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TECHNICAL PAPER

CALCIUM NITRATE CONCENTRATIONS IN FERTIGATION FOR 'TERRA' BANANA PRODUCTION

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ABSTRACT: The aim of this study was to evaluate the effect of calcium nitrate concentration of irrigation water on soil chemical attributes and productivity during the first 'Terra' banana crop cycle. The experiment followed a completely randomized design with six treatments and five replications, with six plants per plot. Treatments consisted in the use of three calcium nitrate concentrations (3.0, 10.0 and 13.0 $g.L^{-1}$), applied via dripping and micro-micro-sprinkling irrigation. The results showed that the soil chemical properties under fertigation are influenced by the water and nutrient delivery system. There was a linear tendency of increase in electrical conductivity of the saturation extract and soil solution with the increase in calcium nitrate concentration in irrigation water. The banana tree productivity was influenced by the fertilizer concentration in irrigation water.

PALAVRAS-CHAVE: soil solution, saturation extract, electric conductivity, trickle irrigation

INTRODUCTION

The application of fertilizers with irrigation water consists of the technique called fertigation. This technique has made it possible to optimize the use of inputs in different irrigated crops, both in productivity and in product quality. Its adoption in crops irrigated by localized irrigation systems (OLIVEIRA et al. 2008) is the most common. The banana tree is a typical tropical plant, which has a high nutritional requirement.

Brazil occupies the fourth position in the rank of producing countries, with about seven million tons of fruit produced in 2008 (AGRIANUAL, 2011). The interaction between irrigation and fertilization causes crop response to fertilizer application to be changed by the soil water regime (MARTINS et al. 2011).

Salinity causes problems for agricultural crops. Therefore, monitoring soil salinity becomes essential mainly in fertigation. The soil electrical conductivity can be used to quantify the salts present in the soil. For fertigation purposes, the electrical conductivity (EC) can be expressed by the soil solution electrical conductivity (ECs) in unsaturated conditions, and by the saturation extract electric conductivity (EC_{se}), i.e., EC saturated soil solution. Electrical conductivity values at certain levels may cause decreased productivity (BLANCO et al. 2008).

The rational fertigation management includes, among other things, paying attention to the monitoring of fertilizer concentrations in irrigation water and in the injection solution. Different salt concentrations in the irrigation water will promote different conductivity in soil solution and in saturation extract. In this sense, it is recommended to promote direct monitoring of salinity in the root zone to evaluate the current situation, and the efficiency of various management programs in irrigated areas. The excess of fertilizers, the use of saline water, and poor drainage are situations that lead to soil degradation (SILVA et al. 2008b). In this sense, the values of electrical conductivity in saturation extract (EC_{se}) and in soil solution (ECs) become tools to be used in fertigation monitoring.

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The use of fertilizers without criteria may lead to leaching losses. This has significant importance for the farmer due to the excessive application, and may generate low efficiency of nutrients use by crops. Ion leaching through the soil profile is a major cause of nutrient loss. It also contributes significantly to soil acidification, indicating the need to adopt a water and nutrients management guided by established criteria. One of the nutrients most applied by fertigation is nitrogen. It has great soil mobility, mainly in the nitrate form (BORGES et al. 2002).

Among the most widely used nitrogen sources are urea and ammonium sulfate. Nitrogen participates in various compounds considered essential for plant growth and development, especially proteins and chlorophylls (TAIZ & ZEIGER, 2009). Nitrate constitutes one of the nitrogen inorganic forms in the soil, and combined with ammonium, constitutes the final product of the organic nitrogen mineralization.

The aim of this study was to evaluate the effect of concentration of irrigation water calcium nitrate on soil chemical properties during the first ‘Terra’ banana tree cycle, and on this crop’s productivity.

