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NOTA

EFFECT OF NPK FERTILIZATION ON PRODUCTION AND LEAF NUTRIENT CONTENT OF EUCALYPTUS MINICUTTINGS IN NUTRIENT SOLUTION[1]

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SUMMARY

Adequate nutrient levels in plants vary according to the species or clone, age and management practice. Therefore, adjustments of the nutrient solution are often necessary according to the plant material for multiplication. This study aimed to evaluate the influence of NPK fertilization on production and leaf nutrient contents of eucalyptus cuttings in nutrient solution. The study was conducted from November 2008 to January 2009 in a greenhouse. The experimental design was completely randomized fractional factorial (4 x 4 x 4) ½, with a total of 32 treatments with three replications. The treatments consisted of four doses of N (50, 100, 200 and 400 mg L^{-1}) as urea, P (7.5, 15, 30 and 60 mg L^{-1}) in the form of phosphoric acid and K (50, 100, 200 and 400 mg L^{-1}) in the form of potassium chloride in the nutrient solution. Only the effect of N alone was significant for the number and dry weight of minicuttings per ministump, with a linear decreasing effect with increasing N levels. The highest number of cuttings was obtained at a dose of 50, 7.5 and 50 mg L^{-1} of N, P and K, respectively.

Index terms: *Eucalyptus*, fertilization, clonal nursery.

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RESUMO: *ADUBAÇÃO NPK NA PRODUÇÃO E NOS TEORES DE NUTRIENTES FOLIARES EM MINIESTACAS DE EUCALIPTO EM SOLUÇÃO NUTRITIVA*

Os níveis adequados de nutrientes na planta podem variar de acordo com a espécie ou clone, a idade e o manejo adotado. Com isso, muitas vezes, ajustes na solução nutritiva são necessários conforme o material que se deseja multiplicar. Este trabalho teve como objetivo avaliar a influência da adubação NPK na produção e nos teores de nutrientes foliares em miniestacas de eucalipto em solução nutritiva. O trabalho foi realizado de novembro de 2008 a janeiro de 2009, em casa de vegetação da UFVJM. Foi utilizado delineamento inteiramente casualizado em esquema fatorial fracionado (4 x 4 x 4)$^{1/2}$, perfazendo 32 tratamentos com três repetições. Os tratamentos constituíram-se de quatro doses dos nutrientes N (50, 100, 200 e 400 mg L^{-1}) na forma de ureia, P (7,5, 15, 30 e 60 mg L^{-1}) na forma de ácido fosfórico e K (50, 100, 200 e 400 mg L^{-1}) na forma de cloreto de potássio em solução nutritiva. Houve efeito significativo apenas para as doses de N isoladamente para número e massa seca das miniestacas por minicepa, com efeito linear decrescente com o aumento das doses de N. O maior número de miniestacas foi obtido nas doses de 50, 7,5 e 50 mg L^{-1} de NPK, respectivamente.

Termos de indexação: Eucalyptus, *fertilização, minijardim clonal.*

INTRODUCTION

Nowadays, the area of planted forests in Brazil ranks ninth in the world, although only 0.67 % (5.74 million ha) of the national territory is covered with reforested area. Eucalyptus was planted on 61.8 % (3.55 millions ha) of this area. The forestry sector contributes with 3.5 % (SBS, 2007) to the National Gross Domestic Product. Some of the most commonly used eucalyptus species are *Eucalyptus grandis*, *E. urophylla*, and hybrid *E. grandis* vs. *E. urophylla*, and to a lesser extent, *E. camaldulensis*, *E. cloeziana*, *E. dunni*, *E. globulus*, *E. pellita*, and *E. saligna* (Stape et al., 2001).

