	30	89.60 b	91.13 a
(%)	80	91.07 a	91.60 a
	160	91.02 b	91.95 a

Means followed by the same letter in the row do not differ significantly ( $p > 0.05$ ) by F test; DAF - Days after top-dressing fertilization

The increase in biofertilizer doses promoted linear increment in the contents of P and K of the soil at 30 and 80 DAF, respectively. Compared with the non-fertilized soil, the application of 160 m<sup>3</sup> ha<sup>-1</sup> of biofertilizer promoted increments of 361 and 297% in the contents of P and K of the soil (Table 2).

The increase in the P content of the soil at 30 DAF is due to the presence of the nutrient in the biofertilizer and to the reduction of soil pH. The reduction of pH in alkaline soils increases the content of H<sup>+</sup> in the soil solution, favoring the solubilization of complexes of calcium phosphate, commonly

predominant in soils with pH above 7 (Chagas Júnior et al., 2010), as observed in the present study, at 30 DAF (Figure 2A).

The increase in K content in the soil at 80 DAF can be attributed to the mineralization of the K present in the biofertilizer and to the possible reduction in its leaching due to the increment in soil pH (Table 2), because of the increase in the negative charges of the soil (Melo et al., 2013).

The application of 160 m<sup>3</sup> ha<sup>-1</sup> of bovine biofertilizer reduced the content of exchangeable Ca<sup>2+</sup> in the soil by 1.07 cmol<sub>c</sub> dm<sup>-3</sup> at 80 DAF, in comparison to the non-fertilized plots (Table 2), which can be attributed to the increase in the interaction between organic compounds and Ca, reducing the capacity of extraction of exchangeable Ca from the soil and its availability to the plants (Pavinato & Rosolem, 2008).

The increment in biofertilizer doses promoted increment in the values of V and OM at 80 and 160 DAF, respectively. Compared with the control, the application of 160 m<sup>3</sup> ha<sup>-1</sup> of biofertilizer increased OM content by 1.54 dag kg<sup>-1</sup> at 160 DAF and the application of 97 m<sup>3</sup> ha<sup>-1</sup> of biofertilizer promoted the highest V, at 80 DAF (Table 2). Increases in the values of OM and V of the soil with the addition of organic fertilizers are reported in the literature (Strojaki et al., 2013). The increment of OM promotes improvements of soil chemical and physical attributes, resulting in greater availability of nutrients, permeability and water movement in the soil (Krob et al., 2011; Sampaio et al., 2012), besides providing organic acids that are important for the solubility of the minerals and increment in the recycling and mobility of nutrients (Pavinato & Rosolem, 2008).

The P content in the soil was not influenced by the presence or absence of irrigation; in contrast, the K content was higher in the non-irrigated soil in all samplings and the Mg content was also higher in non-irrigated soils at 160 DAF (Table 3), which can be attributed to the leaching of K and Mg in the soil profile in the irrigated system, which may reduce their availability in the surface. In addition, the higher pH in the irrigated soil can

reduce the exchangeable K and Mg, due to the increase in the formation of ionic complexes (Melo et al., 2013).

Irrigation led to increment in Ca content only at 160 DAF, differing in  $0.36 \text{ cmol}_c \text{ dm}^{-3}$  from the non-irrigated treatments (Table 3); this fact can be justified by the relatively high concentration of Ca in the irrigation water ( $65.22 \text{ mg L}^{-1}$ ). Zhang et al. (2015) also observed increment in the concentrations of soluble Ca with the increase in the amount of Ca added to the nutrient solution with high content of bicarbonate.

The OM content in the soil did not show difference due to the variation in water regime. On the other hand, irrigation promoted increase in V at 30 and 160 DAF, in comparison to the non-irrigated treatments, probably because the irrigated soil showed lower potential acidity (H + Al) (Table 3).

Irrigation contributed to the increment in the accumulation of N, P, K, Ca, Mg, S, Zn, Fe, Mn, Cu and B in the leaves of *T. diversifolia* at 80 DAF, differing from the non-irrigated treatments in 259, 394, 424, 236, 306, 328, 442, 296, 182, 411 and 574%, respectively (Table 4). At 160 DAF, irrigation contributed to the increase in B accumulation in the leaves of *T. diversifolia*, differing in 175% in comparison to non-irrigated plants (Table 4). Increments in the amount of nutrients due to irrigation have also been reported by other authors (Alizadeh & Namaz, 2011; Aquino et al., 2012).