MATERIAL AND METHODS

The work was conducted at *Embrapa Mandioca e Fruticultura Tropical* field, located in *Cruz das Almas - BA* (12º48`S;39°06`W; 225m). The climate is classified as humid to sub-humid, with average annual rainfall of 1,143 mm. The soil chemical characteristics at the beginning of the experiment were: (pH 6.3, 11.0 mg/dm^3 P, 0.06 cmolc/dm^3 K, 3.4 cmolc/dm^3 Ca + Mg; 0.09 cmolc/dm^3 Na, 1.32 cmolc/dm^3 Al + H, 3.56 cmolc/dm^3 S; CTC 4.88 cmolc/dm^3 and V 73%).

The experimental area soil is classified as Yellow Latosol with a loamy texture, with 444g.kg^{-1} total sand, 131 g. kg^{-1} silt, 425 g.kg^{-1} clay, 1.55 kg.dm^{-3} density, humidity corresponding to field capacity and the permanent wilting point 0.23 m3.m^{-3} and 0.16 m^3.m^{-3}, respectively. The climate is classified as humid to sub-humid with 1,143 mm of rainfall per year. The culture assessed was the “‘Terra’ Maranhão” banana tree, planted in single rows spaced 3.0m x 2.5m.

An experiment was performed in a completely randomized design in a factorial 3 x 2, three calcium nitrate concentrations in the irrigation water (3.0, 10.0 and 13.0 g L^{-1}) and two localized irrigation systems (dripping and micro-sprinkling), with a total of six treatments, with five replicates. The micro-sprinkling system consisted of an emitter every four clumps, with a flow of 43.0 l.h^{-1}.

Dripping involved a lateral irrigation line by plant row, with three emitters of 4.0 l.h^{-1} by clump. The replacement water depth between two irrigations was calculated by crop evapotranspiration, estimated by the evaporation obtained by the "class A pan" method. Calcium nitrate was used as a nitrogen source, and potassium chloride as a potassium source in fertigation. They were applied weekly. To calculate the amount of fertilizer in the injection solution, the recommendations of BORGES et al., (2007) were followed, using [eq. (1)] (COELHO, 2009) to calculate the solution volume (v):

$$v = \frac{M \cdot Q_{sn}}{Q_f \cdot C_f} \qquad (1)$$

In which,

M = nutrient mass (g);

Qs_n = flow of the fertilizer solution injection device in the irrigation system (L.h^{-1});

Qf = irrigation line flow (L h^{-1}),

C_f = nutrient concentration in the emitters output (g.L^{-1}).

Injection solution samples were collected in the solution tank, and in the emitters output along the sidelines during fertigation. Soil solution samples were collected every 15 days in each plot with three replications using solution extractors, installed radially to the micro-sprinkler at 0.30m from the plant, in the depths of 0.20 and 0.40m. For dripping, solution extractors were installed at 0,30m from the plant, between the plant and a dripper, at a fixed distance of 0.15 m from it, in two depths (0.20 and 0.40m) and three replications. Extractors were located in the wet bulb between two emitters.

To obtain the solution in extractors, a –70 kPa suction was applied with a vacuum pump, with solution removal from the soil two hours later. Samples were taken to the *Embrapa Mandioca e Fruticultura* laboratory of irrigation and fertigation, where NO_3^- readings were performed in an equipment for rapid nitrate assessment (CardHoriba). To increase the reliability of readings, standard nitrate solutions were prepared in the laboratory, followed by equipment calibration.

The variables evaluated were the soil solution electrical conductivity (ECs) and the saturation extract electrical conductivity (ECse), besides the 'Terra' production variables of banana plantations (banana bunches yield, fruit length and diameter). The means of the variables evaluated in the treatments were compared by t test at 5% probability level.

RESULTS AND DISCUSSION

Calcium nitrate concentration effects in the electrical conductivity of soil solution and saturation extract

There was no difference between the means of saturation extract electrical conductivity for two irrigation systems when irrigation water calcium nitrate concentration was fixed (Table 1). The same happened for the means of soil solution electrical conductivity, except for the dripping system concentration of 13.0 g.L^{-1}. Despite the inexistence of statistical difference between the means of electrical conductivities of both irrigation systems, the absolute values were higher for dripping irrigation. This is explained by the lower volume of wet soil, where fertilizer application is site-specific, resulting in a higher concentration when compared to micro-sprinkler (COELHO et al. 2010).