A successful formation of high-yielding forests depends, among other factors, on planting quality seedlings, which can survive under the adverse conditions in the field after planting and produce trees with economically desirable volumetric growth (Gomes et al., 1991). For optimum quality and uniformity of seedlings, the technique of minicuttings was introduced at an operational scale in forest nurseries in the 90s. Currently, 85 % of the seedling production of Eucalyptus in Brazil is produced by this technique (Silva et al., 2009).

For an effective production of eucalyptus minicuttings, adaptations of growth factors such as water, light and nutrients are necessary. Of these, in the tropics, light is not a limiting factor, while water and nutrients are growth-limiting. It is therefore important to establish an adequate nutrient relationship that will not only improve the production of cuttings, but also reduce the susceptibility to physiological and phytopathological stresses (Santana et al., 2008).

Adequate nutrient levels in the plant may vary depending on the species or clone, age and management practice. Therefore, adjustments of the nutrient solution are often necessary according to the material for multiplication (Alfenas et al., 2004). The mineral nutrition presents genotype-dependence with the rooting of minicuttings and the number produced, necessitating the use of a nutrient solution for each individual clone, varying also the type of mini-clonal hedge, to enable the use of full potential of genetic material (Cunha et al., 2008).

Thus, the purpose of this study was to evaluate the influence of NPK fertilization on production and leaf nutrient contents in eucalyptus cuttings in nutrient solution.

MATERIAL AND METHODS

The experiment was carried out from November 2008 to February 2009, in a greenhouse of the Department of Agronomy, Faculty of Agricultural Sciences, Federal University of the Jequitinhonha and Mucuri Valleys (UFVJM), in Diamantina, Minas Gerais State (lat. 18 ° 15 ' S, long. 43 ° 36 ' W, 1.400 m asl). The mean temperature and relative humidity during the experiment in the greenhouse were 24.3 °C and 68.4 %, respectively.

The hydroponic experiment was conducted under compressed air aeration, using 45-day-old seedlings of *Eucalyptus urophylla*. They were provided by the company ArcelorMittal BioEnergia from Itamarandiba, State of Minas Gerais. Seedlings 15.0 ± 0.1 cm height and 3.0 ± 0.5 mm stem diameter were selected.

The experiment was installed in a completely randomized design, in a factorial (4 x 4 x 4)½, with 32 treatments and three replications. Each of the 96 plots contained six ministumps, spaced 0.10 x 0.10 m. The nutrient rates were based on ranges established by Higashi et al. (2005) and Leite (2003) and consisted of: N (50, 100, 200 and 400 mg L^{-1}) as urea, P (7.5, 15.0, 30.0 and 60.0 mg L^{-1}) as phosphoric acid and K (50, 100, 200 and 400 mg L^{-1}) as potassium chloride.

The concentrations of the other nutrients in the solution were 100 mg Ca; 25 mg Mg; 35 mg S; 0.3 mg B; 0.03 mg Cu; 0.3 mg Fe; 0.3 mg Mn; 0.05 mg Zn and 0.01 mg Mo per liter of nutrient solution (Higashi et al., 2005). To facilitate the preparation of nutrient solutions, a stock solution with the following reagents was used: urea, phosphoric acid, potassium chloride, calcium sulfate, calcium chloride, magnesium sulfate, magnesium chloride, boric acid, copper sulfate, manganese sulfate, zinc sulfate, sodium molybdate and ferrous chloride + EDTA. Throughout the experiment, deionized water was used to prepare the nutrient solution and the pH was adjusted to 5.4 ± 0.3.

At the beginning of the experiment, the seedling roots were washed under tap water to remove the potting medium. They were supported by 2 cm thick Styrofoam boards which covered a tray containing 10 L of nutrient solution.

Initially, the plants were acclimatized for a period of 12 days in the nutrient solution, after which the nutrient concentration was gradually increased (by 10, 25, 50 and 75 %), every three days, until reaching 100 % of the lowest NPK rate (50, 7.5 and 50 mg L^{-1}) and 100 % of the other nutrients. At this stage, the pH was only adjusted on the day of solution exchange. After seedling acclimatization, the nutrient solutions were changed every seven days and the pH adjusted three times during each interval.

