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WATER DEPHTS AND MACRONUTRIENTS ACCUMULATION IN 'PÉROLA' PINEAPPLE IRRIGATED BY DRIP[1]

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ABSTRACT – Brazil is one of the largest pineapple producers worldwide, and those fruits are for the juice industry and the *in natura* market. Its cultivation requires high technology investment by using irrigation and balanced fertilization. However, little is known about the influence of drip irrigation on nutrient uptake by pineapple plants. This study aimed to evaluate the influence of different irrigation depths on nutrients accumulation by 'Pérola' pineapples grown in northern region of Minas Gerais State, Brazil. The experimental design was in randomized blocks with five treatments referring to: 30% of Class A Evaporation Pan (ECA); 50% of ECA; 70% of ECA; 100% of ECA; and 150% of ECA. To determine the levels of macronutrients and dry matter, the plants were separated in root, stem, leaves, 'D' leaf, crown, fruit and whole plant. The sequence of macronutrients accumulated in the whole plant was K>N>Ca>P>Mg. The fruits exported from the cultivated area the following amounts of macronutrients: 17.52 kg ha^{-1} of K (12.8%); 16.91 kg ha^{-1} of N (20.7%); 10.77 kg ha^{-1} of Ca (15.9%), 1.29 kg ha^{-1} of P (12.4%) and 1.04 kg ha^{-1} of Mg (20.5%). The irrigation depths that provided the maximum N, P, K and Ca accumulation in the whole plant are 53.6, 61.6, 54.5 and 60.2% of ECA, respectively.
Index Terms: *Ananas comosus* var. *comosus*, semiarid, nutrition.

LÂMINAS DE IRRIGAÇÃO E ACÚMULO DE MACRONUTRIENTES NO ABACAXIZEIRO 'PÉROLA' IRRIGADO POR GOTEJAMENTO

RESUMO - O Brasil é um dos maiores produtores mundiais de abacaxi, cujos frutos se destinam à indústria de sucos e ao mercado *in natura*. Seu cultivo exige alto investimento tecnológico pelo uso de irrigação e adubação equilibrada; todavia, é pouco conhecida a influência da irrigação por gotejamento no acúmulo de nutrientes por plantas de abacaxi. Assim, este trabalho objetivou avaliar a influência de diferentes lâminas de irrigação no acúmulo de nutrientes pelo abacaxizeiro 'Pérola', cultivado no norte de Minas Gerais. O delineamento utilizado foi em blocos ao acaso, com cinco tratamentos referentes a: 30% da evaporação do tanque Classe A (ECA); 50% da ECA; 70% da ECA; 100% da ECA; 150% da ECA. Para a determinação dos teores de macronutrientes e matéria seca, as plantas foram separadas em: raiz, talo, folhas, folha 'D', coroa, fruto e planta inteira. A sequência de macronutrientes acumulados na planta inteira foi K>N>Ca>P>Mg. Os frutos exportaram da área de cultivo as seguintes quantidades de macronutrientes: 17,52 kg ha^{-1} de K (12,8 %); 16,91 kg ha^{-1} de N (20,7 %); 10,77 kg ha^{-1} de Ca (15.9 %); 1,29 kg ha^{-1} de P (12,4 %) e 1,04 kg ha^{-1} de Mg (20,5 %). As lâminas de irrigação que proporcionaram o máximo acúmulo de N, P, K e Ca na planta inteira são de 53,6; 61,6; 54,5 e 60,2% da ECA, respectivamente.
Termos para Indexação: *Ananas comosus* var. *comosus*, semiárido, nutrição.

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The pineapple is a crop that has a high nutritional demand compared to other perennial or annual crops. However, variations in the accumulation of nutrients absorbed by the pineapple occur due to the use of cultivars with different traits and cropping systems (SILVA et al., 2009; GUARÇONI;. VENTURA, 2011).

The adequate association between water and nutrients increases crop yield (MARTINS et al., 2011), being that irrigation increases nutrients demand and export. Depending on the soil and irrigation management, the water applied can still cause nutrient leaching. Some researchers studied productivity and quality of pineapple fruits under the effect of conventional sprinkler-irrigation (ALMEIDA et al., 2002; MELO et al. 2006; BENGOZI et al., 2007; SOUZA et al., 2009) and nutrients (SPIRONELLO et al., 2004; COELHO et al., 2010; SILVA et al., 2012). However, there are few scientific studies related to nutrients accumulation and export by drip-irrigated ‘Pérola’ pineapple organs.

The knowledge about the content of nutrients in the harvested part of plants is important to assess the quality of product and the removal of the nutrients from the cultivated area (SOARES et al., 2008).