ECse means for the concentration of 3.5 g.L^{-1} differed from the means corresponding to 10.0 and 13.0 g.L^{-1}, which did not differ for the micro-sprinkling and dripping systems. ECs means behaved differently according to the irrigation system. As the fertilizer concentration in the irrigation water increased, there were also increases in ECs and ECse, which was also observed by (COSTA et al. 2009), in a study with different urea and potassium nitrate concentrations in irrigation water. In general, concentrations under 13.0 g.L^{-1} were the highest, followed by the ones with concentration under 10.0 g.L^{-1}. The lowest means corresponded to the concentration of 3.5 g.L^{-1}. The average concentrations of irrigation water in both systems up to 10.0 g L^{-1} were lower than 0.83 dSm^{-1}, showing that the use of concentrations up to this level, despite increasing soil electrical conductivity, is not able to adversely affect the banana crop development.

TABLE 1. Electrical conductivity means of saturation extract (ECse) and soil solution (ECs) in dripping and micro-sprinkling fertigation systems with Calcium Nitrate.

Calcium Nitrate Concentration	ECs (dS.m^{-1})		ECse (dS.m^{-1})	
	Micro	Drip	Micro	Drip
3.5 g.L^{-1}	0.4616 Aa	0.5626 Aa	0.5881 Aa	0.7277 Aa
10.0 g.L^{-1}	0.7433 Ab	0.8136 Ab	0.7867 Ab	0.8303 Aa
13.0 g.L^{-1}	0.8544 Ab	0.9513 Ab	0.8228 Ab	1.3584 Bb

* Capital letters compare the irrigation systems at each concentration. The lowercase letters in columns compare salt concentration in irrigation water.

Figure 1 shows the electrical conductivity behavior obtained from the soil saturation extracts (ECse) and from soil solution (ECs) during the 'Terra' banana tree first cycle, under calcium nitrate application by irrigation. There was no increase or decrease tendency in any of the forms of electrical conductivity measured. Conductivity values were higher for the concentration of 13.0 g L^{-1}, followed by the values of 10.0 and 3.5 g L^{-1}. Soil solution electrical conductivity (ECs) was above 1.0 dS m^{-1} in at least 80% of the dripping system measurement, and ECse was above 1.0 dS m^{-1} in at least 20% of measures in both micro-sprinkling and dripping irrigation, for the irrigation water concentration of 13.0 g L^{-1}. Therefore, the use of 13.0 g L^{-1} calcium nitrate must be reasoned, because it poses a risk of increasing soil salinity, which may damage crops.

Data showed the possibility of using a concentration of 10.0 g L^{-1}, since it resulted neither in ECse nor ECs values close to the critical range for banana cultivation as reported by SILVA (2002). Furthermore, electrical conductivity in the saturation extract and soil solution were below the critical range of 1.1 dS m^{-1} as reported by OLIVEIRA (1999) for banana cultivation.