Twenty-one days after installing the experiment, the apex of the adapted seedlings was cut, laeving at least two pairs of fully formed leaves for the development of ministumps. During 40 days, the ministumps were cut four times before treatment application.

The treatments were applied 61 days after the beginning to acclimatize ministumps to treatments with higher rates. Half of the highest rates 400, 60 and 400 mg L^{-1} of NPK, respectively, were applied and the total rates of the other nutrients. Then, 68 days after the beginning, fertilization was completed in the plots treated with the highest quantities.

Apical cuttings were collected four times in a period of 30 days, the first 75 days after the beginning. Cuttings with a length of 6.0 cm and one pair of fully formed leaves were collected.

The sampled minicuttings were counted, washed in deionized water, stored in paper bags per plot at each sampling, and oven-dried to constant weight with forced air circulation at 65 °C. The methodology described by Malavolta et al. (1997) was used to determine the macro and micronutrient contents.

The variables mean number of minicuttings per ministump (MNMC/MS), mean dry matter of minicuttings per ministump (DMMC/MS) of all four samplings; and mean macro and micronutrient contents in the DMMC/MS were evaluated. Data were submitted to analysis of variance and regression analysis for the N, P and K rates.

Based on the equations obtained for DMMC/MS, doses of N, P and K were estimated with a view to maximize the value of the variable. Based on N, P and K associated with the maximum value of DMMC/MS and the regressions that relate the nutrient leaf content with DMMC/MS as a function of applied N, P and K, critical nutrient levels were estimated in the DMMC/MS of eucalyptus in nutrient solution. The critical nutrient levels in the DMMC/MS were compared with the standards proposed by Higashi et al. (2005) and Leite (2003).

RESULTS AND DISCUSSION

The only variable with a negative linear response to N rates ($P < 0.01$) was the mean number of minicuttings per ministumps (NMC/MS) and mean dry mass of minicuttings per ministumps (DMMC/MS) (Figure 1). The highest NMC/MS (12.2) and DMMC/MS (1.38 g) were obtained at a rate of 50 mg L^{-1} Ni. Consequently, this N rate should be recommended for this plant material. No significant treatment effect was observed for P and K; rates of 7.5 and 50 mg L^{-1}, respectively, were therefore recommended. The lack of response to P and K was due to the residual effect of these nutrients, caused by fertilizer applied to the seedlings from which the ministumps were derived and the relatively short time of evaluation.

The NMC/MS for eucalyptus is variable depending on the clonal nursery system, intervals between collections, season, nutritional status, temperature, minicutting size, and plant material. The production observed in this study of 3.0 cuttings per stump and week was consistent with results found in the literature: 5.6 cuttings per stump every 5–10 days in a clonal nursery, in sand bed (Wendling et al., 2003); 2.4 cuttings per stump every 7 days in a clonal nursery, in tubes with subirrigation (Titon et al., 2003); 8.1 every 25 to 30 days in a clonal nursery in sand and 4.1 in a system of clonal mini tubes (without subirrigation) (Cunha et al., 2005). By extrapolating the NMC/MS of this experiment to annual production, a production of 14,364 cuttings m^{-2} yr^{-1} is estimated. According to Alfenas et al. (2004), under operational conditions in forestry companies, from 9,762 to 14,820 cuttings m^{-2} yr^{-1} are produced in clonal nurseries, in sand bed, under drip fertigation.