Irrigation promoted increment in the accumulation of all nutrients in the leaves of *T. diversifolia* at 80 DAF and of B at 160 DAF (Table 4). This increase is mainly associated with the increment in the yield of irrigated plants, which showed leaf dry matter of 3,163.79 and 2,632.30  $\text{kg ha}^{-1}$  at 80 and 160 DAF, respectively, while non-irrigated plants showed values of 1,044.54 and 2,179.59  $\text{kg ha}^{-1}$  at 80 and 160 DAF, respectively.

The absence of irrigation promoted increment in Cu accumulation in the leaves of *T. diversifolia* at 160 DAF differing

in 186% from irrigated plants. For the other nutrients studied in the second crop, except for B, there was no significant difference in the accumulation of nutrients in the leaves due to the presence and absence of irrigation (Table 4). This behavior can be associated with the occurrence of rainfalls during the second crop (Figure 1), contributing to the absorption of nutrients and growth and development of non-irrigated plants.

The high content of  $\text{HCO}_3^-$  found in the irrigation water used in this experiment ( $453 \text{ mg L}^{-1}$ ) may have influenced the solubility of nutrients in the soil, indirectly interfering with the absorption of nutrients by the irrigated plants; in general, it is suggested that the content of  $\text{HCO}_3^-$  in the irrigation water is between 0 and  $160 \text{ mg L}^{-1}$  (Roosta, 2011).

The decrease in root/shoot ratio due to the increase in the concentrations of  $\text{HCO}_3^-$  in the soil has been reported in the literature (Roosta, 2011), which causes reduction in the volume of soil explored by the root system. In addition, it is known that high concentrations of  $\text{HCO}_3^-$  in the irrigation water lead to increment in soil pH, promoting indirect effect for balancing the availability of nutrients to the plants until the limit of the ideal pH range for plant cultivation ( $\text{pH}(\text{H}_2\text{O}) = 6.5$ ) (Roosta, 2011).

These results demonstrate high potential of accumulation of nutrients in the leaves of *T. diversifolia* when irrigated; however, fertilization with biofertilizer, despite improving soil chemical properties, did not result in higher accumulation of nutrients.

The conduction of new studies on the nutritional requirement of *T. diversifolia* in soils with low natural fertility, as well as on its irrigation management, is of great importance to establish recommendations of fertilization and management techniques for this species.

## CONCLUSIONS

1. The application of bovine biofertilizer promotes increment in base saturation and contents of organic matter, phosphorus and potassium of the soil.
2. The application of increasing doses of bovine biofertilizer promotes initial reduction in the pH of the non-irrigated soil, but this behavior is inverted at 80 and 160 days after top-dressing fertilization, in both water regimes.
3. Irrigation using water with high concentrations of bicarbonate contributes to the increase in pH, base saturation and calcium content of the soil.
4. Irrigation promotes increment in the accumulation of nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, zinc, iron, manganese and boron in leaves of *T. diversifolia*, associated with the increase in biomass produced in irrigated systems.

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Table 4. Accumulation of nutrients in leaves of *Tithonia diversifolia* at two consecutive cuts, in response to different water regimes

Variables	DAF	Rainfed	Irrigated
N ( $\text{kg ha}^{-1}$ )	80	32.12 b	83.13 a
	160	98.17 a	81.72 a
P ( $\text{kg ha}^{-1}$ )	80	1.42 b	5.60 a
	160	6.32 a	6.07 a
K ( $\text{kg ha}^{-1}$ )	80	21.25 b	90.09 a
	160	53.31 a	64.57 a
Ca ( $\text{kg ha}^{-1}$ )	80	25.88 b	61.14 a
	160	40.42 a	50.75 a
Mg ( $\text{kg ha}^{-1}$ )	80	3.23 b	9.88 a
	160	8.42 a	10.38 a
S ( $\text{kg ha}^{-1}$ )	80	1.86 b	6.10 a
	160	5.12 a	4.46 a
Zn ( $\text{g ha}^{-1}$ )	80	16.10 b	71.23 a
	160	135.48 a	151.83 a
Fe ( $\text{g ha}^{-1}$ )	80	379.22 b	1123.27 a
	160	201.30 a	222.25 a
Mn ( $\text{g ha}^{-1}$ )	80	131.76 b	240.10 a
	160	70.96 a	62.90 a
Cu ( $\text{g ha}^{-1}$ )	80	2.86 b	11.75 a
	160	30.19 a	16.19 b
B ( $\text{g ha}^{-1}$ )	80	67.80 b	388.93 a
	160	171.69 b	300.88 a

Means followed by the same letter in the row do not differ significantly ( $p > 0.05$ ) by F test. DAF - Days after top-dressing fertilization

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