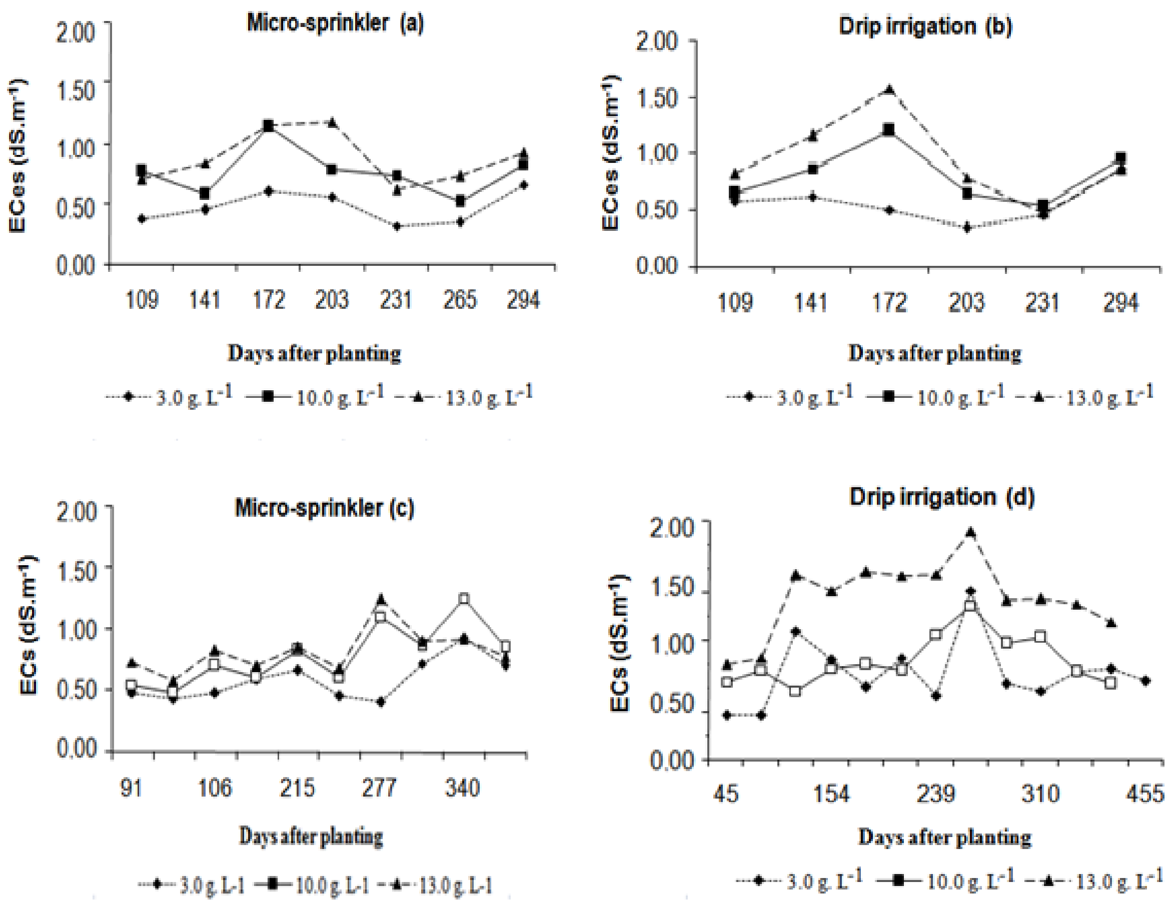

FIGURE 1. Electrical conductivity values of the saturation extract (1a and 1b), and soil solution (1c and 1d) for calcium nitrate fertigation in two systems.

The concentrations of 10.0 gL^{-1} and 13.0 g L^{-1} are high values when compared to COELHO et al. (2009), which suggested concentrations between 0.5 and 1.5 g L^{-1} for the solution applied. OLIVEIRA et al. (2000) report that such values should not exceed 0.7 g L^{-1}, and must be between 1 and 0,2g.L^{-1} and 4g.L^{-1}, especially for dripping systems.

Figure 2 shows that in terms of means, there was a linear tendency of increase in the electrical conductivity of the saturation extract (2a), and soil solution (2b) with calcium nitrate concentration in irrigation water. The correlation coefficients were higher than 0.94 for both irrigation systems.