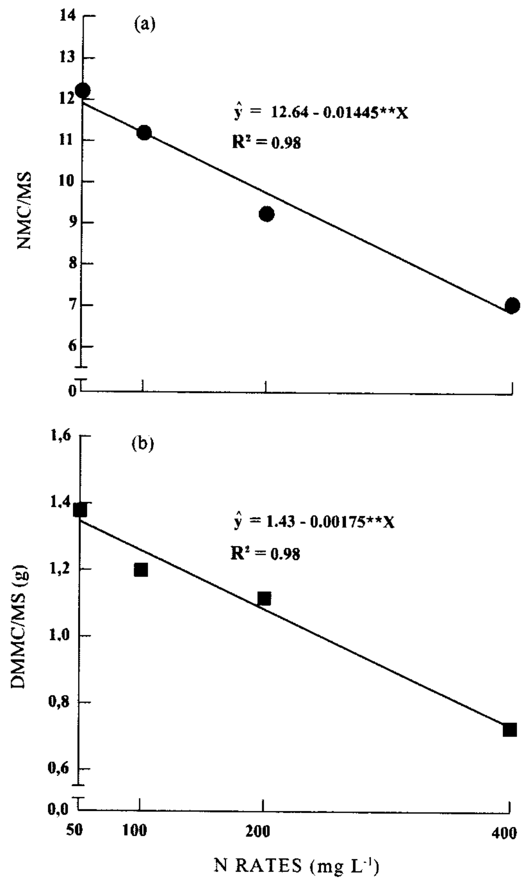

Figure 1. Number of minicuttings per ministumps (NMC/MS) (a) and dry matter of minicuttings per ministumps (DMMC/MS) (b) of one single-cross *Eucalyptus urophylla* hybrid, as related to N rates in nutrient solution, during 30 days of collection. (Significant at 1 % by the t test).**

The recommended NPK dose for the plant material under study of 50, 7,5 and 50 mg L^{-1} was below the ranges established by Higashi et al. (2005) of 100–200, 15–30 and 100 to 200 mg L^{-1} for N, P and K, respectively. This difference in the response to the plant material under study was caused by differences in the management systems: this study was conducted using a nutrient solution in a closed system, and the ranges established by Higashi et al. (2005) were for eucalyptus clonal nurseries, with drip irrigation in sand bed in an open system.

The nutrient contents in the DMMC/MS decreased when N rates increased (Tables 1 and 2), which is mainly because N is rather absorbed as ammonium than as nitrate by eucalyptus (Vale et al., 1984; Shedley et al., 1993; Grespan et al., 1998). This behavior has been explained as an evolutive adaptation of the species to acid soil. Urea was used as unique N source, with more intensive nitrification than other sources (Silva & Vale, 2000). Nitrification increases linearly with increasing pH from 4.7 to 6.5 (Dancer et al., 1973) or from 4.9 to 7.2 (Gilmour, 1984) or from 5.0 to 8.0 (Kyveryga et al., 2004). By the adjustment of the pH solution to 5.4 ± 0.3, ammonium nitrification was favored and nitrate levels in solution increased as N rates were increased.

The critical nutrient levels in the DMMC/MS of this study (Table 2) were higher compared with the range determined by Higashi et al. (2005) for P, Ca, Mg, S, Fe, and Zn; comparable for N, K, B, and Mn and lower for Cu. In relation to the ranges established by Leite (2003), the critical levels were higher for P, Ca, Mg, S, and Zn, comparable for N, K, B, and Fe and lower for Cu and Mn. There was a shift in the classification of critical levels from Higashi et al. (2005) to Leite et al. (2003) for K, Fe and Mn, when K and Mn were classified as adequate instead of low and Fe as high instead of adequate.

Table 1. Mean content of macro and micronutrients in DMMC/MS, as related to N rates in the nutrient solution

Variable	N rates (mg L^{-1})			
	50	100	200	400
		Macronutrients (dag kg^{-1})		
N	3.99	3.84	3.88	3.47
P	0.76	0.68	0.63	0.49
K	1.62	1.50	1.35	1.05
Ca	1.65	1.64	1.63	1.43
Mg	0.39	0.32	0.31	0.29
S	1.51	1.41	1.38	1.16
		Micronutrients (mg kg^{-1})		
B	44.86	43.33	42.75	41.46
Cu	6.32	6.30	6.12	5.72
Fe	231.08	230.22	206.35	203.84
Mn	300.80	267.21	243.74	204.53
	97.25	91.08	89.22	78.06