The nutrient with higher extraction by the pineapple and very responsive in quality fruits is the K (SPIRONELLO et al., 2004). According to Paula et al. (1985), the most required nutrients are K, N and Ca. Paula et al. (1985) found that macronutrient uptake by the pineapple cultivar Smooth Cayenne at a density of 50,000 plants ha^{-1} were 444 kg ha^{-1} of K, 300 kg ha^{-1} of N, 161 kg ha^{-1} of Ca, 35 kg ha^{-1} of S, 33 kg ha^{-1} of Mg and 14 kg ha^{-1} of P.

Most of the studies are conducted under sprinkler irrigation systems. However, under drip-irrigation the roots are restricted to a smaller soil volume and the amounts of water and nutrients are reduced. Therefore, this study aimed to evaluate the influence of different drip-irrigation depths on nutrient accumulation in ‘Pérola’ pineapple cultivated in a Fluvic Neosol, in semi-arid conditions.

The experiment was conducted from May of 2008 to March of 2011, in the experimental area, located at 43°16’18, 2” W and 15°49’51, 5” S, and 545 m of altitude. The climate according to Köppen’s classification is “Aw” (warm tropical with cold and dry winter), with averages of rainfall of 718 mm and air temperature of 25 °C, during the experiment.

The soil at the experimental area is a Fluvic Neossol with the following physico-chemical characteristics in the arable layer (0-20 cm): 86 dag kg^{-1} of sand; 9 dag kg^{-1} of silt and 5 dag kg^{-1} of clay (sandy texture class); pH in water 5.6; 61 mg dm^{-3} of P (Mehlich-1); 187 mg dm^{-3} of $K^{+;}$ 2.6 $cmol_c$ dm^{-3} of Ca^{2+}; 0.9 $cmol_c$ dm^{-3} of Mg^{2+}; 1.3 $cmol_c$ dm^{-3} of H + Al; 0.2 mg dm^{-3} of B; 0.7 mg dm^{-3} of Cu; 48.5 mg dm^{-3} of Fe; 16.9 mg dm^{-3} of Mn; 2.8 mg $dm^{-3}$of Zn and EC 0.2 dS m^{-1}.

The amount of water applied in each treatment was based on the class A evaporation pan (ECA) installed between two plots in the center of experimental site. Readings of the evaporated depth were performed daily no later than 9 p.m. with a caliper installed on a stilling well. The method used is simplified, based only on the evaporation of the pan, being the treatments the different water depths: referring to 30% of ECA (691.2 mm yr^{-1}), 50% of ECA (1152.0 mm yr^{-1}), 70% of ECA (1612.8 mm yr^{-1}), 100% of ECA (2304.0 mm yr^{-1}) and 150% of ECA (3456.0 mm yr^{-1}).

The experimental design was a randomized block design with five plants per plot, four double rows of 5 m length spaced at 1.2 m x 0.4 m x 0.3 m, making a total of 41,666 plants ha^{-1}, and four replications. After harvesting the experiment, the plants were separated in root, stem, leaves, ‘D’ leaf , crown and fruit; then, they were weighed (0.01 g precision), packed in paper bags and dried in an oven at 70 °C until reaching constant mass.

By means of the nitric-perchloric extract, contents were determined: P by colorimetry; Ca and Mg by atomic absorption spectrophotometry and K by flame photometry. The total N contents were determined by the semimicro Kjeldahl method.

Accumulation of each nutrient for the respective plant compartments was quantified by means of the mathematical expression described below:

$$Accumulation = \frac{DMxT}{100}$$

In which: *Accumulation*: nutrients accumulation in the plant compartment (kg ha^{-1} and g ha^{-1}); DM: dry matter in the plant compartment (kg ha^{-1}); T: nutrient content in the plant compartment (%).

Evaluated characteristics were: dry matter content (kg ha^{-1}); nutrients accumulation (kg ha^{-1}): N, P, K, Ca and Mg, in the different parts of the ‘Pérola’ pineapple [root, stem, total leaves, ‘D’ leaf, crown, fruit and whole plant (root more aerial part)] .

The analysis of variance with the F test and regression analysis were performed to a 10% level of significance by the t test. The models were fitted based on the ability to biologically explain the phenomenon, on the coefficient of determination and on the significance of the parameters. Statistical analysis was performed with the aid of the Statistical and Genetics Analysis System of the Federal University of Viçosa, SAEG V. 5.0.

Accumulation of macronutrients in the different 'Pérola' pineapple components was influenced by the application of drip-irrigation depths, except for the accumulation of: N -total leaves and crown; P - 'D' leaf, crown and total leaves and Mg - stem, total leaves , 'D' leaf, crown and whole plant (Table 1).