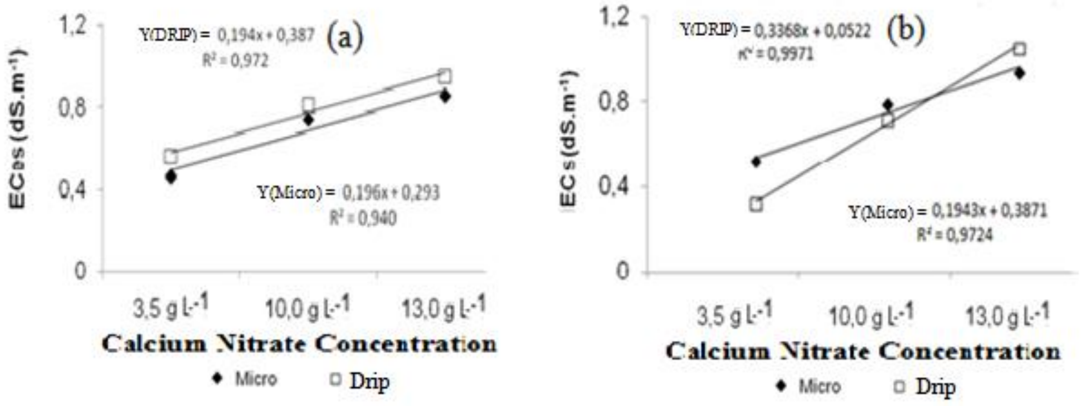

FIGURE 2. EC variation with an increased salt concentration in the saturation extract (2a) with calcium nitrate, and in the soil solution (2b).

Differences were observed between the NO_{3-} mean concentrations in soil solution for the calcium nitrate concentrations in irrigation water in both micro-sprinkling and dripping (Table 2), for both studied depths. As concentration increased, NO^{3-} soil solution content significantly increased. NO_{3-} mean concentrations in soil solution under application of 13.0 g L^{-1} calcium nitrate in irrigation water were statistically superior to those under application of 3.0 and 10.0 g L^{-1}.

There was a difference between the NO_{3-} mean concentrations in soil solution for the systems studied in two depths ($P<0.05$). Micro-sprinkler presented higher NO_3^- concentrations in both depths at all the concentrations. One reason is that calcium nitrate application turns NO_3^- ions more readily available to plant roots in the soil solution. Notwithstanding, larger water volumes per wet area by drip irrigation enhance absorption of these ions, in contrast to a microsprinkler system, in which this volume is lower. Therefore, microsprinkler irrigation will provide less soil solution to plant roots and, consequently, lower extraction of NO_3^-, increasing its concentration.

TABLE 2. NO_3^- means in soil solution at depths 0.20 and 0.40m, in two fertigation systems with calcium nitrate.

Calcium Nitrate concentration	NO_3^- mg L^{-1} (0.20 m)		NO_3^- mg L^{-1} (0.40 m)	
	Drip	Micro	Drip	Micro
3.0 g.L^{-1}	163.58 Aa	159.73 Ba	110.73 Aa	153.33 Ba
10.0 g.L^{-1}	195.62 Ab	241.36 Bb	225.00 Ab	231.11 Bb
13.0 g.L^{-1}	308.46 Ac	352.91 Bc	331.82 Ac	450.00 Bc

*Capital letters compare nitrogen sources at each depth. Lowercase letters in columns compare irrigation water salt concentrations.

In the 0.20m layer, there was a general nitrate increase of 145.0 mg L-^{1} in soil treatment solution from 3.0 g L^{-1} to 13.0 g L^{-1} in the dripping system. This variation was even greater in micro-sprinkler, which had an increase of 190.0 mg L-^{1}. In the 0.40m layer, despite the lower absolute nitrate level values, increases observed between the two treatments were higher, i.e., about 220.0 mg L-^{1} and 300.0 mg L-^{1} respectively for the dripping and micro-sprinkling systems. LI et al. (2003), when using different nitrogen fertilizer concentrations, observed the following NO_3^- contents in soil solution between 390.0 and 1550.0 mg L^{-1} regarding irrigation water concentrations between 100.0 and 700.0 mg L^{-1}.