Table 2. Regression equation adjusted to macro and micronutrient contents, simple correlation coefficients (r), of nutrient critical levels (CL) in function of N rates in nutrient solution, during 30 days of evaluation

Nutrient[1]	Regression equation	R^2	r[2]	CL	Adequate range	
					Higashi et al. (2005)	Leite (2003)
N	$\hat{y} = 4.05 - 0.00137^{**}x$	0.89	0.90**	3.98	2.8–4.0	3.5–4.0
P	$\hat{y} = 0.77 - 0.00071^{**}x$	0.97	0.98**	0.73	0.25–0.40	0.35–0.4
K	$\hat{y} = 1.68 - 0.00158^{**}x$	0.99	0.99**	1.60	1.5–3.0	2.0–2.5
Ca	$\hat{y} = 1.71 - 0.0066^{**}x$	0.91	0.89**	1.38	0.5–0.7	0.8–1.1
Mg	$\hat{y} = 0.27 + 5.15826^{**}/x$	0.96	0.85**	0.38	0.2–0.3	0.25–0.30
S	$\hat{y} = 1.54 - 0.00095^{**}x = 1.54$	0.96	0.96**	1.49	0.20–0.25	0.25–0.30
B	$\hat{y} = 44.70 - 0.00855^{**}x = 44.70$	0.88	0.96**	44.28	35–70	45–65
Cu	$\hat{y} = 6.45 - 0.00179^{**}x$	0.99	0.97**	6.36	8–15	10–16
Fe	$\hat{y} = 246.86 - 0.26632^{**}x + 0.0003942^{**}x^2$	0.92	0.93**	234.53	101–220	180–300
Mn	$\hat{y} = 301.63 - 0.25367^{**}x = 301.63$	0.94	0.99**	314.31	250–500	500–1000
Zn	$\hat{y} = 98.39 - 0.05062^{**}x = 98.$	0.96	0.97**	95.86	30–60	35–55

(1) Macronutrients in dag kg^{-1} and micronutrients in mg kg^{-1}. (2) Simple linear correlation (r) among nutrient contents with number of minicuttings per ministumps. **: significant at 1 % by t test.

The change in the classification of critical levels of K, Fe and Mn occurred due to variations in the amplitude of ranges established by Higashi et al. (2005) and Leite (2003). Cunha et al. (2008) evaluated 14 genotypes and also found that the ranges of nutrient concentrations in the brotações/cuttings established by Higashi et al. (2005) were not adequate for all clones and nutrients studied in clonal nurseries in tubes with sub-irrigation and clonal nursery, in sand bed under drip fertigation. Thus, the ranges of macro and micronutrient contents reported in the literature should be used to guide fertilizer application, bearing in mind that the applied nutrient rates should be adjusted according to the nutritional requirements of each plant material, based on nutritional monitoring.

The results found here indicate the possibility of using urea as exclusive N source to produce eucalypt minicuttings. The rates determined in nutrient solution for the plant material under study (50, 7.5 and 50 mg L^{-1} of N, P and K) were four to five times lower than the values reported in the literature. The NMC/MS is comparable to the values found in the literature and nutrient contents, positively correlated with the NMC/MS (Table 2), are adequate or close to the contents considered adequate by Higashi et al. (2005).

CONCLUSIONS

1. For the evaluated plant material, the N, P and K rate recommended for the highest production of minicuttings per ministumps was 50, 7.5, and 50 mg L^{-1}, respectively.

2. An increase in the N rate as urea reduced the number, dry matter and leaf nutrient contents in minicuttings per ministumps of eucalypt.

3. Under the experimental conditions, there was no yield response to P and K rates applied to eucalypt minicuttings in nutrient solution.

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