The N accumulation in the stem showed linear behavior, decreasing markedly with increasing amount of water in the soil. The other plant compartments showed cubic behavior, being that the irrigation depths that conferred the highest N accumulations were 48.9%, 52%, 54.3% and 53.6% of the ECA for 19.35 kg (fruit), 1.26 kg ha^{-1} (root), 2.15 kg ha^{-1} ('D' leaf) and 97.62 kg ha^{-1} (whole plant), respectively (Table 1). According to Coelho et al. (2010) there was no significant effect for N contents in the 'D' leaf for the 'Smooth Cayenne' pineapple, being the contents below the 20 - 22 g kg^{-1} range. This fact suggests splitting N doses, according to the nutritional demand, in the different crop growing stages (RODRIGUES et al., 2010).

P accumulation showed linear behavior for root, indicating increased availability of this nutrient for the plant with increasing irrigation depths, despite its low mobility in soil. As for the accumulation in the stem, by the quadratic model, in the 76.7% of ECA depth, there was a maximum accumulation of 3.62 kg ha^{-1} of P. In the other plant compartments, accumulation was 1.74 kg ha^{-1} (fruit) and 13.31 kg ha^{-1} (whole plant), in the 60.2% and 61.6% of ECA irrigation depths (Table 1). The P content in the 'D' leaf was below the recommended for the crop, agreeing with Guarçoni M. and Ventura (2011), in a condition in which the reduction in foliar P can be generated mainly by the addition of N as urea.

K accumulation ranged from 1.32 kg ha^{-1} (crown), 1.53 kg ha^{-1} ('D' leaf), 4.41 kg ha^{-1} (root), 25.71 kg ha^{-1} (fruit), 37.83 kg ha^{-1} (stem), 90.9 kg ha^{-1} (leaves) and 166.65 kg ha^{-1} (whole plant), when applied the 61.4%, 41.4%, 63.7% , 45.6%, 58.7%, 57.2% and 54.5% of ECA irrigation depths, respectively. According to Albuquerque et al. (2011) the application of the 120% depth of the crop evapotranspiration with a dose of 120 kg ha^{-1} of K_2O causes higher losses by leaching of potassium as K_2O, and these losses can cause economic losses when expressed as potassium fertilizers. However, according to Veloso et al. (2001) and Teixeira et al. (2011) the fruit production increased in response to potassium fertilization.

A cubic behavior was observed in Ca accumulation in roots (2.44 kg ha^{-1}), total leaves (39.22 kg ha^{-1}), 'D' leaf (3.92 kg ha^{-1}), crown (7.21 kg ha^{-1}) and whole plant (80.95 kg ha^{-1}). A quadratic model was fitted for Ca accumulation in the stem, and the maximum accumulation (17.89 kg ha^{-1}) occurred in the 77.9% of ECA irrigation depth. It was observed that the Ca accumulation in the fruit decreased with increasing irrigation depths (Table 1).

The amount of Mg accumulated by the 'Pérola' pineapple in roots and in the fruit were of 0.24 kg ha^{-1} (70% ECA) and 1.3 kg ha^{-1} (30% ECA), respectively. The behavior of the data for the fruit is linear negative, indicating that the amount of Mg in roots decreases with increasing irrigation depths (Table 1). This may have occurred because the K source applied (potassium chloride) has a high mobility in the soil, with K competing for the same absorption site of the Mg, and the plant accumulating greater amount of the first nutrient. Similar response was observed by Silva et al. (2008) in the shoots of banana seedlings. These autors observed that the Mg contents decreased quadratically with the increase of the K doses applied to the soil.

Under the edaphoclimatic conditions in which the study was conducted, the sequence of macronutrients accumulated in the whole plant was: K>N>Ca>P>Mg. The fruits exported on average from the cultivation area the following amount of macronutrients: 17.51 kg ha^{-1} of K; 16.91 kg ha^{-1} of N; 10.77 kg ha^{-1} of Ca; 1.29 kg ha^{-1} of P and 1,04 kg ha^{-1} of Mg. Such accumulations correspond to the following export order in percentage: 12.8% of the K; 20.7% of the N; 15.9% of the Ca; 12.4% of the P and 20.6% of the Mg absorbed by the 'Pérola' pineapple at the end of the crop cycle.

The irrigation depths that provided the maximum N, P, K and Ca accumulation in the whole plant are 53.6, 61.6, 54.5 and 60.2% of ECA, respectively, although there is no effect of the used irrigation depths on Mg accumulation. Otherwise, it is indicated that most of the nutrients absorbed by the pineapple plant can remain in the cultivated area as plant residues, if incorporated to the soil.

TABLE 1 - Fitted models for macronutrients accumulation by drip-irrigated ‘Pérola’ pineapple cultivated in the semiarid region of Minas Gerais State, Janaúba, MG, 2011.