There was no clear increase or reduction tendency of nitrate concentration in soil solution with time for any of the calcium nitrate concentrations over the culture cycle, both in micro-sprinkling and dripping systems. For treatments with calcium nitrate, mean NO_3 levels in soil solution ranged from 163.58 to 308.4 mg.L^{-1} with dripping, and from 159.7 to 352.9 mg.L^{-1} with micro-sprinkler for the layer of 0.20m. For the layer of 0.40m, these variations were from 110.7 to 331.8 mg L^{-1} and from 153.3 to 450.0 mg L^{-1} for dripping and micro-sprinkling, respectively. Such variations are similar to those found by ALVES et al. (2007), which studied different urea and calcium nitrate combinations over the culture and obtained NO_3 soil solution levels between 3.5 and 225.0 mg.L^{-1}. These results were similar to those obtained by KAISER (2006), which obtained nitrate levels in soil solution between 8 and 226.0 mg L^{-1}.

Figure 3 shows the behavior of NO_3^- soil solution concentration (ECs) along the first ‘Terra’ banana tree cycle. The increase in soil solution NO_3^- content at the layer of 0.40m (Figure 3c and 3d) for calcium nitrate application at a concentration of 13.0 g L^{-1} in the micro-sprinkling system can be justified by ion leaching for that layer. The NO_3^- anion originated from calcium nitrate is presented with availability for plants, not being retained by soil micelles, and therefore presenting greater leaching potential compared to ammoniacal nitrogen and amidic sources (SILVA et al. 2008a). Results show NO_3^- concentration extreme values compared to others only for the concentration of 13.0 g.L^{-1}, and for 3 to 10g.L^{-1} they are lower than 400 mg L^{-1}.

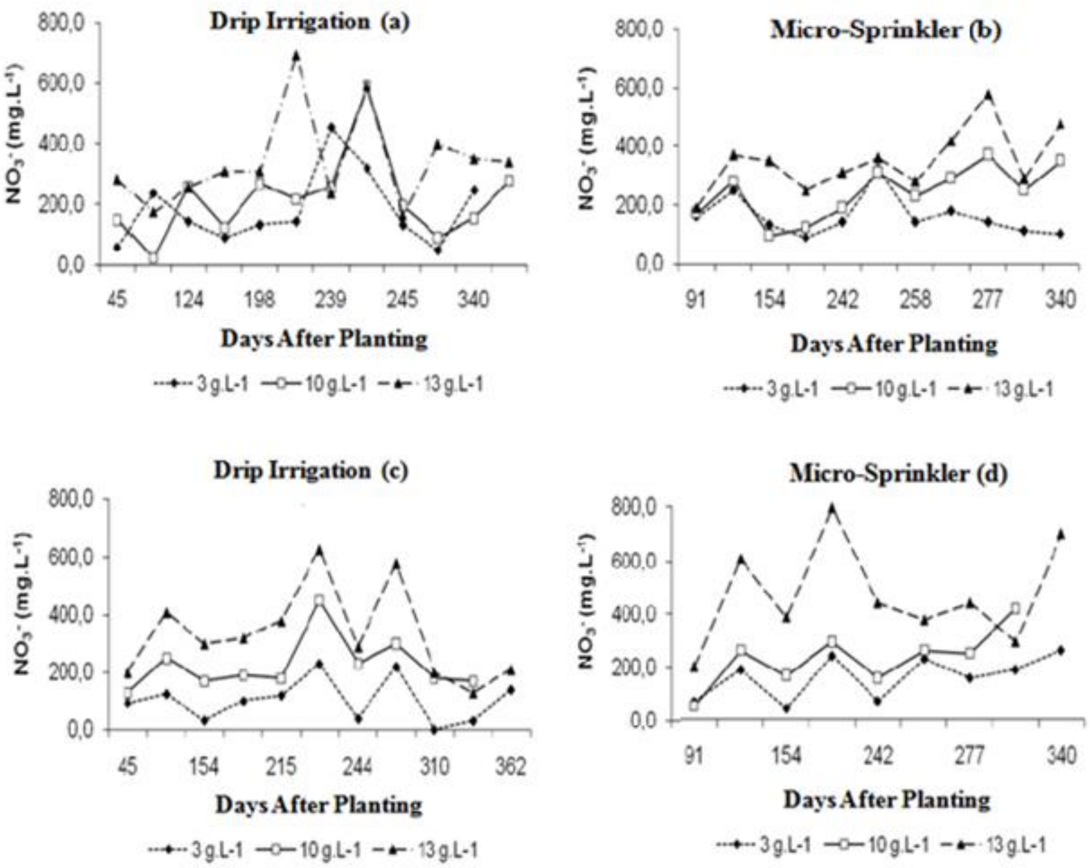

FIGURE 3. NO_3^- soil solution levels at a depth of 0.20m (3a and 3b) and 0.40m (3c and 3d), in calcium nitrate fertigation applied in two systems.

Treatment effects on growth and yield parameters

There was no effect of calcium nitrate irrigation water concentration on plant height, pseudo stem diameter, or leaf area. As concentration increased, no increase response in growth parameters was observed (Table 3).

TABLE 3. Average plant height, pseudo stem diameter, and leaf area of ‘Terra’ banana tree.

Calcium Nitrate Concentration ($g.L^{-1}$)	Height (cm)		Diameter (cm)		Leaf Area (m^2)	
	Drip	Micro	Drip	Micro	Drip	Micro
3.0	4.38Aa	4.52Aa	28.97Aa	29.73Aa	17.62Aa	16.72Aa
10.0	4.51Aa	4.28Aa	29.84Aa	30.50Aa	16.62Ab	18.31Aa
13.0	4.46Aa	4.37Aa	29.90Aa	29.78Aa	15.90Ac	16.64 Aa

* Capital letters compare nitrogen sources at each depth. Lowercase letters in columns compare irrigation water salt concentration.

Salt concentration had an effect on production characteristics for both irrigation systems used, which was also observed by ANDRADE NETO et al. (2008) when studying different calcium nitrate concentrations in irrigation water. The average productivity of treatments ranged from 39.80 t ha^{-1} to 55.86 t ha^{-1} in the dripping system, and the treatment with 3.0 g L^{-1} showed higher productivity, being significantly different from the means for 10.0 and 13.0 g L^{-1}.

In micro-sprinkling treatments, the concentration of 3.0 $g.L^{-1}$ showed higher productivity, differing from the other means. The results were different from those found by BORGES et al. (2002), which did not observe differences in productivity with increased salt concentration. However, the variable fruit diameter and length in the second bunch did not differ for different irrigation water concentrations, which was also observed by BORGES et al. (2002), and ANDRADE NETO et al. (2011) when evaluating different nitrogen sources.

TABLE 4. Means of fruit productivity, length and diameter, for different calcium nitrate concentrations applied in two localized irrigation systems.

Calcium Nitrate Concentration	Productivity (t ha^{-1})		Mean fruit length 2nd bunch		Mean fruit diameter 2nd bunch	
	Drip	Micro	Drip	Micro	Drip	Micro
3.0 $g.L^{-1}$	55.86Aa	48.8Aa	26.80Aa	25.50Aa	41.25Aa	39.50Aa
10.0 $g.L^{-1}$	39.80Bb	37.14Aa	22.00Aa	21.70Aa	35.50Aa	35.75Aa
13.0 $g.L^{-1}$	46.18Aa	42.25Ba	24.75Aa	24.00Aa	38.30Aa	36.65 Aa

* Capital letters compare the nitrogen sources at each depth. Lowercase letters in columns compare irrigation water salt concentration.

CONCLUSIONS

Soil chemical properties under fertigation are influenced by the water and nutrient delivery system.

There was a linear trend of increased electrical conductivity of the saturation extract and soil solution with increased irrigation water calcium nitrate concentration.

The “‘Terra’ Maranhão” banana tree productivity was influenced by fertilizer concentration in irrigation water.

Irrigation water calcium nitrate concentrations up to 10 g L^{-1} ensure electrical conductivity of soil solution or extract saturation in more proper levels for the banana tree in the soil conditions Evaluated.

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