Part	Models	R^2
	N	
RO	$\hat{y} = -1.44019 + 0.121713^{***} x – 0.00168188^{***} x^2 + 0.0000065505^{***} x^3$	0.99
ST	$\hat{y} = 33.6214 – 0.146753^{***} x$	0.92
TL	$\hat{y} = 38{,}02$	
DL	$\hat{y} = -1.38759 + 0.154066^{***} x – 0.00207040^{***} x^2 + 0.00000800139^{***} x^3$	0.98
CR	$\hat{y} = 5{,}11$	
FR	$\hat{y} = 7.48442 + 0.557522^{***} x – 0.00791642^{***} x^2 + 0.0000302037^{***} x^3$	0.71
WP	$\hat{y} = -7.96432 + 4.58918^{***} x – 0.0610010^{***} x^2 + 0.000226344^{***} x^3$	0.92
	P	
RO	$\hat{y} = 0.0511489 + 0.00143430^{***} x$	0.92
ST	$\hat{y} = 1.30559 + 0.0604609^{***} x – 0.000394302^{***} x^2$	0.87
TL	$\hat{y} = 5.80$	
DL	$\hat{y} = 0.19$	
CR	$\hat{y} = 0.21$	
FR	$\hat{y} = -1.24251 + 0.116003^{***} x – 0.00138697^{***} x^2 + 0.00000469234^{***} x^3$	0.64
WP	$\hat{y} = -11.2809 + 0.946998^{***} x – 0.0113076^{***} x^2 + 0.0000392027^{***} x^3$	0.90
	K	
RO	$\hat{y} = -4.79241 + 0.349811^{***} x – 0.00417997^{***} x^2 + 0.0000150287^{***} x^3$	0.77
ST	$\hat{y} = 6.54805 + 1.23343^{*} x – 0.0147985^{*} x^2 + 0.0000488022^{\circ} x^3$	0.72
TL	$\hat{y} = -74.7448 + 6.87857^{***} x – 0.0886332^{***} x^2 + 0.000332289^{***} x^3$	0.70
DL	$\hat{y} = 0.627669 + 0.0494739^{***} x – 0.000809809^{***} x^2 + 0.0000034198^{***} x^3$	0.53
CR	$\hat{y} = -1.02805 + 0.0906778^{***} x – 0.00108718^{***} x^2 + 0.00000378805^{***} x^3$	0.95
FR	$\hat{y} = -15.0857 + 2.05148^{***} x – 0.03109^{***} x^2 + 0.000125449^{***} x^3$	0.93
WP	$\hat{y} = -79.9722 + 10.6182^{***} x – 0.140612^{***} x^2 + 0.000528659^{***} x^3$	0.83
	Ca	
RO	$\hat{y} = -3.14890 + 0.226757^{***} x – 0.00286644^{***} x^2 + 0.0000106700^{***} x^3$	0.99
ST	$\hat{y} = 9.1112 + 0.225388^{***} x – 0.00144611^{***} x^2$	0.92
TL	$\hat{y} = -38.8894 + 3.24417^{***} x – 0.0417568^{***} x^2 + 0.000155825^{***} x^3$	0.88
DL	$\hat{y} = 0.538081 + 0.155713^{***} x – 0.00219041^{***} x^2 + 0.00000859126^{***} x^3$	0.99
CR	$\hat{y} = -13.6117 + 0.759765^{***} x – 0.00866533^{***} x^2 + 0.0000292871^{***} x^3$	0.90
FR	$\hat{y} = 12.1766 – 0.0176132^{**} x$	0.76
WP	$\hat{y} = -42.5694 + 4.87853^{***} x – 0.0598462^{***} x^2 + 0.000214135^{***} x^3$	0.96
	Mg	
RO	$\hat{y} = -0.392654 + 0.0251679^{\circ} x – 0.000310468^{\circ} x^2 + 0.00000113350^{\circ} x^3$	0.99
ST	$\hat{y} = 1.46$	
TL	$\hat{y} = 1.98$	
DL	$\hat{y} = 0.16$	
CR	$\hat{y} = 0.47$	
FR	$\hat{y} = 1.37489 – 0.00414599^{***} x$	0.87
WP	$\hat{y} = 5.06$	

$\hat{y}$ - nutrient accumulated (kg ha^{-1}); x - irrigation depht (mm); ^{NS}, ^{o}, *, **, *** - not significant at 10% and significant at 10, 5, 1 and 0.1% significance level by the t test, respectively; RO - roots, ST - stem, TL - total leaves, DL - ‘D’ leaf, CR - crown, FR - fruit, WP - whole plant

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